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GEOLOGY AND MINERAL RESOURCES OF THE FAR EAST

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VOLUME TWO

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PREFACE

The geologist's units are often continents and oceans, centuries and millenia. Within the vast scope of geology, this book is devoted to China, Korea and Manchuria. It complements other English-language studies of Asian geology by Japanese geologists: *Geology of Japan* (1963), *Geology and Palaeontology of Southeast Asia* (volume I, 1964; volumes II and III forthcoming), and *Geologic Sheet Maps of the Far East* (1964).

This volume is derived from the formation of a committee in March, 1950, by the Tokyo Geographical Society, which had the purpose of compiling material on the geology and mineral resources of the Far East. Inaugurating a program for the preservation, compilation, and publication of such data, the committee collected articles from more than 200 specialists who had been repatriated after the war, and edited a three-volume series, *Toa Chishitsu Kosan Shi* (Geology and Mineral Resources of the Far East). One volume was devoted to each of the major areas, China, Manchuria, and Korea.

The series was published in 1952 and is now out of print. Since it was the committee's hope that the study be made accessible to Western as well as Japanese scholars, it is considered appropriate to publish an English version of the series rather than a second edition in Japanese.

The present volume consists of a selection of seventeen articles from the 1952 edition. It deals with stratigraphy, geology and mineral resources in the three areas. The remaining articles will be translated and edited for future publication.

Much of the basic research data were gathered before and during World War II. The intervening years have been ones of accelerating scientific research with the development of new tools and techniques, but since all of China and Manchuria and the northern half of the Korean Peninsula is now closed to Western—and Japanese—geologists, and since a few decades are minute in terms of geologic time, the value of the studies based on these data and included here have increased. Some articles were, of necessity, written from memory due to the destruction of data.

Publication of the Japanese and English editions was made possible by grants from the Ministry of Education and the generosity of the United States Geological Survey, which supplied the committee with topographic base maps and continued assistance in translating and editing.

The editors have striven for consistency in Romanization, particularly of place names. Some names conform to U.S. Board of Geographic Names style but no

feasible way of obtaining complete consistency was available. A glossary is, however, provided.

Because of the trying conditions under which some of the articles were written, it was not always possible to include an extensive bibliography.

We would like to acknowledge with gratitude the assistance of the following staff members of the U.S. Geological Survey who, while they were stationed in Tokyo, were especially active in the promotion of the committee's work: Messrs. T. KUROSAKA, S. K. NEUSCHEL, M. E. WING, C. S. JOHNSON, Helen L. FOSTER, D. H. DOAN, G. CORWIN, and R. C. KEPFERLE.

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PREFACE TO VOLUME 2

As is stated in the preceding PREFACE, this is an English version of a three-volume series, *Toa Chishitsu Kosan Shi* (Geology and Mineral Resources of the Far East). The original three-volume series contains 260 articles in Japanese. In preparing the English version, topics considered to be of more general interest were selected. Volume 1 contains seventeen articles, and another seventeen articles have been selected for Volume 2. These articles cover fields in structural geology, stratigraphy, topography, volcanic geology, mineral deposits as well as hydrogeology in major areas of Korea, Manchuria, and North China.

These articles, like those in Volume 1, are the results of years of comprehensive or original studies by the authors who actually worked in each of the above areas. It is hoped that these articles may serve as good references in studies on geology and mineral resources of the Far East.

We would like to thank Miss Reiko FUSEJIMA who prepared the glossary and Mrs. Annik CHAMBERLAIN who edited the English text.

CONTENTS

Preface
Preface to Volume 2

KOREA

Geologic Structure of North Korea and South Manchuria ..... Teiichi KOBAYASHI 3
Cyanite-Andalusite Deposits in the So-Called Okch'ŏn(Yokusen) System ..... Takao YAMAGUCHI 124
Boron Mineral Resources in Korea ..... Takeo WATANABE 132
Lithia Mica Deposits in Korea with Special Reference to Spodumene and Amblygonite ..... Hidekata SHIBATA 158
Allanite in Korea ..... Jitsutaro TAKUBO, Mitsue SAITO 169
Monazite Deposits in Korea ..... Hideo TSUDA 185
Mica ..... Chuzo KONDO 188
Supplement to "Minerals of Korea" ..... Hideo TSUDA 198
Thermal Springs and Cold Mineral Springs in Korea ..... Chuzo KONDO 241

MANCHURIA

Summary of Physiography of Manchuria..... Riuji ENDO 263
Topography of the Liao-Tung Peninsula ..... Sadajirō TSUCHIDA 284
The Sinian System of Kuan-Tung Province ..... Susumu MATSUSHITA 316
Carboniferous and Permian Systems of Manchuria ..... Mitsuo NODA 324
Volcanoes in Manchuria..... Tsutomu OGURA 373
Copper-bearing Contact Deposits of Hua-tung-kou, Fu Hsien, Feng-tien Province, Manchuria ..... Kamezo MATSUDA 414

CHINA

Banded Magnetite Ore Deposits and Metamorphic Rocks in the Vicinity of Yen-tou-tsun, Wu-tai-shan, Shan-hsi Province, China (with Appendix on Hematite Ore Deposits in the Vicinity of Ting-hsiang and Tung-yeh-chen) ..... Shuichi IWAO 425
Exploration of Ground Water Resources in North Chian ..... Nobuo KURATA 442
Place Names 463

KOREA

Geologic Structure of North Korea and South Manchuria

Teiichi KOBAYASHI

Introductory Note

Various geologic structures, each bearing its own history of tectonic development, are found in Japan, Korea and Manchuria. Their comparison is, therefore, a subject of more than local interest. I have already published the results of my studies on Japan in 1941.

In Korea and South Manchuria there are three folded zones called, from north to south, the Taitzuho, P'yeongnam and Okch'eon zones. They are separated by the P'yeongbuk and Shantung-Kyeonggi massives. The stratigraphic sequences of these zones are very different from one another, but agree in the absence of volcanic material in Palaeozoic and older sediments. In contrast, volcanic eruptions took place repeatedly in the Chichibu geosyncline from which the Japanese islands developed. The Akiyoshi, Sakawa or Oyashima folded mountains in Japan differ from the structures of the folded zones in Koreo-Manchuria in that a metamorphosed axis is present in each.

The anticlines and synclines in the Okeh'eon zone in South Korea have prolonged axes which are nearly parallel to one another and have many long thrust lines. Such parallelism is not seen in the P'yeongnam-Liaotung or the Taitzuho-Yalu zone. The P'yeongnam-Liaotung zone consists of many brachy-anticlines and -synclines, and structural domes and basins which are disposed in checker pattern. In the Liaotung peninsula remarkable differences in the stratigraphic sequence and the mode of crustal deformation between the P'yeongnam geosyncline and P'yeongbuk massif, on the south and north side of the Yatung bay respectively, are interesting. From the Taitzuho valley to the Yalu-Hunchiang tributaries one can see a great variety of deformation which occurred in kratonic and quasikratonic terrains. It is of primary importance to describe these various aspects of geologic structures to the extent that they are known in the Taitzuho-Yalu zone as well as the P'yeongnam-Liaotung zone.

Because different types of structures were produced at one place or another by the same disturbance, such differences must be attributed to the quality and quantity of sediments and the character of their basement. There are excellent examples

of differential movement between plastic sediments and a rigid basement. An attempt to classify the major and minor structures is presented in the concluding chapter.

Korea and South Manchuria were consolidated almost completely by the late Mesozoic batholithic invasion of a granitic magma. After this oronization, the terrain was anoronized, as discussed in my paper on the geology of South Korea. "Geology and Mineral Resources of the Far East, vol. 1." Although little can be said of the Tertiary history of these two zones, additional information is provided in the first chapter as to fragmentation and topo graphic development of the region.

Since 1926 I have visited the continent many times to make geological surveys in the Huolienchai, Niuhsintai, Chinchiachengtzu and Wuhutsuei basins in South Manchuria and the Ch'osan, Kojang, Koweon, Mandal-san and Kyeomi-p'o areas in North Korea. In addition, I made short trips to the Hsiaoshih coalfield, the eastern area of Liaoyang, and Sanshihlipu and its vicinities in the Liaotung Peninsula and the Manp'o-jin, Huch'ang, Ch'angni, Chunghwa, Sangweon, Sariweon, and Sinmak areas in Korea to see geological sections or to make fossil collections. These geological surveys and reconnaissances were made chiefly for the purpose of studying the Eo-Palaeozoic stratigraphy and palaeontology, but I have also noted the tectonic aspects as much as possible.

In 1941 I had the opportunity to conduct geological surveys in the tectonically very important Penhsihu and Wafangtien areas with my students, and was able to visit many places in the region. Compared with the vast terrain of North Korea and South Manchuria, however, the areas I saw are very small in total, though they include key points.

Geological descriptions of many areas, some of which go into great detail, exist, and certainly Korea and South Manchuria belong to the part of Asia whose geology has been well surveyed. Nevertheless, the results so far achieved in the geology of this region have never been schematized from the tectogenetic point of view. I have taken the liberty to make such a synthesis for the P'yeongnam geosyncline and Taitzuho depression, as I have seen many places on both sides of the Yalu river, and have published the results in three papers in *Geology and Mineral Resources of Eastern Asia* in 1953. In 1956 I revised the papers and published them as "A Contribution to the Geotectonics of North Korea and South Manchuria," with the addition of an outline of the regional geology and comparative tectonics.

Thanks to the efforts of many geologists, the stratigraphy of the Sinian, Korean and Heian groups which constitute the folded areas are now so well defined that we can see their general picture. This is not the case for the Mesozoic formations, notwithstanding the fact that a knowledge of Mesozoic stratigraphy is a prerequisite for phase analysis, because the Mesozoic was the orogenic era whereas the Palaeozoic was the epirogenic era in the region. For this reason I have undertaken studies of the non-marine Mesozoic formations and fossils in Eastern Asia with several collaborators. This project advanced fairly rapidly for some years after 1941, but I still found need for careful checking of selected Mesozoic areas.

Fortunately, I was able to refer to many papers gathered by the Committee for the Compilation of Geology and Mineral Resources of the Far East of the Geographic Society of Tokyo. I have also tried to refer to recent contributions published in China and North Korea, although this could only be done to a limited extent. The Pre-Cambrian rock-sequence has been emended here on the basis of new geochronological data. Because my field experience is limited, I cannot be responsible for all the facts. However, their evaluation, interpretation and orientation in the tectonic synthesis were made on the basis of my own experience and are my responsibility. My sincere thanks are due to the many persons and organizations who provided assistance and cooperation in this study.

Two kinds of romanization of geologic terms commonly used in geology of Korea and South Manchuria (Northeast China).

Old Romanization	**New Romanization**
Bukkokuji igneous group	Pulguksa igneous group
Chokken series	Chikhyeon series
Chosen group	Jeonseon or Korean group
Daido series	Daedong series
Gishu disturbance	Üiju disturbance
Genzan-Keijo tectonic valley	Weonsan-Seoul tectonic valley
Greenstone series	Nogam series
Heian group	P'yeongan group
Heihoku land	P'yeongbuk land
Heinan zone	P'yeongnam zone
Honkeiko formation	Penhsihu formation
Jido series	Sadong series
Kankyo fault system	Hamgyeong fault system
Keiki land	Kyeonggi land
Keirin group	Kyerim group
Kenjiho limestone conglomerate	Kyeomip'o Limestone conglomerate
Kishu-Meisen graben	Kilchu-Myeongch'eon graben
Kobosan series	Gobangsan series
Koten series	Hongjeom series
Kuken series	Kuhyeon series
Liao-Gaima land	Liao-Kaema land
Miyanohara formation	Tayü formation
Rakuro complex, peneplain	Naknang complex, peneplain
Reinan land	Yeongnam land
Rensen system	Yeonch'eon system
Rishu piedmont plain	Yeoju piedmont plain
Roppyakusan peneplanation	Yukpaeksan peneplanation
Shichihosan horst, series	Ch'ilbosan horst, series
Shidogu series	Sadongmor series
Shiragi series	Silla series
Shogen group	Sangweon group
Shorin disturbance	Songnim disturbance
Taihakusan dislocation line	Taebaegsan dislocation line
Taiho disturbance, series	Taebo disturbance, series
Taishiin series	T'aejaweon series
Yokusen zone	Okch'eon zone
Yotoku series	Yangdeok series

I
A Geological Sketch of North Korea and South Manchuria

1. Research in the Geology of Manchuria

In 1869 Ferdinand von Richthofen travelled through South Manchuria from Yingkou to Moukden by way of Fuchou, Takushan, Fenghuangcheng and Penhsihu, and published his observations in 1882, in vol. II of *China*. His fossil collections were later described by Dames, Kayser, Schenk and Frech in vols. IV and V in 1883 and 1911. Prior to this, A. P. Kropotkin traversed the northern part of the Great Khingan range in 1864. In his journey through Central Asia, Mongolia and North China, 1892–94, W. A. Obrustchew visited Barga and East Manchuria. From 1896, when he was sent to the Far East by the Royal Geographic Society of Russia, E. Ahnert devoted his life to the geology of Central and North Manchuria and the maritime province of the U.S.S.R. and made valuable contributions until his death in 1945.

At the end of the last century, however, Manchuria was still not far removed from *terra incognita* geologically. At the beginning of this century fossil plants from Manchuria were described by F. Krasser (1905), M. D. Zalessky (1905), I. V. Palibin (1906) and M. Yokoyama (1908), and Cambrian Fossils by C. D. Walcott (1913). Subsequently many papers on Cambrian fossils, the Hokang and Peipiao coal field, etc. were published by Sun (1923), Tan (1924), Wong (1927) and others.

Among Japanese geologists, Kochibe was the first to be sent to Manchuria. He surveyed coal and gold resources in the Liaotung peninsula in 1895. Subsequently in 1905, T. Ogawa and other geologists made geological surveys of the Wuhutsuei, Yentai, Fushun and other mines. In 1907, the Geological Institute was established at the South Manchurian Railway Company at Talien. Since then systematic investigations in South Manchuria have advanced steadily.

In 1928 two geological institutes were established at the Ryojun College of Engineering and at the Manchurian Teachers' College, and a number of studies were carried out by their staffs. Among them were R. Endo's study on the Cambrian and Ordovician Fossils, Matsushita's study on the geology of the Chinchou and Talien areas, and Ogura's study on Wutailienchi and other volcanoes, etc. Since 1928 the geological institute of the railway company published the Talien sheet and several other geological maps (scale: 1/400,000) and explanatory texts for each. In 1931 this institute sent some parties to Central and North Manchuria; the results included a geological map of Manchuria (1/1,000,000) and 4 volumes of Geology of Manchuria (1937). In 1933 Tokunaga led the Manmo Science Expedition to Jehol and the results were published in a series, in which a report of explorations (1933, 1934) at Kuhsiangtun near Harbin is included.

In addition to these there are large numbers of papers written by professors and their students in the universities in Japan, e.g., YABE and HAYASAKA's "Palaeozoic corals" (1915–16), HAYASAKA's "Brachiopods from Penhsihu" (1922), M. MATSUYAMA's "Gravity anomaly in Fushun coal-field" (1924), OZAWA's "Upper Palaeozoic fossils" (1926), S. ENDO's "Cenozoic fossil plants" (1926–28), KOBAYASHI's "Cambro-Ordovician" (1927–1966), UWATOKO's "Oil shale of Fushun" (1931), YABE and OISHI's "Mesozoic plants" (1935), etc. OZAKI's "Upper Palaeozoic Brachiopods" and OKADA's "Natural Na Compounds" belong to the contributions from the Shanghai Science Institute, founded in 1928.

After 1931, or thereabouts, surveys of the mineral resources of Manchuria became very active. In 1937 the Geological Survey was transferred from Talien to Changchung; the Geological Society of Manchuria was instituted in 1939. The systematic exploration of Kuhsiangtun was undertaken in 1938 and 1939 and several valuable works in palaeontology were produced by the staff of the Manchurian Central Museum. Knowledge of the geology of Central and North Manchuria increased very rapidly in the 15 years before the end of World War II. Sinian and other Palaeozoic fossils were described by YABE, EGUCHI, NODA and several others; Mesozoic and Tertiary coal-bearing formations were clarified considerably by MORITA, NISHIDA and many others; non-marine Mesozoic fossils were studied by KOBAYASHI, SUZUKI, TAKAI and a few others; intensive studies were made of the Pre-Cambrian geology by MATSUSHITA, SAITO and some others.

In addition, there are studies on "Banded iron ore of Anshan" (MURAKAMI, 1922), "Magnesite of Tashihchiao" (NIINOMI, 1923), "Bauxite shales" (SAKAMOTO, 1924), "Kungchangling iron ore deposit" (TSURU, 1935), etc. Other contributions to economic or applied geology are too many to mention here.

The results of the geological research achieved near the end of the war largely remained unpublished, until a committee in the Tokyo Geological Society undertook the project of compiling *The Geology and Mineral Resources of Eastern Asia.* The recent advancement in stratigraphy of South Manchuria is summarized in *Scientific Reports of the Stratigraphic Conference* published in 1964 at Peking. The reader is referred to a brief note in "Geology of South Korea," in volume I of this publication, for the history of research on the geology of Korea.

2. Outline of the Geology of North Korea and South Manchuria

Between the central plain of Manchuria on the west and the Hanka-Suifun plain on the east, the mountainous land of East Manchuria extends into Korea. The Sinian or northeast trend is predominant in the orography of East Manchuria. Following this trend are the Wantashan, Laochangkuang, Sueiling and Sahaliangling ranges, all of which are parallel to the Changpaishan range and the national boundary, which is marked by the Touman and Yalu rivers, respectively on the northeast and southwest side of Mt. Paektu or Changpaishan.

In North Korea the Kaema plateau on the east side is tilted up and cut by a

steep scarp on the southeast. In front of its middle part there is the Kilchu-Myeonch'eon graben and the Ch'ilbosan horst beyond the graben. On the west side of the plateau there are several ranges with a Sinian trend. The Weonsan-Seoul rift valley runs diagonally across the Korean peninsula, Following a NNE trend, as does the Myeonch'eon graben. The Taebaeksan range is the backbone of the peninsula that runs through Central Korea near the Sea of Japan. Its northern extension is the Nangim range, which parallels the Paektu volcanic range running across the Kaema plateau.

From the stratigraphic point of view Central and North Manchuria, to which the northern part of the east Manchurian mountainous land belongs, are quite different from South Manchuria, which in turn is intimately related to Korea except for the northeastern part, called the Touman area. As discussed elsewhere (KOBAYASHI, 1942), Central and North Manchuria was a part of the Mongolian

Table 1. Two Types of Stratigraphic Sequences of Older Rocks in Korea-Manchuria.

Geological Age	South Manchuria and North Korea			North and Central Manchuria
Triassic				Mongolian Batholith
Permian	P'yeongan Group	Nogam Series Gobang Series Sadong Series		Manmo group
Carboniferous		Hongjeom Series		
Devonian	(Kyeomip'o Ls. Cg.)			
Silurian				
Ordovician	Korean Group	Toufangian Wolungian Wanwanian	Rakuroan Complex	?
Cambrian		Chaumitian Fuchouan Mantoan		
Cryptozoic	Sinian Group	Kuhyeon Sadongmor Chikhyeon		
	Mach'ollyong Group			
	Older Metamorphose Complex			

geosyncline where the Manmo group had accumulated. The geosyncline was disturbed by the Akiyoshi cycle of orogeny in the Permo-Triassic period. During the orogeny, batholithic invasion of the Mongolian granitic magma oronized a major part of the geosyncline. The Triassic and Upper Palaeozoic history of this geosyncline is allied to the Chichibu geosyncline of Japan.

Korea and South Manchuria, on the contrary, occupy the northeastern part of the Koreo-Chinese Heterogen. In the positive elements of this Heterogen, the Pre-Cambrian basement is widely exposed. In the negative elements there are Proterozoic and Palaeozoic formations to which a part of the Triassic system is added. In the Hwangho basin on the north side of the Tsinlingshan, however, there is a large Middle Palaeozoic break in the stratigraphic sequence.

The tectonic lineament of Korea which I proposed in 1933 needs little emendation, but was modified in 1953 to include adjacent areas. Together with a part of North Korea, the larger part of South Manchuria belongs to the Liao-Kaema land where the ancient basement complex is largely bared. On the western side of the land, however, the positive and negative zones are arranged alternately from north to south as follows:

1. Kaiyuan zone of elevation
2. Tiehling zone of depression
3. Shenyang (Moukden) zone of elevation
4. Taitzuho zone of depression
5. Pyeongbuk zone of elevation

The elevated zones are bare, but the depressed zones are mantled with Palaeozoic and Proterozoic veneers. The P'yeongnam geosyncline which extends from North Korea into the Liaotung peninsula is on the south side of the fifth zone. This geosyncline is separated from the Okch'eon geosyncline in South Korea by the Kyonggi-Shantung land.

The ancient basement rocks are exposed extensively in the Liao-Kaema land. In 1926 KAWASAKI proposed the *Mach'ollyong (Matenrei) system* for metamorphic rocks in the Kaema plateau, which reveal a grand cycle of sedimentation, 12,500 m in total thickness, with the *Collenia*-bearing carbonate facies in the middle part (KINOSAKI, 1932, 38). The upper part of the system, now called the *Namtaech'eon series,* includes rocks 1600 to 1630 million years old. The Archaean basement complex of North Korea is composed of Nangim gneiss and crystalline schists, Andoli basic intrusive rocks and Yonghwasan (Renkwasan) acidic intrusives and one old intrusive rock was estimated at 2040 million years (MASAITIS et al., 1964; KIM, 1967).

In Korea the Pre-Cambrian granites were collectively called *Kokulian granite,* but TATEIWA (1926) distinguished the older or Hamhŭng (Kanko) from the younger or Seohochin (Seikoshin) granitic gneiss in North Korea. In South Manchuria the older and younger granites are called Tueimienshan and Kungchangling granite, respectively. Pre-Cambrian granites, however, are undifferentiated in most areas.

In South Manchuria the *Anshan series,* which bears banded iron ore, is unconformably underlain by the Tueimienshan granite and intruded by the Kungchangling granite (SAITO, 1941). Pegmatite from the series was estimated to be 2100 to 2300 million years old (Comm. Strat. China, 1964). Muscovite from a chlorite-muscovite schist along the contact of enriched ore body of Anshan, and muscovite in the western marginal part of the Anshan series were estimated to be 2270 and 1909 million years old, respectively (LI PU, 1965). Like the Mach'ollyong system,

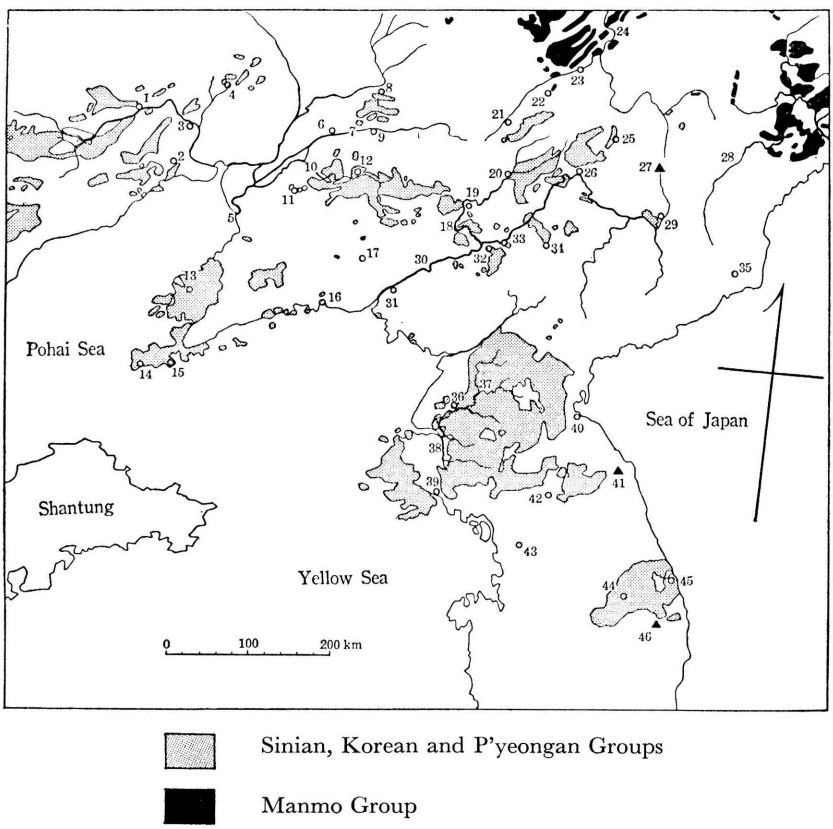


Fig. 1. Distribution of the Rakuroan Complex and P'yeongan Group in North Korea and South Manchuria

1. Chaoyang 2. Chinchou 3. Ihsien 4. Fuhsin 5. Liaoho 6. Shenyang (Fengtien, Moukden) 7. Hunho 8. Tiehling 9. Fushun (Bujun) 10. Taitzuho 11. Anshan (Anzan) 12. Penhsihu (Honkeiko) 13. Fuchou 14. Lüshun (Ryojun, Port Authur) 15. Talien (Dairen) 16. Takushan 17. Fenghuangcheng 18. Hunchiang 19. Huanjên 20. Tunghua 21. Liouho 22. Hueinan 23. Huatien 24. Mutanchiang 25. Fusung 26. Lingchiang 27. Changpaishan, Paektu-san (Hakutosan) 28. Touman river 29. Changpai 30. Yalu river 31. Sinŭiju (Shingishu) 32. Ch'osan (Sosan) 33. Wiweon (Igen) 34. Kanggye (Kokai) 35. Kilchu (Kishu) 36. P'yeongyang (Heijo) 37. Taedong-gang (Daidoko) 38. Chaeryeong-gang (Saineiko) 39. Haeju (Kaishu) 40. Weonsan (Genzan) 41. Kŭmgang-san (Kongosan) 42. Ch'eolweon (Tetsugen) 43. Seoul (Keijo) 44. Yeongweol (Neietsu) 45. Samch'eok (Sanchoku) 46. Taebaegsan (Taihakusan)

the *Liaoho system* (SAITO, 1938) represents a large sedimentary cycle, 14,000 m at its thickest and extensive on the Manchurian side of the Liao-Kaema land. The middle part, the *Tashihchiao series,* is mainly composed of marble and dolomite and contains magnesite deposits. It was previously considered older than the Anshan, but 1400 million years was given for the age of a pegmatite in the Liaoho group. At Howfin, Anshan, the Anshan series is unconformably overlain by the *Langtzu-shan seires,* which is the lower division of the Liaoho group (MA and LIN, 1966). It is quite probable that the Liaoho group belongs to the same formation as the Mach'ollyong system.

The ancient basement complexes are discordantly overlain by the late Proterozoic Sinian, the Cambro-Ordovician Korean (or Chosen) and the Upper Palaeozoic to Triassic Heian (or P'yeongan) groups. The first and second groups are collectively called the *Rakuroan (Naknang) complex.*

The sequence and thickness of the Sinian group are very different in the depressed zones. It is best developed in the P'yeongnam geosyncline where it is represented by a grand cycle of sediments, several thousand meters in thickness, called the Shogen (Sangweon) group; the middle and upper parts are often separated by a disconformity. The group is totally absent, however, in the Okch'eon geosyncline of South Korea, although there is an excellent display of the Korean and P'yeongan groups. The middle and upper Sangweon group is well developed in the Tiehling zone, but no Palaeozoic formation is present. Therefore it can be said that there

Table 2. Four Types of the Stratigraphic Sequences in the Zones of Depression in Korea and South Manchuria.

Tiehling Zone	Taitzuho Zone	P'yeongan Zone	Okch'eon Zone
		P'yeongan Group	P'yeongan Group
	Taitzuho Group		
	Korean Group	Korean Group	Korean Group
Up. Fanho Series		Kuhyeon Series	
Low. Fanho Series		Sadongmor Series	
	Hsiho Series	Chikhyeon Series	

was a reciprocal relationship between the emergence of the northernmost zone and the submergence of the southernmost zone which took place at the transition from the Proterozoic to the Palaeozoic era.

The remarkable differences in the distribution of the Sangweon group among these subsiding zones is shown in Table 2.

Although the difference in facies and thickness is fairly distinct between the axial and peripheral parts of the Okch'eon geosyncline, the Korean group is monotonous in most other zones. The group in Korea was first divided into the Yangdeok series below and the Great Limestone series above. Shale and sandstone are more abundant than carbonates in the basal part; the remainder is composed mostly of limestone and dolomite. The sequences of the group in the P'yeongnam and Taitzuho zones resemble each other; their average thickness is about 1,500 m.

It is noteworthy that the Korean group is generally overlain by the P'yeongan group para-unconformably in the vast Hwangho basin, even though there is such a large stratigraphic break corresponding to the prolonged period of emergence from late Ordovician to early Carboniferous. It is quite evident that neither the Caledonian nor the Variscan orogeny existed in this region.

The P'yeongan group in Korea is divided into four series, known as the Hongjeom, Sadong, Gobangsan (Koten, Jido, Kobosan) and Nogam (Green) series. Its equivalent in South Manchuria is the Taitzuho group which is also divisible into four series, called in ascending order the Penchi, Huangchi (or Yatung), Lioutang and Tsaichia series. As shown in Table 3, however, it must not be overlooked that the Nogam series is apparently absent in South Manchuria and that the Huangchi and Lioutang series are combined into the Sadong series in Korea. Marine fossils are present in the Hongjeom and a part of the Sadong series in Korea and South Manchuria, but not in the Gobangsan and later sediments.

Silurian derived fossils in the Older Mesozoic conglomerate near Kyeomip'o (Kenjiho), North Korea, indicate a local ingression of the Silurian sea into the P'yeongnam geosyncline. It is also noted here that Devonian type corals are reported from the basal part of the P'yeonan group at two localities in the P'yeongnan and Okch'eon zones, which used to be referred to the Hongjeom series. Whether this coralline limestone is Devonian in age or whether they are relic corals in the Moscovian sea is unclear (YABE and SUGIYAMA, 1939).

The Hwangho basin was not deformed much until the Middle Triassic epoch. Therefore the Shogen, Korean and P'yeongan groups generally accumulated in the Hwangho basin or in the P'yeongnam geosyncline, the Taitzuho depression or other subsiding basins. This accumulation has para-unconformable or disconformable relations except for a few small spots where angular discordance is reported. This long-lasting basin was, however, destroyed by the Songnim disturbance.

Broadly speaking, the Palaeozoic was the epirogenic era whereas the Mesozoic was the orogenic era for Eastern Asia. Therefore the Mesozoic stratigraphy must be established before the orogenic movements can be analyzed into phases. The stratigraphic study of the Mesozoic is more difficult than the Palaeozoic, in pro-

portion to this tectonic importance, because Upper Triassic and later formations were deposited in separate basins, each having its own history. Accordingly no two basins have the same sequence. Moreover, guide fossils are scarce in the non-marine sediments and their facies change horizontally as well as vertically, as is usual with orogenic sediments. Therefore some ambiguities remain in the Mesozoic stratigraphy of the continent. An analysis of the crustal movements by means of the Mesozoic strata is shown in Table 4.

Table 3. Relation between the P'yeongan and Taitzuho Groups.

Geological Age	Okch'eon and P'yeongan Zones		Taitzuho and Yalu Areas	
Anisic	Greenstone (Nogam)	P'yeongan Group		
Skytic				
Tartarian	Kobosan (Gobangsan)		Tsaichia	Taitzuho Group
Kazanian				
Kungurian	Jido (Sadong)		Lioutang	
Artinskian				
Sakmarian			Huangchi	
Uralian	Koten (Hong'eom)			
Moscovian			Penchi	

Table 4. Mesozoic Formations and Crustal Movements.

Palaeocene	Pulguksa Igneous Activity
Upper Cretaceous	and Block Movements
Middle Cretaceous	Silla Series
	Late Taiho (Taebo) Disturbance
Lower Cretaceous	Naktong Series
	Early Taiho (Taebo) Disturbance
Oolite	Jehol Series
	Gishu (Ŭiju) Disturbance
Rhaeto-Lias and Keuper	Daedong Series
	Shorin (Songnim) Disturbance
Bunter	Nogam Series

The Triassic Shorin (Songnim) disturbance was paroxysmal in the P'yeongnam geosyncline. It was, however, probably no more than embryonic folding for the Taitzuho and Okch'eon zones where the late Mesozoic Taiho (Taebo) disturbances were strong. The Songnim mountains of the P'yeongnan zone were also modified greatly by the Taebo movement.

The Daedong (Daido) series is distributed widely in Korea and contains a copious flora which KAWASAKI (1925) has referred to Lias. But a part of the series is now thought to be older than Lias, because of the occurrence of some Estherian species common to the Upper Triassic Mine series in West Japan. (KOBAYASHI, 1951). Because the series is composed of synorogenic or metaorogenic sediments, its precise classification is important for a better understanding of the Songnim disturbance.

In Central and South Manchuria plant fossils related to the Daedong flora are known to occur at Saimaki, Wafangtien and some other localities, but *Clathropteris,* which is almost ubiquitous in the Daedong localities in Korea, is not found in Manchuria except at Tienshuaifukou.

The Jehol fauna is known from Ŭiju near the embouchure of the Yalu river, whence the Gishu (Ŭiju) movement was proposed by TAKAHASHI (1950) on the basis of the discordance between this and the Daedong series. Because of the limited distribution of the Jehol series in Korea and adjacent Manchuria, however, it is difficult to distinguish the deformation of the Ŭiju phase from the later ones.

The late Mesozoic Taiho (Taebo) disturbance was strong and extensive in Eastern Asia. In South Manchuria it is well marked by discordances at the bases of the Penhsihu-Tayü formation in the Penhsihu coal-field and of the Pulantien formation at the neck of the Liaotung peninsula. In the P'yeongyang (Heijo) coal-field there is a distinct discordance at the base of the Taebo series. Hence the name Taebo (Taiho) disturbance. The lithology of this series is more like the Middle Cretaceous Silla (Shiragi) than the Lower Cretaceous Naktong series of South Korea. In South Korea the Naktong, containing *Plicatounio,* is overlain disconformably by the Silla series and the latter in turn is overlain disconformably by the Pulguksa (Bukkokuji) volcanic series. Therefore the Taebo disturbance may be split into the pre-Naktong or the first Taebo phase and the pre-Silla or the second Taebo phase. For the Wafangtien and Penhsihu basins the first Taebo movement was more important than the second.

During the Cretaceous period violent volcanic eruptions took place. The effusive rocks were mostly andesitic in the earlier stage, and liparitic in the later. At the same time as the later effusion in the late Cretaceous period there was batholithic invasion of granitic magma, which may have continued till the beginning of the Tertiary. This is called the Pulguksa igneous activity and was intimately related to the block movement. In view of the thrusting of the neighboring block upon the Penhsihu or Tayü formation, the movement was compressive at the beginning, but later became tensional. The magmatic invasion was on a grand scale and, as a result, the terrain was completely oronized or consolidated and stabilized.

Table 5. Cainozoic History of Korea and South Manchuria.

Alluvium	Salt-Field on Pohai Coast Peat Deposti; Basalt Cones in Central Manchuria
Diluvium	Naknang and Liaotung Peneplains Malan Loess Kaema Plateau Basalt
Pliocene	Yeoju and Kuangningszu Piedmont Planes (Plateau Gravels) Ch'ilbosan Volcanic Series
Miocene	Hamgyeong Fault System Yukpaek Plane Myeongch'eon Series
Oligocene Eocene	Yongdong Basalt Yongdong Series Fushun Series; Pongsan Series
Palaeocene Senonian	Pulguksa Igneous Group

Tertiary sediments are very scarce in this region. Therefore it is difficult to decipher this part of the history. At Pongsan near Sariweon, Hwanghae-do, North Korea, there is a coal-bearing formation which yielded late Eocene mammals that are intimately related to the Shara Murun and Irdin Manha faunas of Mongolia (TAKAI, 1939).

The Palaeogene coal-bearing deposits of Fushun, east of Shengyang, comprise a formation more than 1,000 m thick, overlying the ancient granitic gneiss and late Mesozoic formations. It may be coeval with the Pongsan coal-bearing formation or a little younger, because the Fushun flora is Oligocene according to FLORIN (1922), but late Eocene according to S. ENDO (1934). The latter opinion is upheld by *Anostreia manchuriana* R. ZANGERI from the oil shale of the series, which is similar to *A. ornata* LEIDY from the Eocene of North America (IMAIZUMI, 1951).

The Oligocene Yongdong (Ryudo) formation in North Hamgyeong-to is composed of coal-bearing sediments in its lower part and alkaline basalt in its upper part. It lies on the fairly level surface of the basement, which consists of the Mach'ollyong metamorphic rocks, ancient granitic gneiss and the older Mesozoic formation. It is disconformably overlain by the paralic Myeongch'eon (Meisen) formation, about 700 m thick. *Bunolophodon annectens* and other fossils from the upper part are middle Miocene in age.

Subsequently the Kaema plateau was tilted, causing faulting of the Hamgyeong (Kankyo) system in a NE to NNE direction along the southern periphery (TATE-

IWA and YAMANARI, 1925). As a result, the Kilchu-Myeonch'eon graben and the Ch'ilbosan horst appeared in front of the plateau. It is certain that this block movement occurred before the Ch'ilbosan volcanic series, which is considered Pliocene in age. On the plateau there still remains the Yukpaeksan (Roppyakusan) plane, which is the unfinished or incomplete peneplain of a previous erosion cycle. The front of the plateau was strongly dissected by the headward erosion of young rivers to form a steep scarp.

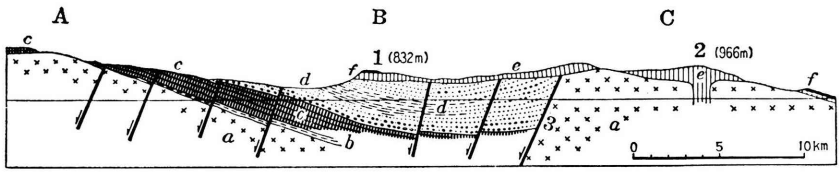


Fig. 2. Kilchu-Myeongch'eon (Kishu-Meisen) Graben and Ch'ilbosan (Shichihosan) Horst (after TATEIWA).

A. Kaema Plateau
B. Kilchu-Myeongch'eon Graben
C. Ch'ilbosan Horst
1. Chaeteok-san
2. Ch'ilbo-san
3. Kilchu-Myeongch'eon
a. Basement Complex
b. Yongdong (Ryudo) Coal-bearing Formation
c. Yongdong Alkaline Basalt
d. Myeongch'eon Series
e. Ch'ilbosan Volcanic Series
f. Pleistocene Basalt

As discussed on a former occasion (1953), strong faulting occurred in the Taebaegsan (Taihakusan) dislocation zone in Central Korea during the Pulguksa igneous activity, but the subsequent peneplanation was far advanced by the Middle Tertiary period. The Taebaegsan backbone range was elevated in the middle Neogene in the form of an asymmetrical geanticline, as is traceable with the Yukpaeksan plane. The oldest deposits on the marginal peneplain are upper Miocene. They are found at Samch'eok, Yeonghae and Yeonil. All have boulder conglomerates at their base and at the last named locality lie with strong discordance on the Middle Tertiary formations. Thus there were two important phases of movements in Korea, one in late Cretaceous or early Palaeogene times and the other in Middle Tertiary or middle Neogene times.

In Manchuria the Middle and Upper Cretaceous Sungari series, which forms the bottom of the central basin, is mostly underformed, but is tilted up along the Taheishan range. Behind the range at Kangyao and other places there is a spatulate depression where the Palaeogene formation overlies the Upper Palaeozoic Chilin formation. Granite intrudes it and dips to the other side, forming some undulations.

The Palaeogene of Fushun fills a narrow trough along the Hunho river, and dips 20 to 30 degrees to the north. It is cut by a strike fault or, in part, an upthrust. The southerly inclined Diluvium near Yungantai indicates the recurrence of movement along the same trend in the near past. The Palaeogene monocline is thrust from the northwest. This disturbance belongs to the Liao system of dislocation, from which the Sungari and Kangyao formations have suffered.

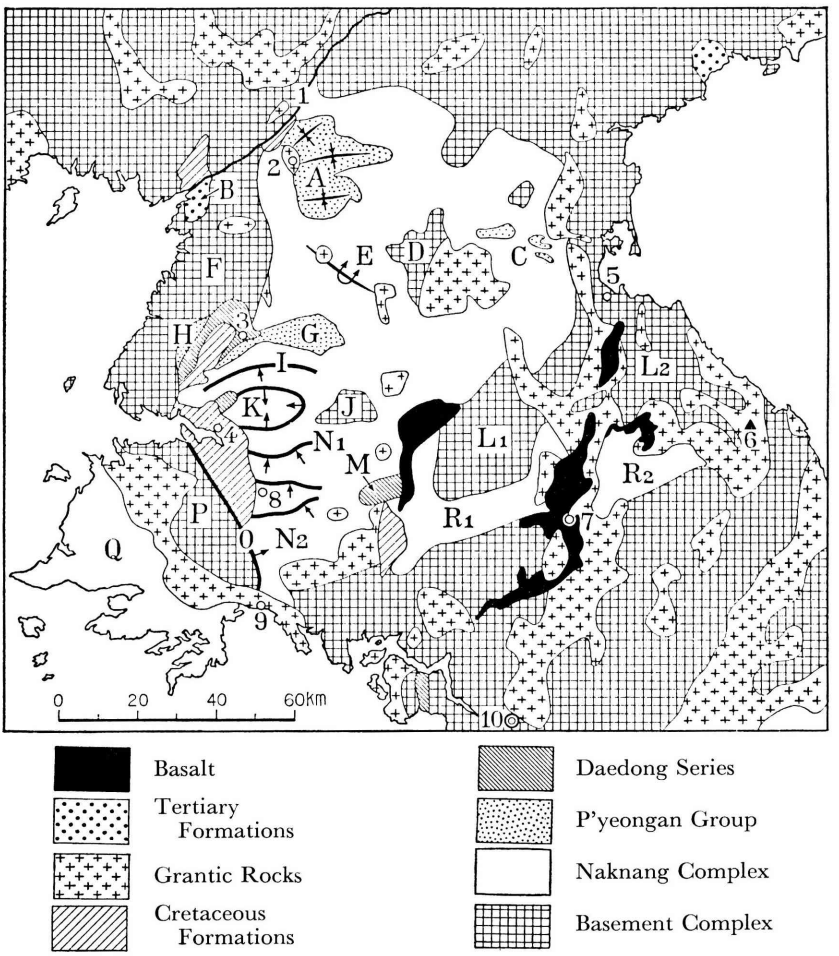


Fig. 3. Tectonic Division of the Orogenic Zone in North Korea

A. North P'yeongan-namdo Coal-Field
B. Anju (Anshu) Tertiary Formation
C. Koweon (Kogen) Coal-Field
D. Yangdeok (Yotoku) Dome
E. Seongch'eon (Seisen) Anticlinorium
F. P'yeongweon (Heigen) Block
G. Kangtong (Koto) Coal-Field
H. Kangseo (Kosai) Coal-Field
I. Chunghwa (Chuwa) Disturbed Zone
J. Chungbongsan (Sohozan) Dome
K. Hwangju (Koshu) Basin
$L_1/_{-2}$ Ich'eon-T'ongch'eon (Isen-Tsusen) Basement Anticline
M. Pongsan (Hosan) Group
$N_1/_{-2}$ Chaeryeong-gang (Saineiko) Disturbed Zone
O. Annak (Angaku) Fault
P. Sinch'eon (Shinsen) Block
Q. Changyeon (Choen) Disturbed Zone
$R_1/_{-2}$ Kumch'eon-Kumhwa (Kinsen-Kinkwa) Syncline
1. Ch'ongch'eon-gang (Seisenko) 2. Kaech'eon (Kaisen) 3. P'yeongyang (Heijo)
4. Kyomip'o (Kenjiho) 5. Weonsan (Genzan) 6. Kŭmgang-san (Kongozan)
7. Ch'eolweon (Tetsugen) 8. Sariweon (Shariin) 9. Haeju (Kaishu) 10. Seoul

The Chinchou fault in the Liaotung peninsula is also parallel to the Liao tectonic line which delimits East Manchuria. Its southwestern extension is oc-

cupied by the I-Wei graben which divides the Shantung block into two parts. The Palaeogene Kuanchuang series and older formations and rocks in Western Shantung are repeatedly cut by a series of step-faults with the downthrow on the southwest side. This faulted block is truncated by the I-Wei graben.

Unless the gravel beds, which are overlain by the Kaema plateau basalt on the Yukpaeksan plane, is Pliocene, no sediment of this age is present in South Manchuria. During this period of emergence the mountainous lands were fringed by piedmont steps called the Yeochu (Rishu) plane in Korea and the Kuangningszu (Koneiji) plane in Liaotung.

According to TATEIWA (1925), 3 or more series can be distinguished among the Diluvium and later basalts, among which the Kaema basalt is the oldest and most widespread.

Near P'yeongyang there is a low peneplain called the Naknang (Rakuro) peneplain, 20 to 50 m above sea-level. Its equivalent at a similar altitude in Liaotung is called the Liaotung peneplain or the Pitzuwe (Hishikwa) plane. It is dissected by valleys in which peat was deposited during subsidence. The latest emergence is indicated by salt fields around the Liaotung peninsula or the Pohai sea.

II
THE P'YEONGNAM (HEINAN) OROGENIC ZONE IN NORTH KOREA

1. Introduction (see Geological Map I)

I proposed the name "Heinan geosyncline" for the zone extending from P'yeongan-namdo and Hwanghae-do in North Korea to the Liaotung peninsula in 1930, because the very thick Shogen (Sangweon) group distributed in this zone is overlain by the Korean and Heian (P'yeongan) groups, which are also thick. These groups were strongly folded and thrust by the Middle Triassic Shorin (Songnim) disturbance. The Daedong series was subsequently deposited as a lacustrine sediment in intermontane basins of this folded zone. Its structure was later greatly modified by the Taiho (Taebo) disturbance at the transition from Jurassic to Cretaceous. During the Cretaceous period strong igneous activity took place and the Silla series, rich in pyroclastic material, accumulated there. The volcanic eruptions were followed by a batholithic invasion of granitic magma, through which the zone was well oronized. There was block movement near the end of the Cretaceous or the beginning of the Tertiary period. During the tranquil Palaeogene period, the land was levelled by erosion. In the Middle Tertiary period intense block movement occurred. The marginal peneplain called Rakuro (Naknang) is a product of later erosion.

a. Tectonic Lineament.

In North Korea the P'yeongnam folded zone is delimited by the Ch'ongch'eongang (Seisenko) river on the north and the Haeju-Ch'eolweon line on the south. The P'yeongbuk massif lies to the north and the Kyeonggi massif to the south. The zone is divided into two parts by a basement ridge which wedges to the ENE through Ich'eon and T'ongch'eon, the principal part being on the northwest side. On the other side there is a narrow auxiliary part through Kŭmch'eon and Kŭmhua. The Sangweon group forms a broad syncline in the Kŭmseong area with the axis trending ENE (TAKAHASHI, 1955). The principal part is a subquadrate basin which is called the "Daidoko (Daedonggang) basin." It is separated by the Annak fault from the Sinch'eon tilted block to which the Changyeon folded zone of the Sangweon group is added to the west. The P'yeongweon block exists north of this block.

The Daedonggang basin consists of disturbed belts and folds with short axes. The basement domes of Yangdeok and Chŭngbongsan are aligned with the Sinch'eon block and the Pyeongp'ung-san projectile in a line nearly parallel to the basement ridge of T'ongch'eon and Ich'eon.

The distribution of the P'yeongan group indicates the sites of brachysynclines. More precisely, a few patches of the group, to the east of the Yangdeok dome, form the Koweon coal-field. On the northwest side of the dome is the north P'yeongannamdo coal-field where the group forms a triaxial structural basin. Near P'yeongyang the Kangtong and Kangseo coal-fields of P'yeongyang lie on the east and west side, respectively, of the Daedonggang river. The Hwangju basin which lacks the P'yeongan group, is further south. All of these basins have equatorial axes. The Seongch'eon disturbed belt is found between the P'yeongyang and north P'yeongan-namdo basins. The Chunghwa belt is found between the P'yeongyang and Hwangju basins. South of the last basin is the broad Chaeryeonggang disturbed belt, which branches off into two wings in the east by the insertion of the Ich'eon-Tongch'en ridge. These disturbed belts are anticlinoria which are, however, in some way strongly deformed. They are distributed alternately with the structural basins. It is the general tendency for calcareous rocks of the disturbed belt to be deformed more than the coarse clastics of the coal basins. The Imch'eon shale, Sunch'eon clayslate or the like often serves as a lubricant in tangential displacement.

In the eastern part of the Daedonggang basin the rocks are largely metamorphosed. The Sangweon group is wider there than in the west. The Korean group is almost unfossiliferous except for the Koweon and Munch'eon coal-fields where some fossils occur in Ordovician limestones as well as in the P'yeongan rocks (KODAIRA, 1930). Much still remains to be studied on the geology of this part.

In marked contrast with this, the geological survey is well advanced and the structure is known in great detail in the western part along the Seoul Sinŭiju railway line. There the Daedonggang basin measures about 200 km from north to south. In the northern 50 km or so is the northern basin of the P'yeongan group,

which is surrounded by belts of the Korean and Sangweon groups. The Seongch'eon belt is a complicated anticlinorium, with the Sangweon group in the core and the Korean group on the two wings. The P'yeongyang coal-fields mark the median synclinorium of the P'yeongan group. The southern 70 km, called the Chaeryeong belt, are composed chiefly of the Sangweon group. This section of the Daedonggang basin can be divided broadly into the following three parts:

1. The northern part, composed of the Sangweon, Korean and P'yeongan groups; many thrusts toward the south or southwest in the Seongch'eon belt.
2. The median part, composed mostly of the Korean and P'yeongan groups; many thrusts toward the north in the Chunghwa belt.
3. The southern part, composed of the Sangweon group.

The boundaries of the parts are not sharp. The Kangtong thrust is taken here as the boundary between the northern and median parts. The median part is most sunken. The thrusts in the Seongch'eon and Chunghwa belts are directed toward the synclinal axes of the P'yeongyang coal-fields. With regard to the Seongch'eon anticlinoriumt he north P'yeongan-namdo coalfield may be called a hinter basin. The southern part, devoid of the Korean and P'yeongan groups, is the most elevated. The Chang'yeon disturbed belt represents its western extension. Tilted up along the Annak fault, the sedimentary blanket was taken off and the basement exposed widely in the Sinch'eon block. The P'yeongweon block, on the other hand, is a dome elevated reciprocally to the subsidence of the northern coal-basin. The Sangweon group still remains on some isles and the coast of the west Korean bay. (TAKAHASHI, 1952).

b. Crustal Movements.

The folded structure of the Daedonggang basin was first thought to be a product of the late Mesozoic Taebo disturbance. I emphasized the great importance of the Songnim disturbance in 1930 when I discovered a remarkable clino-unconformity between the Ordovician and Daedong formations at Songnim-ni (Shorin-ri), Kyeomi-p'o at the northwest side of the Hwangju basin. Subsequently HORIUCHI also found a clino-unconformity at the base of the Jurassic formation at Wafangtien at the neck of the Liaotung peninsula, which belongs to the same zone of folded mountains. Still later KOBATAKE and others found several examples of the pre-Daedong clino-unconformity in the coal-field. Thus MATSUSHITA, KOBATAKE and IKEBE (1952) referred the principal folding and thrusting of the P'yeongyang coal-field to the Songnim disturbance. They further concluded that the already folded terrain was secondarily deformed by reverse faulting and sliding in the Taebo disturbance.

The early Mesozoic Songnim disturbance was an important phase of crustal deformation through which the P'yeongnam geosyncline became folded mountains. The Daedong series is made up of orogenic sediments deposited in intermontane basins. It is distributed most extensively from P'yeongyang to the western coal-field of this town. In addition, a patch of the series is found on the northwestern side of the Hwangju basin. Its age can be determined on the basis of the

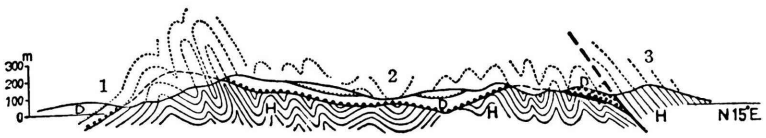


Fig. 4. Clino-unconformity of the Songnim phase in the West P'yongyang Coal-Field.
(After MATSUSHITA, KOBATAKE and IKEBE).

D. Daedong Series H. Pyeongan Group
1. Songui-ni 2. Anjong-ni 3. Songhak-san

plants, molluscans and estherians present. East of Sinmak near the bifuraction of Chaeryeong disturbed belt, there is the so-called Posan (Hosan) formation of unknown age. Judging from the clino-unconformity at its base, its lack of volcanic material and its equatorial axis of folding, this formation most probably belongs to the Daedong series (KOBAYASHI, 1930). On the northwest side of the northern coal-basin there is a small Mesozoic area which extends along the south bank of the Ch'ongch'eon-gang. Other patches of a Mesozoic formation are found on both sides near the mouth of this river. They have not, however, been well surveyed.

Subsequent to the Taebo disturbance strong volcanic eruptions took place. The Silla series is a sediment of this age. It is extensive in the lower Ch'aeryeong-gang valley and the western coal-field of P'yeongyang and yields early Cretaceous plants in rare instances. Cut by a meridional fault, the red formation of P'yeongsan, 800 to 900 m thick, forms a half basin along the Yeseong-gang (Reiseko) river. It consists of tuff and conglomerate and is separated into lower and upper parts by a middle tuffaceous shale and mudstone. This red formation is considered a member of the Silla series (TAKAHASHI, 1955). The Pongsan coal-field to the east of Sariweon is a small basin in the Sinian Sangweon terrain where early Eocene mammalian remains were discovered (TAKAI, 1939). At the mouth of the Ch'ongch'eon-gang on the south bank there is the so-called Anju formation which may be Palaeogene in age (HATAI, 1952). The Silla series in the lower Ch'aeryeonggang is cut by the Annak fault. This fault extends in a straight line from the vicinity of Haeju to the north northwest for about 100 km as far as Kyeomip'o and then shifts a little to the east in the north of this town. The Pongsan Palaeogene is cut by this fault system (MATSUSHITA, ONOYAMA and MAEJIMA, 1935). Therefore it is certain that dislocation has recurred in this fault system due to the Middle Tertiary disturbance. The Weonsan Seoul rift valley cuts obliquely across the basement ridge of T'ongch'eon and Ich'eon and the southern wing of Kŭmch'eon and Kŭmhwa. Basalt effused during the Pleistocene in this valley and also in the valley of the Yeseong-gang, which flows 60 to 70 km west of the tectonic valley. At these NNE tectonic lines the eastern block is shifted repeatedly to the south. The late Mesozoic batholith is exposed extensively near the tectonic valley, but exposures are limited to small areas within the Daedong-

gane basin. A granite mass of moderate size is found in the Yangdeok area. Patches of smaller exposures are in parallel arrangement 10 or 20 km west of the Yeseong-gang valley. Farther west a large granite mass is found to penetrate the Changyeon folded belt as well as the basement complex of the Sinch'eon block. This granitic mass is elongated in a NW direction. The acidic rocks which are distributed from Kaech'eon to P'yeonggang through the Yang'deok area run parallel to the preceding.

c. Stratigraphic Sequence.

Little is known of the basement complex. MATSUSHITA's Keirin (Kyerim) system (1941) in the southern area is composed of mica-schist, quartzite or quartz-schist, and a small amount of lenticular limestone. It is intruded by the Kokulian granite. Similar rocks are found in other places also. The extensive display of paragneiss and orthogneiss and the minor inclusions of carbonate rocks are two characteristics of the basement complex.

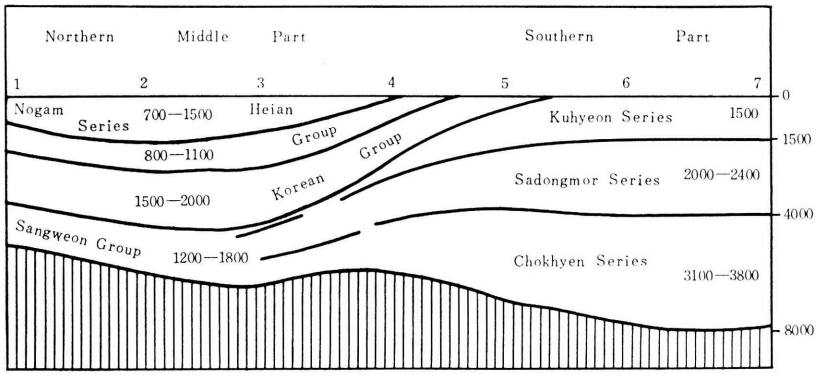


Fig. 5. Variation of Thickness of the Sediments in the P'yeongnam Geosyncline in North Korea. Number = thickness in m.

1. Kaech'eon
2. Seongch'eon
3. P'yeongyang
4. Hwangju
5. Sariweon
6. Haiju

The Shogen (Sangweon) group consists of the following three parts in ascending order: (1) the Chokhyeon (Chokken) series, which is chiefly composed of quartzite and shale, (2) the Sadongmor (Shidogu) series, which contains limestone and dolomite as the principal components and slate and phyllite as accessories, and (3) the Kuhyeon (Kuken) series, which consists of quartzite, slate and phyllite. The total thickness of the three series attains 7,700 m in Hwanghaedo. The Shogen group, however, becomes thinner in the median and northern parts, where it measures 1,200 to 1,800 m in thickness.

The Korean group measures 1,500 to 2,000 m in thickness. The middle and upper parts consist of calcareous rocks, and have been called "the Great Limestone

Series." Shaly rocks are the leading members in the Imcheon shale and the lower part of the group, called the Yangdeok (Yotoku) series.

The Heian or P'yeongan group is divisible into the Hongjeom, Sadong and Gobangsin series in addition to the top division which is called the Nogam series or the T'aejaweon (Taishiin) series. Hornstone and limestone are inserted only in the Hongjeom series and in the lower Sadong. The remainder is composed of sandstones and shales. Their total thickness ranges from 1,500 to 2,600 m.

The Korean and P'yeongan groups are separated by a para-unconformity indicating the stratigraphic break from late Ordovician to early Carboniferous. At the base of the Daedong series near Kyeomi-p'o, however, a limestone conglomerate containing abundant limestone (SHIMIZU, OZAKI and OBATA, 1934) suggests a local ingression of the Silurian sea which was invited by the embryonic folding of the Hwangju basin (KOBAYASHI, 1951). Devonian types of corals are reported at Ch'eonseong-ni near Seongch'eon (YABE and SUGIYAMA, 1939), although the existence of any Devonian formation has not yet been proven conclusively.

The Daedong series which overlies the Sangweon, Korean or P'yeongan group in clino-unconformity is composed of lacustrine sediments in which the facies and thickness vary greatly. Ammonites and a few other marine shells were once reported to occur in it (TOKUNAGA, 1931), but their source is doubtful. It is an orogenic sediment attaining a thickness of more than 1,300 m and is estimated to be about 1,500 m thick north of Kyeomi-p'o. It is thrust locally, but not much disturbed on the whole. There is a remarkable limestone conglomerate at the base of the Posan formation and the subjacent Sangweon group is the source of the material.

The Silla series is a red formation rich in andesitic lavas and tuffs. Its thickness is about 2,000 m in the western coal-field of P'yeongyang and more than 2,450 m in the Chaeryeong-gang valley. The Pongsan formation is an Eocene sediment of about 350 meters' thickness in a small basin. The reported occurrence of marine shells in this formation (TOKUNAGA in KOBAYASHI, 1931) was later found to be erroneous. There are small basins north of Kŭmgang-san (Kongozan) which yield Middle Tertiary plants. They are located on the basement ridge of T'ongch'eon-Ich'eon.

2. Kaech'eon-Teokch'eon (Kaisen-Tokusen) Area

The description given here is based chiefly on the geological map of the anthracitic coal-field of north, P'yeongan-namdo (KODAIRA and SHIRAKI, 1927) and a study of the Ordovician formation surrounding this coal-basin and a reconnaissance from the Naech'ang area to the Sunch'eon area which I made in 1927–30.

The P'yeongan group forms here a triaxial synclinorium, about 25 km meridionally as well as equatorially. The three main axes strike from east to west; the

middle one is the longest. This structural basin is surrounded by an Ordovician formation, 400 to 500 m thick. The Taedong-gang gorge penetrates the saddle between the middle and southern brachysynclines, crosses the eastern part of the middle syncline at right angles and then trends northward. From Teokch'eon to Yeongweon one can see a good display of the Korean and Sangweon groups. At Samsang-dong, 13 km northeast of Teokch'eon, here is a *Cryptozoon* limestone at the base of the Ordovician formation. South of this boundary the great limestone formation which belongs mostly to the Ordovician repeats anticlines and synclines having equatorial axes or axes trending slightly north of east.

The P'yeongweon massif is on the southwest side of the basin. It is composed chiefly of paragneiss and is covered by basal quartzite of the Sangweon group. Above the quartzite is a thick formation of mica-schist, slate and clayslate. This is overlain by another formation of greater thickness which is composed of well bedded and massive limestones and dolomites. These formations evidently belong to both the Sangweon and Korean groups. It is not easy, however, to draw the boundary between the two groups, because of their metamorphism and the absence of key beds except in the uppermost part where Ordovician fossils occur.

On the west side of the basin the Naknang complex strikes almost meridionally and dips toward the east. There are, however, several faults in the WNW or ENE direction through which its base is dislocated. Cut by meridional faults or thrusts, the basal clastic rocks of the Sangweon group occur repeatedly at some places. Several NW or NE faults are found in the limestone and dolomite terrain. Some other faults are found within the basin of the P'yeongan group, most faults being on its north side.

Along the Ch'ongch'eon-gang there is a narrow strip of Mesozoic rocks. Their exact age has not yet been determined. This formation forms a monocline with a NW dip and is cut by faults at right angles. Its northwestern margin is marked by a fault trending slightly north of east. The west side of the basin is intruded by the granite by which iron ore was deposited at Kaech'eon (Kaisen).

On the south side of the basin the Hongjeom and Sadong series are thrust upon the Ordovician. At Solbong southeast of Teokch'eon the lower Pyeongan group is slipped over the Cambro-Ordovician limestone formation at the eastern end of the middle syncline. Such horizontal displacements are seen more commonly in the Seongch'eon area.

3. Seongch'eon-Sunch'eon (Seisen-Junsen) Area

The geologic structure of this area is discussed here chiefly on the basis of TATEIWA's survey of four sheet maps (1931). It is a disturbed belt of the Naknang complex between the above-mentioned basin and another of the eastern P'yeongyang basin, both of which are composed of the P'yeongan group. Broadly speaking, it is an anticlinorium striking from NW to SE through Seongch'eon, the axis being indicated by distribution of the Sangweon group. Resisted by the Yangdeok

massif, however, the folding of its northern wing is strongly disturbed. On the west side resistance of the P'yeongweon massif produced the Ap'ari thrust.

As noted already, there are several thrusts near the southern margin of the northern basin. The longest of them is the Yeongdaeni thrust, which consists of two arcs. Cut by a fault, the eastern arc terminates at a distance of 6 km from the node, but the western one extends for more than 35 km, describing an outer circle around the basin. The Imcheon shale or Sunch'eon clayslate is quite liable to be displaced along its boundary plane along with the superjacent or subjacent limestone. Due to this habit the imbricated arc of Sinch'ang was produced in front of the Yeongdaeni thrust. Likewise another imbricated arc of Soha-ri was brought about east of the Sinch'ang arc. Farther east the Ŭnsan (Inzan)

Table 6. Stratigraphic Sequence of the Seongch'eon-Sunch'eon (Seisen-Junsen) Area (after TATEIWA).

P'yeongan Group	Nogam Series	+300 m
	Gobangsan Series	500 m
	Sadong Series	−100 m
	Hongjeom Series	−300 m
	Discordance	
Korean Group	Great Limestone Series	−1,500 m
	Imch'on Shale	−80 m
	Sunch'eon Clayslate	+1,000 m
Sangweon Group	Yangdeok Quartzite	−200 m
	Sadongmor Series	−2,100 m
	Chikhyeon Series	700 m
	Discordance	
Ancient Gneiss and Schist		

limestone which occupies the major part of the lower Great Limestone series is slipped upon the Sunch'eon clayslate along a long tectonic line of Sadosan. This already belongs to the northern wing of the Seongch'eon isoclinal anticline of the Sangweon group. The wing comprises the gentle structural basin of Hyangp'ung-san in the east and a gentle anticline on its northeast side, but it is cut by the Changnim fault with the downthrow on the north side. The pre-Sangweon basement is exposed on its south side.

On the east side of the Hyangp'ungsan basin is the dome of Pueom with the Yangdeok quartzite at its center and the small Yeongtae-san basin on its east side. The Sangweon group dips to the west as far as the Yangdeok dome and slips up to the east along the base of the Sadongmor series.

The Sangweon group along the axis of the large Seongch'eon anticlinorium and the lower Korean group on its south wing repeat isoclinal foldings with the north-

east dip. The upper Korean group thrusts up along the Ap'ari thrust, cutting the above anticlinorium obliquely.

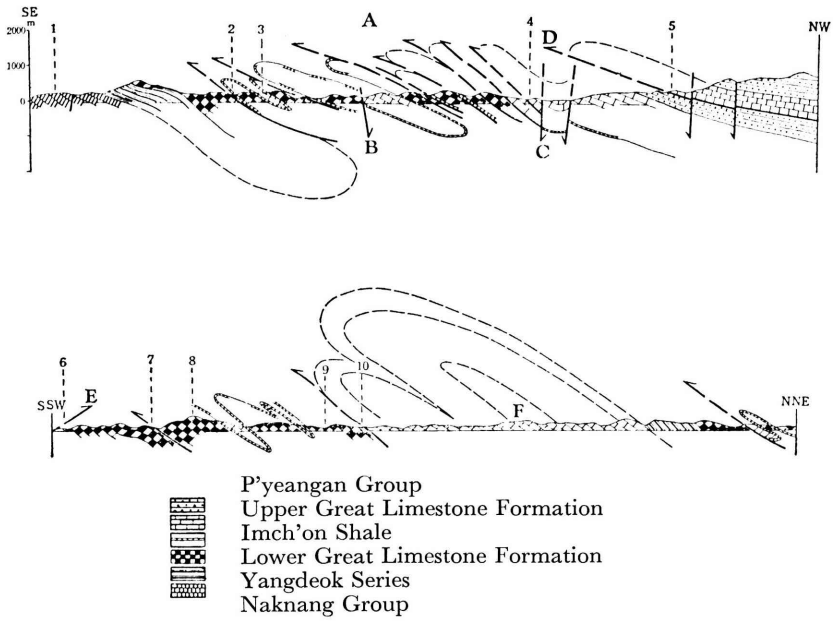


Fig. 6. Two Profiles of the Songch'on or (Seisen) Disturbed Belt (After TATEIWA).

A. Sunch'ang (Shinso) Imbricated Arc
B. Changnim (Chorin) Fault
C. P'yogasan (Hyokasan) Fault
D. Yeongdoeni (Reiyari) Thrust
E. Ap'ari (Ahari) Thrust
F. Seongch'eon (Seisen) Isoclinal Anticlinorium

1. Munweol-li
2. Weont'ong-ni
3. Sinsam-ni
4. Kwich'ol-li
5. Unch'ol-li
6. Hyangsu-ni
7. Unyong-ni
8. Hyeongmyeong-san
9. Piryu-gang
10. Yongbong-ni

Running through the axial zone is the Majollyong fault, which is a strike fault with downthrow on the south side. The Changnim fault parallel to the Majollyong fault cuts a subordinate axis of the northern fold. The Hyang'p'ungsan basin and Pueom dome located between the two faults are destroyed by faults in the E to W as well as WNW direction. In the eastern part of the area there is a fault system having meridional and submeridional trends. The Sakkŭm-ni and Hoeeom-san faults are two of prime importance. These two systems of faults cut each other, but more commonly the meridional ones are cut by the others.

The granite mass of Kuryong-myeon in the south-eastern part of the area is elongated meridionally. It is an intrusive mass younger than these faults. The granite mass of S'unga-san in the west is cut by faults and is surrounded by a broad contact aureole.

There is no Mesozoic or Tertiary formation in this area. Because of the lack of the Daedong series it is difficult to break down the tectonic development into the Songnim and Taebo phases. It is evident, however, that the most important element is the principal Seong'ch'eon anticline accompanied by the auxiliary Changnim anticline. They diverge to the east by the insertion of the Yangdeok block. While basins and domes were produced between the two anticlines, the zone between the auxiliary axis and the northern basin was strongly disturbed, forming the imbrication. Sliding is also very common there. There horizontal dislocations generally occur between a limestone and clayslate bed or within a clayslate or shale bed. The imbricated arcs of Sin-ch'ang and Sohari are deformed anticlinoria of the Ŭnsan limestone. On the southern margin the limestone slips up on the gentle dome of Sado-san.

The Seongch'eon and Changnim anticlines, gentle folds on the sides of the latter, brachyanticline in the farther north and the gentle folds near the Yangdeok block must all be primary tectonic elements. With increasing lateral compression, these embryonic folds developed into the Seongch'eon isoclinal anticlinorium or the imbrication north of the Sadosan basin. The compression was, however, released by the Sadosan sliding. This folded zone is slipped up *en bloc* east along the Pyeolgunni line. Caused by the compression between the P'yeongweon and Yangdeok blocks, this sliding presumably appeared in the latter part of the crustal deformation almost simultaneously with the Ap'ari thrusting, which may be referred to the Taebo rather than the Songnim phase.

After the Seongch'eon belt had been strongly disturbed, block movements occurred. The meridional or submeridional faults common in the eastern part are mostly older than the equatorial ones. Later, granitic magma intruded into this terrain. Some of the faults, however, probably date from still later.

4. P'yeongyang (Heijo) Coal-Field (see Profile Va)

A long history of research is connected with this coal-field. First, Nishiwada (1898), Fukuchi and Sugimoto (1905), Iki (1906), Yokoyama (1906), Kochibe (1908) and others made contributions to the geology of the coal-field. The stratigraphy of the coal-bearing formations was later clarified in great detail by Tokunaga (1919), Yabe (1919), Kikkawa (1925) and others. The Ordovician formation below the coal-bearing was classified by Kobayashi (1930, 31). Prior to this Nakamura (1918) and Konno (1928) respectively pointed out the significance of the Jido and Taiho thrust. Since 1934 Nakamura has conducted a research project on the complicated structure of the coal-field and its surroundings in collaboration with his students. The geology of the coal-field was compiled by Matsushita (1938), and later the research was summarized by Matsushita, Kobatake and Ikebe (1952). The last tectonic interpretation differs from previous ones in some details, but detailed discussions are here omitted.

The coal-field is divided into eastern and western parts by the synclinal basin

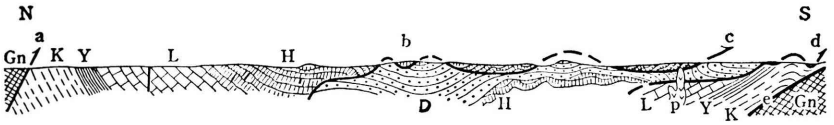
Table 7. Stratigraphic Sequence of the P'yeongyang Coal-Field (after MATSUSHITA, KOBATAKE and IKEBE).

Pulguksa Series		
Intrusive Contact		
Taebo Series		2,000 m
Discordance		
Daedong Series		1,300 m
Discordance		
P'yeongan Group	Taijaweon Series	650 m
	Gobangsan Series	300— 500 m
	Sadong Series	150— 300 m
	Hongjeom Series	250— 300 m
Discordance		
Korean Group		1,420 m
Discordance		
Sangweon Group	Kuhyeon Series	10— 200 m
	Discordance	
	Middle and Lower Parts	1,060—1,700 m
Discordance		
Kokulian Granite		
Intrusive Contact		
Kyerim Group		

of the Daedong series, which extends to the northeast from P'yeongyang city as far as Taeseong-san. The western or Kangseo coal-field is located south of the P'yeongweon block. Its gneiss complex thrusts itself upon the Kuhyeon series on the southeast side along the Kinsai (Kŭmche) thrust. This thrust plane is steeply slanted toward the northwest. The paragneiss of the complex, however, forms a low hill of Ch'e-bong, west of P'yeongyang and is thrust upon the Daedong series. Two small *Klippen* are found at Todu-san and its vicinity to lie on the series beyond the thrust front. According to MATSUSHITA (1938), this thrust together with the *Klippen* reveals the frontal part of the Kŭmche thrusting mass. One cannot trace the outline of the thrusting mass from the front to the root continuously, as it is interrupted by a porphyrite mass which was intruded into the thrusting mass, but the Kŭmche thrusting mass was transported for about 15 km toward the southeast, assuming this interpretation to be correct.

Beneath the Kŭmche thrusting sheet there is the Taebo thrusting sheet which consists of the Kuhyeon series, the Korean and P'yeongan groups. They form a synclinal basin and thrust themselves upon the Daedong series on the south-east side. Because the thrusting plane of the Taebo thrusting sheet is subhorizontal in the main, its frontal margin is considerably protruded to the southeast in Tongjin-

myeon and Taebo-myeon. On its rear side the underlying Daedong series is exposed at three small windows.



p. Porphyrite
D. Daedong Series
H. P'yeongan Group
L. Great Limestone Series
K. Kuhyeon Series
Y. Yangdok Series
Gn. Gneiss.

a. Kŭmche (Kinsai) Thrust
b. *Fenster* at Taeryong-dong
c. Taebo (Taiho) Thrust
d. Yongjeong (Ryusei) Thrust
e. Muhaksan (Bukakusan) Fault

Fig. 7. Profile of the Western Part of the West P'eoyngyang Coal-Field (after MATSUSHITA).

At Kambuk-san, north of P'yeongyang, the P'yeongan group, which is capped by the Daedong series at Ami-san is thrust upon the Daedong series on the south side and is thrust by the group on the north. The Kuhyeon series is sliced and shut in along the latter thrust line. These thrusting sheets are considered to belong to the Taebo *Decke*, although this part is separated from the main mass of the *Decke* by the intrusion of porphyrite.

South of Kambuk-san there is a gentle synclinal basin of the Daedong series where the city of P'yeongyang lies, but it is thrust by the Hongjeom series from the southeast side. This is called the Giyo (Kiyang) thrust, because it is traceable from Taeseong-san to Kiyang. Beyond the last locality, it is considered by NAKAMURA to be bent up abruptly toward the north, although the bending point is cut off by the Muhak-san fault. This northern section was formerly called the Yongjeong thrust, where the Daedong series was thrust on the Kuhyeon or lower Korean group. The amount of displacement, however, is in question. Because the Daedong is incorporated with the Yongjeong, Taebo and Kŭmche dislocations, it is quite evident that they are products of the Taebo disturbance. All are cut by the Muhak-san fault which marks the western border of the west P'yeongyang coal-field.

On the southeast side of the Kiyang thrust is the Sadong thrust, along which the Chunghwa series and the higher formations on the southeast side thrust themselves upon the Hongjeom and Sadong series on the other (SAKAKURA, 1936). In front of the Sadong thrust is the Taeseongni thrust. Near Taeseong-ni it is marked by the boundary thrust of the eastern P'yeongyang coal basin, which runs between the Hongjeom and Sadong series. On its south side the Hongjeom and Ordovician formations are repeatedly folded. Farther south the Ordovician formation around

Mandal-san (Bantatsusan) is cut by the Sadong thrust and a subordinate thrust, termed post-Sadong (KOBAYASHI, 1930).

East of Mt. Mandal the Sadong thrust outlines the Koyeongsan thrusting sheet which is composed of the middle and upper Sangweon and Korean group. The Taeseongni thrust, on the other hand, becomes a low angle thrust to the east, called the Teoksan thrust by IKEBE (1937). According to him the Teoksan *Nappe* or *Decke,* consisting of the Hongjeom and older formation, has ridden over the Sadong and younger formations toward the northeast. Because of its tangential

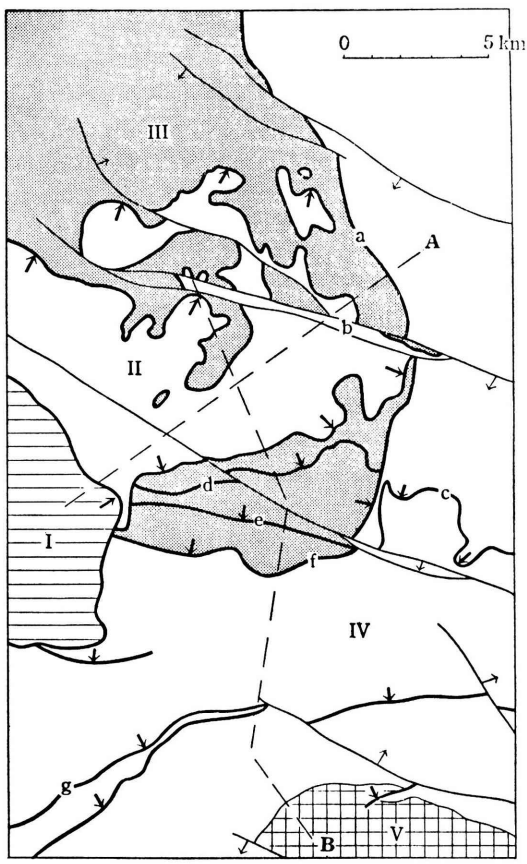


Fig. 8. Tectonic Map of the Samdŭng Area (After IKEBE).

I. Koyeongsan (Koreizan) Thrusting Sheet
II. Teoksan (Tokusan) Nappl
III. Parautochthonous Coal-Basin
IV. Autochthonous Sediments
V. Chung'bongsan (Sohosan) Basement Dome

a. Suip (Suinyu) Thrust
b. Samdŭng (Santo) Graben
c. Suich'eonni (Suisenri) Thrust
d. Taedalli (Daitatsuri) Thrust
e. Sinmadong (Shinmado) Thrust
f. Kojeongsan (Koteizan) Thrust
g. Sangweon (Shogen) Thrust

displacement, the thrust line has a peculiar meander. There are several *Klippen, Windows* and *Halfwindows*. a further complication stems from the development of the *Decke* into three or four *Teildecken.*

The basement of the *Decke* is also parautcohthonous in this part of the coal-basin. The Hongjeom series and upper Korean group have ridden upon the middle and lower Korean group along the Suip tectonic line on the northeastern border of the basin. It is thought to continue to the Kojeongsan tectonic line in the south of Samdŭng, but there are two or more subordinate dislocations behind the Kojeosan line.

The Suip line is traceable as far as Kangtong. On the south side of Kangtong there are several dislocation lines along which sliding has taken place within the Hongjeom series. At Hyeongje-san in the northwest, the Hongjeom series thrusts upon the Sadong on the south side.

If the tectonic complication near Samdŭng is ignored, the P'yeongan group in the east P'yeongyang coal-field is rather simple. It forms a subtriangular basin, but it is polyaxial, taking the form of a synclinorium. Its northeastern margin is marked by the Suip line. The Ap'ari upthrust mentioned above probably occupies its northern extension. The Kangtong thrust which extends from Kangtong to the west southwest marks the boundary between the Seongch'eon anticlinorium and the P'yeongyang coal-field.

Because the Daedong series plays a role in this complicated structure of the P'yeongyang coal-field, it has long been thought to be the product of the Taebo disturbance. It was found, however, that the Daedong series of the P'yeongyang basin lies clino-unconformably on the Korean group and the Kuhyeon series at Taeseong-san where there is a conglomerate, 80 to 100 m thick, at the base of the Daedong series. The Taejawean and Gobangsan series of Kambuk-san and Ami-san on the north side of the P'yeongyang basin is also overlain clino-unconformably by the Daedong series which consists of conglomerate, breccia and coarse sandstone. In the west P'yeongyang coal-field the Daedong series beneath the Taebo *Decke* is gently undulating. At Seogŭi-ni and Anjong-ni of Taebo-myeon the basal conglomerate and coarse sandstone lie clino-unconformably on the Hongjeom and Sadong series which are intensely folded parallel to the equatorial axis (See Fig. 4). These facts in general show that the Songnim disturbance was strong in this region.

The Daedong series near the town of P'yongyang forms a basin structure with the NE axis which gently undulates in the form of a wavy synclinorium. Its base is unexposed, but it is known that the upper or Yukyeong (Ryukyo) formation is 600 m thick and the lower or Seonseon (Senken) formation, more than 700 m thick. They are composed of sandstone and shale, but the lowest sandstone of the Seonseon formation contains quartzite pebbles, suggesting the approach to the base of the series. The conglomerate at Chueom-san, which is detached from the main Daedong area by a fault, consists of round pebbles of quartz, quartzite and other rocks in the northwest but angular limestone blocks in the southeast, where

quartzite is very rare. The series of the basin yields plant fossils in several horizons. Molluscan shells and a fossil forest are present in the Yukkyeong formation (MAEJIMA, 1935).

The Daedong series at Taeseong-san consists of the Taeseongsan (Taiseizan) basal conglomerate, 80 to 100 m thick, the Taesongni (Daijoshi) sandstone, 80 m thick and the Noseongni (Roseiri) black shale, more than 150 m thick. Plants occur in various horizons and molluscan shells are contained in the Noseongni black shale. The basal part of the series is also known to exist at Ami-san and Kambuk-san, as mentioned earlier (KOBATAKE, 1941).

The lower part of the Daedong series in the west P'yeongyang coal-field consists of the Okkabong (Gyokukaho) formation, 300 m thick, chiefly composed of black shales containing plants and divided in two by Ch'aeseoksan (Saisekizan) sandstone, 50 m thick; the upper part yields Molluscan shells, the basal conglomerate, only 15 m thick, contains shale and quartzite pebbles.

The upper formation of the Daedong series is more than 1,000 m thick, contains plants, shells and Estherians, and is subdivided into Tosolli (Tosanri) black shale, over 350 m thick, Munhyeon (Bunken) conglomeratic sandstone, 250 m thick, and Kunoni (Kurori) alternation of sandstone and shale, over 400 m thick; coal seams are contained in the Kunoni alternation and the Okkabong formation, and aluminous shale is found in the lower part of the latter (IKEBE, 1935).

In short, the Daedong series in the western and central P'yeongyang areas is a formation more than 1,300 m thick, and its sequence is different between the two areas. The variation in consitution and thickness is especially significant in the basal conglomerate. This suggests the great variation of its basement and also of the topographic relief at the beginning of the sedimentation. The conglomerate, however, is restricted to the base, if the Munhyeon conglomeratic sandstone is neglected. Aluminous shale in the lower part may be an erosion product of a temporary upheaval of the margin. The Munhyeon conglomeratic sandstone, together with the fossil forest, suggests the emergence and revival of the topographic relief.

Judging from these facts, it may be concluded that the crustal movement did not cease at the end of the Daedong epoch. The Daedong series is a sediment ranging from late Triassic to Liassic in age. Although its age cannot be determined more precisely, the part in the P'yeongyang area may be younger than that in the western area.

MATSUSHITA, KOBATAKE and IKEBE (1952) analyzed the dislocations of the P'yeongyang coal-field into two types, namely the A type, which is developed from intense folding, and the B type, which is unrelated and subsequent to the folding. They concluded that the former is a product of the Songnim disturbance, while the latter is mostly a product of the Taebo disturbance. The distribution of the Daedong series, however, is restricted on the one hand and the secondary deformation in the Taebo phase goes too far on the other. For these reasons it is not easy to restore the Songnim folded mountains. Presumably, however, the east-

ern synclinal basin of P'yeongyang between the embryonic anticlinoria of Chunghwa and Seongch'eon must have extended into the western area as far as the Daedong is distributed. Because the series lies on the folded Pyeongan group, the Daedong basin must have been brought to being in the latter part of the Songnim disturbance. The Kiyang tectonic line which cuts the southeastern and southwestern margins of the basin belongs to the Taebo deformation. The Taebo thrust is another deformation of secondary origin. The Daedong basin must have been large, as can be recognized from the Daedong series at the windows. It was in the Taebo phase that the frontal part of the P'yeongweon block rode over the Taebo *Decke* to the south for a long distance, assuming that the geneiss mass of Ch'e-bong indicates the frontal' margin of the Kŭmche *Decke*.

It is impossible to determine whether it was in the Taebo disturbance or in the latter part of the Songnim disturbance that the Taeseong thrust developed southeastward into the Teoksan thrust in the Samdŭng area. It appears reasonable, however, to attribute the Suip dislocation to the Taebo disturbance, if it belongs to the same system as the Ap'ari upthrust.

West of P'yeongyang the Taebo series dips to the southeast at 30 to 45 degrees. Its sequence at Pongsu-ri of Yongsan-myeon consists of (1) basal conglomerate, (2) red shale containing limestone lenses, (3) reddish purple tuffaceous breccia containing porphyrite pebbles, (4) tuff or sandstone containing round pebbles among which quartzite and other sedimentaries are more common than volcanic rocks, and (5) top conglomerate. The total thickness is estimated to be about 2,000 m or so, and the lower two beds (1–2) are intruded by porphyrite and quartz-porphyrite.

The Taebo series is cut by NE and NW trending faults. The Muhaksan fault at the western end of the coal-field occupies the northern terminus of the long Annak fault. It is a large NW fault with a NE dip at 30 degrees or so. In addition, there are several long parallel faults on the east and west sides of P'yeongyang. Some of them cut the Taebo series. This fault system is also found in the east P'yeongyang coal-field. Near Samdŭng there is a narrow graben trending west northwest. Dykes of acidic rock are sometimes encountered along these post-Taebo faults.

5. Chunghwa-Sangweon-Hwangju (Chuwa-Shogen-Koshu) Area

The area from the Taeseongni or Sadong thrust as far south as Hwangju consists chiefly of the Korean group. The Chunghwa brachyanticlinorium is in the north and the Hwangju brachysynclinorium is in the south. On the east side of the latter there is the Chŭngbongsan dome which is surrounded by the Sangweon group.

The front of the Chunghwa anticlinorium is marked by the Taeseongni or Sadong thrust. Near the southern margin of the Sadong thrust the lower P'yeongan group is found to occupy small areas. The pre-Chunghwa *Decke* thrusts itself upon

the Sadong *Decke*. On the south side of the pre-Chunghwa thrust are the Chunghwa and Chuyeomjong thrusts. All of the thrusts are convex toward the north and in the east bend abruptly to the south or even to the southwest.

The younger formations become better developed in the northern thrusting sheet, but the reverse is true for the southern ones. The Chuyeomjong, Ch'udangni and Kuhyeonch'i thrusts describe parallel arcs on the north side of the Hwangju basin. This is the axial part of the Chunghwa anticlinorium which is composed of the lower Korean and the upper Sangweon group; the anticlinorium is asymmetrical because the Hwangju basin is sunken (K. SAITO, 1937).

The Hwangju basin is a brachysyncline or brachysynclinorium of elliptical outline with the major diameter twice as long as the minor one. The Ordovician, Cambrian and Kuhyeon formations are aligned concentrically, but their distribution is disordered to some extent by folding and thrusting near the periphery. The southern thrusts are centrifugal like the Kuhyeonch'i and other northern ones (TAKEHARA, 1934; SAWADA, 1941).

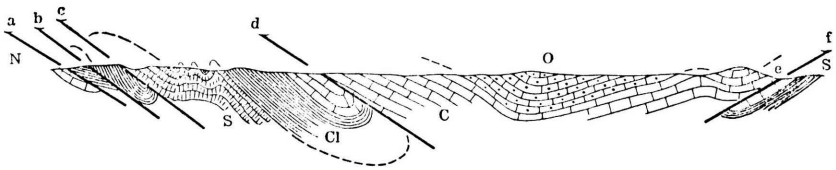


Fig. 9. Profile of the Eastern Part of the Hwangju (Koshu) Basin (after TAKEHARA).

O. Ordovician Formation
C. Upper and Middle Cambrian Formations
Cl. Lower Cambrian Formation
S. Kuhyeon Series

a. Chuyeomjeong Thrust
b. Ch'udangni Thrust
c. Kuhyeonchi Thrust
d. Hukkyo Thrust
e. Yeongp'ung-ch'eon
f. Ch'onjŭ-san

To the east of this structural basin is the Chŭngbongsan dome, which is nearly triangular in outline and is composed of gneissose granite which belongs to the pre-Sangweon basement complex. The dome is surrounded by the Sangweon group. On the northwest side it is folded with a northwest dip and is thrust toward the southeast. Among the thrusts two important ones are the Sangweon and pre-Sangweon thrusts (see Fig. 8). They appear to correspond to the Kuhyeonch'i and Chuyeomjong thrusts in the west, but the direction of thrusting is opposite for the two sides, showing torsion of the Sangweon group between the centripetal thrusting toward the Chungbangsan dome and the centrifugal thrusting from the Hwangju basin.

In the northwest part of the Hwangju basin is the Daedong' series, about 1,500 m thick (SHIMAMURA, 1929). It begins with the Kyeomip'o limestone conglomerate, which is a talus debris containing angular boulders of Silurian limestone (KOBAYASHI, 1935). The lower Daedong is a deltaic sediment containing Esthe-

rians. The middle and upper parts of the series consist of sandstone and shale accumulated on a lake bottom. Plant fossils are found therein. The middle part contains conglomerate, conglomeratic sandstone and some coal seams. The southerly dipping Ordovician of the Hwangju basin is overlain unconformably by the Daedong series with a northwest dip. Their contact is found in Songnim-myeon, whence the "Shorin (Songnim) phase." was proposed (KOBAYASHI, 1930). The series covers the lower Korean group in the north and is cut by a fault at the northwestern end. As mentioned above, the Kenjiho (Kyeomip'o) limestone conglomerate is a Mesozoic talus deposit. Therefore it must be the earliest sediment in the intermontane basin, surrounded by rugged mountains after the Songnim disturbance. At that time the Silurian formation must have been on the Ordovician. Except for the basal conglomerate, limestone boulders are seldom found. Round pebbles 2 to 3 cm across are mostly quartzite, clayslate and shale. These pebbles are thought to have been brought by a river from fairly far off, probably from the south, and to have been deposited in a delta. On the northwest side there was a lowland of the lower Korean group which was later submerged and covered by lacustrine sediments.

6. The Chaeryeong-gang (Saineiko) Valley

The Sinch'eon block is limited by the Annak fault on the east side. East of this fault is the lowland of the lower Chaeryeong-gang valley. The Taebo series forms low hills above the broad flood plain of the river. Beyond the valley there is an excellent display of the Sangweon group. East of Sariweon a patch of the Eocene series fills a small basin of Pongsan in the limestone tableland of the group. The stratigraphy of the group in this region was immensely clarified by the efforts of MATSUSHITA (1935, 1941, 1943).

The Kokulian granite is extensive in the southernmost part. Its injection has produced the mica-schist of the Kyerim (Keirin) group, but the schist is not extensive at present. The relation of the Kyerim to the Sangweon group has not been determined. The Yulla (Ritsura) group is composed of micrographic granite, quartzite, crystalline siliceous limestone, sericite-schist, sericite-quartz-phyllite, quartz-schist, and a small amount of mica-schist. The Yulla granite looks younger than the Kokulian.

The Chikhyeon series is 3,100 to 3,800 m thick, the Sadongmor 2,000 m to 2,400 m thick and the Kuhyeon about 1,500 m thick. The total thickness of the Sangweon group is estimated to be 7,000 to 7,500 m. As it is cut by thrusts, however, no continuous sequence of the Chikhyeon series can be observed. The Changbong arkose quartzite at the lowest part of the series is conformable with the superjacent beds, but apparently it is para-unconformable with the subjacent ones. The arkose material of the quartzite is inferred to have been supplied from the Yulla granite.

In a distance of more than 35 km from Hwangju to the east of Haeju, the

Table 8. Stratigraphic Sequence of the Sangweon Group in the P'yeong'nam Geosyncline.

Central Hwanghae-do (Kokaido)		Liaotung Peninsula	
Kuhyeon Series, 2,000–2,500 m	Unbong'ni Slate, 370 m	Nanshan Stage, 400–800 m	Nanshan (or Chinhsien) Series 500–1,000 m
	Pirangdong Conglomeratic Phyllite, 900 m		
	Kusan Slate and Quartzite, 250–1,500 m		
	Okuhyeonni Siliceous Limestone, 50–330 m	Machiatun Siliceous Limestone, 50–200 m	
	Seolhwasan Slate, 250–450 m	Shihsanlitai *Collenia* Limestone, 50–150 m	
Sadongmor Series, 1,500–2,000 m	Ch'eongseoktu Limestone, 450–600 m	Yingchengtzu Limestone, 370–400 m	Kuantung (or Lutai) Series 2,500–3,000 m
		Onoda Limestone, 270–400 m	
	Teokchae Dolomite, 250–540 m	Kanchingtzu Dolomite, 450–700 m	
	Ŭngeok Limestone, 700–1,000 m	Nankuanling Limestone, 800–1,000 m	
	Ansimryeong Calcareous Phyllite, 625 m	Changlingtzu Phyllitic Limestone, 700 m	
Chikhyeon Series, 3,100–3,800	Changsusan Quartzite, 1,000 m	Lungtou Quartzite, 450 m	Tahoshangshan (or Hsiho) Series, 3,200 m
		Yingkeshih Phyllitec and Limestone, 30–200 m	
		Chakou Quartzite, 1,000 m	
	Obongni Slate, 500–1,800 m	Lungwangtang Slate and Quartzite, 800 m	
		Waitoushan Quartzite, 500 m	
		Huangmichuan Slate, 330 m	
	Changbong Feldspathic Quartzite, 600–1,000 m	Base unexposed	

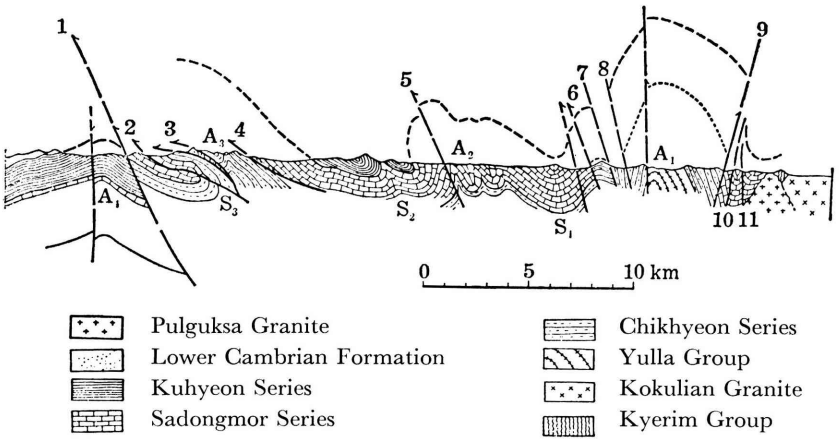


Fig. 10. Profile of the Chaeryeong-gang (Saineiko) Disturbed Zone (after MATSUSHITA).

A_1. Yulla Anticlinorium
S_1. Seolhwasan Syncline
A_2. Changsu Anticlinorium
S_2. Ch'ailbong Synclinorium
A_3. Obongni Anticline
S_3. Nodongni Syncline
A_4. Pirangdong Anticline

1. Toch'i Thrust 2. Teongmor Thrust 3. Cheongbangsan Thrust 4. Pongsan Thrust
5. Ŭllyong Thrust 6. Songhyangni Thrust 7. Ch'ilbongsan Thrust 8. Kwanamni Thrust
9. Chakch'eonni Thrust 10. Samch'eonni Thrust 11. Ch'ucheongni Thrust

Sangweon group forms 4 anticlines and 3 synclines. The southernmost is the Yulla anticline, or anticlinorium with the Yulla group at its axis. On its south wing the Yulla group is overlain by the Changbong arkose quartzite, and farther to the south the superjacent sequence extends as far as the lower Sadongmor series, but it is separated from the Kokulian granite by an intrusive mass of late Mesozoic granite. In the northern wing the two formations are separated by a high angle thrust. Farther north is the Seolhwasan syncline of the Sadongmor series, whose axis is subvertical. On its north side is the Changsusan anticlinorium and then the Ch'allbong synclinorium. The former consists of the lower and middle Sadongmor and the latter of the upper Sadongmor and the lower Kuhyeon series. Their folding axes are inclined to the south. On the north side of this recumbent folding are the strongly destroyed Obongni anticline and Nodongni syncline. The former is composed of the Chikhyeon series, whereas the latter comprises the formations from the upper Chikhyeon to the lower Sadongmor series. These two are again overturned toward the north. At length one reaches the Pirangdong anticline, which is composed of the Lower Cambrian and Kuhyeon series. It is an asymmetrical anticline with a vertical axis, having a gentle northern and a steep southern limb.

Looking at the whole section, it is evident that the Yulla and Obongni anticlines

composed of the Chikhyeon series in main are deformed strongly by thrusting, but the Sadongmor series in their interval is deformed to a much smaller degree. The fold axis is high-angled in the south, but it becomes overturned toward the north and at length the Nodongni syncline is thrust upon the Pirangdong anticline along the Toch'i thrust line.

This fundamental structure is deformed considerably by secondary thrusting and faulting. On the northern and southern side of the Yulla anticline are several high angle thrusts. On the southern part of the southern wing the thrusts are directed to the south, but in the northern part they are directed to the north like those in the northern wing. Farther north the quartzite of the Chikhyeon series protrudes into the limestone of the lower Sadongmor series forming an elliptical dome. These deformations may be attributed to the compressive block movement of secondary origin. There are the Ŭllyong thrusts in the central folded zone and the Pongsan thrust in the north. This thrust plane is low-angled in the west, but becomes steep in the east. The Obongni anticline and Nodongni syncline farther to the north are strongly deformed by the Cheongbangsan and Teongmon thrusts. The Cheongbangsan thrust in particular is low-angled and branches off in the western terminus. Two minor *Klippen* are found in front of this western part. It is, however, high-angled in other places. This disturbed zone is delimited by the Toch'i thrust at the northern end.

Some of these thrusts are thought to be the products of the Songnim disturbance, but many others are upthrusts, thought to be caused by compressive block movement in the Taebo phase, because the dislocation is inconsistent with the folding.

After the geologic structure of the Sangweon group had thus been constructed by the Taebo disturbance, the Taebo series was deposited in the lower Chaeryeong-gang valley and now forms low hills. According to SHIMAMURA (1929) it can be divided in descending order as follows:—

3. Honanri or P'onamni formation, over 350 m thick; black shale and dark gray or light brown sandstone; ripple marks common in the latter; plant fossils uncommon.
2. Kanposan or Hanbongsan formation, 750 m thick; tuffaceous gray shale, sandstone and limestone; green or reddish brown shale containing plants; angular gravels of porphyrite in basal conglomerate.
1. Goryusan or Oryongsan formation.
   b. Upper part, 750 m thick; thick andesite lava flow with intercalations of reddish brown tuff.
   a. Lower part, 600 m thick; tuff, tuffaceous shale, sandstone, conglomerate, shale and quartzite; round or angular pebbles, 60 cm at the largest, of quartzite, clayslate, sandstone, limestone, quartz-porphyry and porphyrite in conglomerate.

Various kinds of porphyrite, i.e., compact pyroxene porphyrite, quartz porphyrite, brecciated porphyrite and so forth intrude the Hanbongsan and older formations. The eruptions of these andesitic rocks were repeated several times before the deposition of the Oryongsan formation. In the late Oryongsan epoch strong effusions of lava recurred.

At present the Taebo series widely covers the southwestern margin of the Hwangju basin. In the lower Chaeryeong-gang valley it is cut by faults on the

east and west sides, but south of Sariweon it lies unconformably and gently undulating on the Sangweon group, forming a basin. The western margin of this basin is marked by the Annak fault which is traceable for more than 100 km in a NNW trend, and dips gently to the east northeast at about 30 degrees. It is indicated by a shuttered zone of several meters in breadth, which is penetrated at places by dykes of beresite and felsite.

In the southern part, the Okuhyeon fault, which is parallel to the preceding, runs along the east side of the valley. Its downthrow is on the east side. The Tohyeon fault in the north is parallel to the Sariweon fault and its downthrow is on the west side. It cuts a strike fault with downthrow on the south side. Thus the strike fault is older than the meridional one and may be coeval with or even older than the Annak fault. The block movement is supposed to have changed from compression in the Taebo phase to tension later. The strike fault may be a product of the beginning of the latter movement.

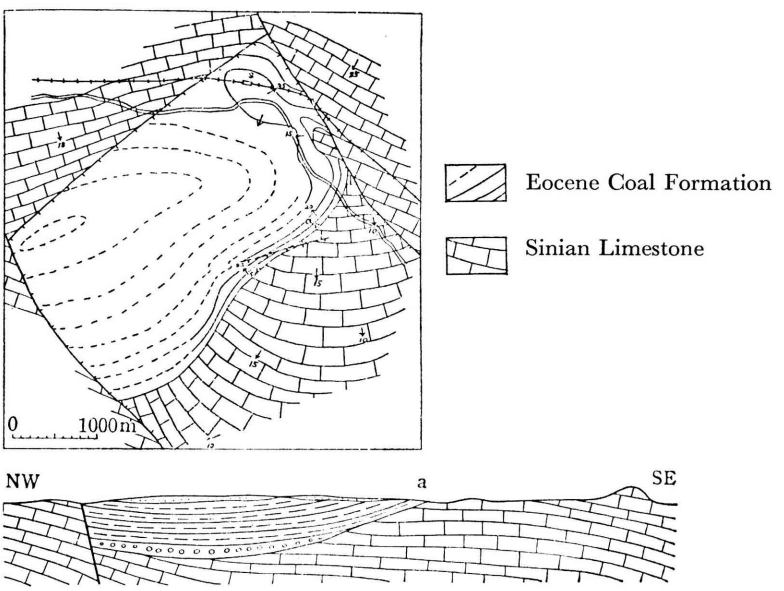


Fig. 11. Geological Map and Profile of the Pongsan (Hozan) Coal-Field (after MATSUSHITA, ONOYAMA and MAEJIMA).

a in the profile is the Sariweon (Shariin) Coal Mine; a, b and s in the map indicate respectively the main pit of the Pongsan Coal Mine, the first pit of the Sariweon Coal Mine and Sin-Pongsan Station.

The Chaeryeong-gang depression is presumed to have been produced by downwarping. Volcanic eruptions took place and the Taebo series accumulated there. Subsequently the Sinch'eon block was yielding the Annak dislocation line. Thus, the block movement was related to the Pulguksa igneous activity, which continued with the batholithic invasion of granitic magma, causing a grand culmination and

renewed tension faulting. Beresite and felsite dykes along the meridional faults as well as the Annak fault suggest that they are products of successive block movements, although the Annak fault is older than the meridional ones.

The Eocene Pongsan series was deposited in a small basin on the Sinian limestone. Marine shells have erroneously been reported from the series. The basal conglomerate, about 50 m thick, is restricted to the central part of the basin. It is overlapped by coal-bearing sediments, about 300 m thick, which yield plants, fresh-water shells and late Eocene mammalian remains. This series forms a gentle basin structure, having its major axis in an east northeast trend. It is cut by faults on three sides, the northwest, northeast and southwest. It is a small but typical fault angle basin, about 4 km long from NE to SW and a little broader than 2 km. The basin is thought to have been faulted down by the Middle Tertiary disturbance (MATSUSHITA, ONOYAMA and MAEJIMA, 1935).

Differential erosion is well displayed in the Sangweon terrain. Quartzite and allied rocks are resistant, while clayslate and slate form low lands. Numerous dolines are found on the wide tablelands of calcareous rocks. Flat-topped piedmont plateau or rock terraces are especially well developed along the Seohŭnggang tributary, which is an eastern branch of the Chaeryeong-gang.

7. Discussion and Summary

The tectonic development of the P'yeongnam geosyncline is thought to have commenced in North Korea with embryonic domes and basins disposed in checker pattern. There were at least four disturbances—Songnim, Taebo, early Tertiary and middle Tertiary. The Songnim phase of crustal deformation is responsible for most of the fundamental architecture. The original folds and thrusts were, however, considerably modified by later thrusting and sliding in the Taebo disturbance which was succeeded by vigorous volcanic eruptions and intrusion of granite. While these Mesozoic deformations were compressive, the Tertiary ones were characterized by tension and dyke rocks were intruded. Still later, basalt was effused extensively along the weak lines. Controlled by rigid domes, trends of the fold axes and dislocation lines vary to a great extent. Nevertheless, the equatorial trend is so predominant that it is recognizable that the P'yeongnam geosyncline was compressed meridionally. The Tertiary faults take either the NNW or NNE to NE direction, forming a complicated mesh.

The thickness of the Sangweon group attains 7,700 m at the maximum. The Korean and P'yeong an group are respectively 2,000 and 2,600 m at the thickest. Their total thickness is therefore more than 10,000 m. The embryonic folds at the beginning of the deformation were the Yangdeok dome, the basins at its northwest and southwest sides, the Seongch'eon anticline, the Chŭngbongsan dome, the Hwangju basin to its west side and the anticlines on the north and south sides of this basin.

The Chaeryeong belt is a large asymmetric anticlinorium which lacks the

Korean and Pyeongan groups. The axis of folding is subvertical in the southern part of the belt, but inclined and thrust toward the north in the middle and northern parts of the belt. The Hwangju syncline is very gentle and its axis short and vertical. Its south side is bordered by the Pirangdong anticline. The anticline on the northern margin is deformed by the Kuhyeonch'i and other thrusts along which the Kuhyeon series is exposed. The Chunghwa anticlinorium is complicated by thrusting and the Kuhyeon series well developed on its southeast side, where the thrusting in the early stage was directed toward the Chŭngbongsan dome. Later, however, the Koyeongsan and other elements of the Chunghwa anticlinorium were pushed toward the northeast. The tangential movement of the Teoksan *Decke* may be a local event of the early Taebo disturbance, if not of the late Songnim.

MATSUSHITA (1943) has distinguished the thrusting or the A-type dislocation from the B-type dislocation, or a kind of upthrusting, and referred the former to the Songnim disturbance and the latter to the Taebo disturbance. It is, however, also possible that the change from thrusting to upthrusting occurred in the latter part of a disturbance, because the difference between the two kinds of dislocation depends principally upon the plasticity. At all events, it is clearly shown by the structure of the Sangweon group in the Chaeryeong area that the A-type thrusting has generally proceeded to the B-type thrusting.

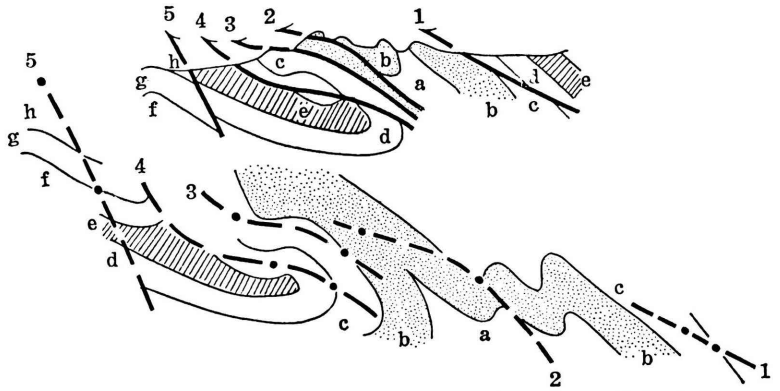


Fig. 12. A and B Types of Thrusts in the Chaeryong (Sainei) Zone (after MATSUSHITA).

1. Pongsan Thrust
2. Cheongbangsan Thrust
3. Pre-Cheongbangsan Thrust
4. Teongmor Thrust
5. Toch'i Thrust

h. Unbongni Slate
g. Pirangdong Boulder-bearing Phyllite
f. Kusan Slate
e. Teokchae Dolomite
d. Ŭnjeok Limestone
c. Ansimnyeong Calcareous Phyllite
b. Changsu Quartzite
a. Obongni Slate

In the west P'yeongyang coal-field the Taebo and other thrusts which were produced by the Taebo disturbance can be distinguished clearly from the deforma-

tion of the Songnim phase. There the B-type dislocation, with which the Daedong series is incorporated, sometimes developed into horizontal transportation for long distances. Some *Fenstern* and *Klippen* are met with in this area.

It is seen at Taeseongni and its adjacent area in the east P'yeongyang coal-field that the thrust line runs between the Sadong and Hongjeom series. Farther east one can see a highly complicated horizontal dislocation as far as Samdŭng. According to IKEBE the Teoksan, Koyeongsan and Piseoktong thrusting sheets are piled up there one above another, but the amount of displacement is no more than 10 km. It is remarkable that the Kojeongsan and a few other southern thrusting sheets are ridden over toward the south.

The northerly thrusting cannot be seen beyond Kangtong. The axis of the Seongch'eon anticlinorium is inclined to the northeast. Beyond it there are many thrusts and slides toward the south, or toward the southeast in the part where the Yangdeok block has rested. Without the Daedong series this tectonic development is difficult to separate into the Songnim and Taebo phases.

This orogenic zone is overlain by the Silla series and intruded by granitic rocks by which the folded zone was well consolidated. Subsequently the zone was broken into blocks. There must have been block movement near the end of the Cretaceous or the beginning of the Tertiary period. Faults which cut the Eocene series at Pongsan are not very large and were probably produced by the Middle Tertiary block movement.

III

THE P'YEONGNAM OROGENIC ZONE IN THE LIAOTUNG PENINSULA

1. Introduction

In his geological reconnaissance through South Manchuria in 1860, RICHTHOFEN traveled from Fuhsien through the Wuhutsuei basin. He was the first to pay attention to the Yungning sandstone. Subsequently in 1903 BLACKWELDER made a trip through Fuchou and Hsiungyüeh cheng and gave a chapter in *Research in China* (1907). During his visit to the Far East in 1909, IDDINGS made a rich collection of Cambrian fossils at Changhsingtao, which were later described by WALCOTT in *Cambrian Faunas of China,* 1913.

Systematic research into the geology of the Liaotung peninsula, however, was not undertaken before the geological survey at the South Manchurian Railway Company was instituted in 1907. In the same year MURAKAMI compiled the results of the survey of the Kuantung District. The geological outline of the Liaotung peninsula was presented for the first time with a geological map of the Dairen sheet (scale 1/400,000) with an explanatory text.

Since then a number of papers have been published, including SAWATARI's on

the Liaotung gneiss complex (1936), MATSUSHITA's on the Sinian system and on the geologic structure in the west of the Chinchou fault (1930, 31, 40). SAITO's on the Pre-Cambrian stratigraphy (1938), studies on the stratigraphy and palaeontology of the Korean group by ENDO (1924, 32, 35, 37) and KOBAYASHI (1930, 31, 33), on the P'yeongan group by OZAWA (1927), INAI (1935), NODA (1941, 42, 50), and HANZAWA (1944), on the geology of Chinchiachengtzu and Hsitao by NAKAMURA and SOO (1942), on the topography by HANAI (1928) and TSUCHIDA (1952), etc. In addition to these studies by Japanese geologists, there are reports on the Wuhutsuei coal-basin by CHAO (1926) and WANG (1928). Finally, a Jurassic mammal descibed by YABE and SHIKAMA (1938) and the article on the budding of *Nelumbo* seeds from the peat deposit of Pulantien by OHGA (1927) are of special interest to palaeontologists and neontologists.

The area dealt with here extends from the P'yeongnam geosyncline to the P'yeongbuk massif, Yatang bay lying at their boundary. In North Korea, the

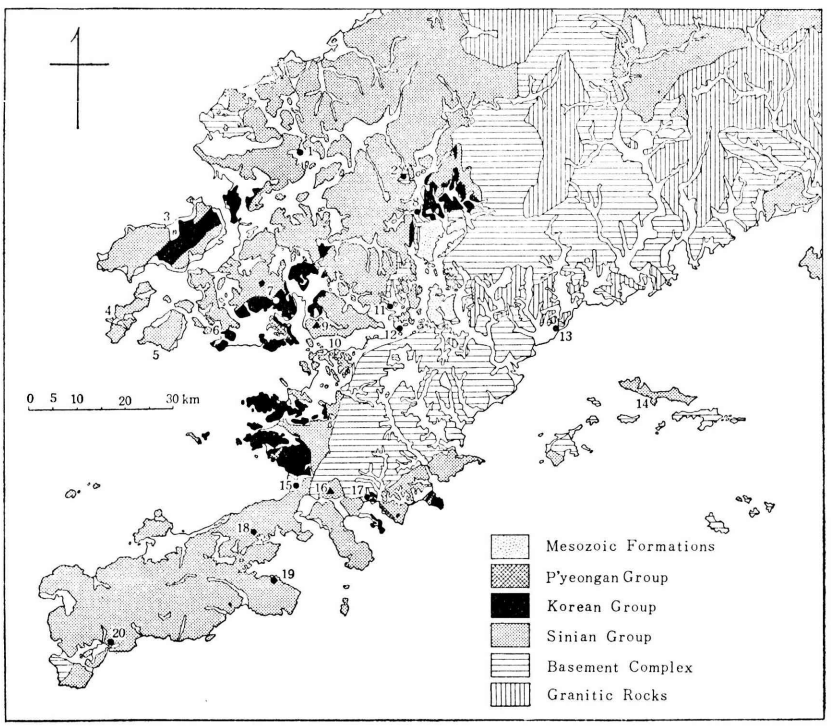


Fig. 13. Geological Map of the Liaotung Peninsula (after AOJI et al.)

1. Fuchou
2. Taipingkou
3. Changhsingtao
4. Hsichungtao
5. Fengmingtao
6. Hsitao
7. Chinchiachengtze
8. Wafangtien
9. Wangpashan
10. Yatang Bay
11. Sankuanmiao
12. Pulantien
13. Chinchou
14. Pitzuwe
15. Tachangshantao
16. Tangchiakou
17. Tahoshangshan
18. Nankuanling
19. Talien (Dairen)
20. Lüshun, (Ryojun, Port Arthur)

displacement along the Ch'ongch'eon-gang (Seisenko) river is so great that the P'yeongbuk massif side is bared by erosion. The relation between the massif and geosyncline is a problem of the Liaotung peninsula which should be investigated. It can hardly be overlooked that the pre-Songnim formations are thinner and stratigraphic break larger in the massif than in the geosyncline.

The mode of crustal deformations caused by the Songnim and Taebo disturbances is also quite different between the two tectonic elements. When intense folding and thrusting were taking place in the geosyncline, basins and domes were formed on the massif by undulation, or upthrusting and sliding at some places. There are Mesozoic formations but no Tertiary in this peninsula. Therefore it is difficult to discriminate later block movements. The Chinchou fault is a clear-cut tectonic line, the scarp of which has topographic significance. Compared to North Korea the Sinian trend is well emphasized in the fault system.

2. Stratigraphy

This region is composed of (1) an ancient gneiss complex, (2) Sinian group, (3) Korean group, (4) lower P'yeongan group, (5) older Mesozoic Wafangtien formation, (6) Cretaceous Pulantien formation, (7) igneous rocks and (8) Diluvium and Alluvium.

a. Ancient Gneiss Complex.

This is widely exposed in the peninsula to the east of the Chinchou fault. It was called the *Liaotung gneiss system* by SAWATARI. Epidote-biotite schist and epidote- and mica-bearing granitic gneiss are the leading members; some hornblendite and heleflinta are included. All are intruded by aplite. The metamorphic rocks are considered originally igneous rocks, mostly andesitic or dioritic, but the original rock of the heleflinta must have been trachytic.

MATSUSHITA designated a formation of 250 to 400 meters' thickness on the northwest side of Tahoshangshan, which rests on the gneiss complex and is overlain by the Tahoshangshan series, the "Hsiangshueiszu series". It consists of mica schist and phyllite in the lower part and limestone and clayslate in the upper. As its relation to the Tahoshangshan appears conformable, it may be a lower member of the Tahoshangshan series lying on the gneiss with an intrusive contact. However, there are probably two granites to be distinguished in the region. One intrudes the Hsiangshueiszu but the other intrudes only the Liaotung gneiss.

b. Sinian Sangweon Group.

The sequence of this group differs considerably on the two sides of the Yatang bay. In the peninsular part on the south side its base is unknown. Elsewhere its sequence is complete and very thick. On the north side the upper Sangweon is

absent and there are breaks in the middle and lower parts, most of which are comparatively thin.

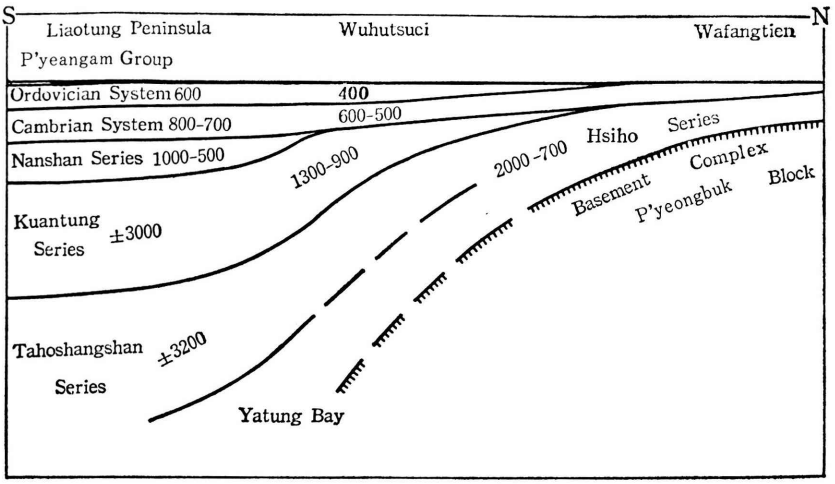


Fig. 14. Variation of Thickness of Sediments in the P'yeongnam Geosyncline in the Liaotung Peninsula. Numbers Thickness in m.

The group occupies an extensive area of the southern part west of the Chinchou fault and was studied in detail by MATSUSHITA and SAITO. As a result it can be classified into 3 series and 14 stages (see Table 8). The lower or Tahoshangshan series is more than 3,200 m in thickness and comprises 6 stages, the leading component being quartzite, but in addition it contains siliceous slate, calcareous phyllite and phyllitic limestone. This series plus the lowest stage of the middle or Kuantung series is correlated by MATSUSHITA to the Chokhyeon series in Hwanghae-do, North Korea. The Kuantung series, about 3,000 m thick, comprises 5 stages. Its major part is occupied by limestone and dolomite, but phyllitic clayslate is intercalated in the basal stage. *Collenia* is sometimes found in the middle part.

The upper or Nanshan series, which overlies the Kuantung disconformably, varies from 500 to 1,000 m in thickness and consists of 3 stages. The lower stage is represented by *Collenia* limestone and the middle one by light-colored thin-bedded siliceous limestone. The upper 400 to 800 meters, called the Nanshan stage, is built up of clayslates with intercalation of quartzite, quartzose sandstone and limestone. The facies and thickness, however, are quite variable through this stage. The Nanshan series is correlated to the Kuhyeon series in North Korea.

The group north of Yatang bay was first classified by AOJI (1928), and later revised by SAITO (1938) and others. AOJI distinguished the Hsiho and Wuhangshan series in the group and divided the Hsiho into the Tiaoyütai quartzite, Nanfen shale and marl and the Chiaotou quartzite, and the Wuhangshan series into the

Kaochiatun shale and sandstone and the Chinchia black limestone. The Tiaoyütai quartzite rests on the Liaotung gneiss complex with remarkable discordance.

According to a recent opinion put forth by MATSUSHITA, the Chiaotou quartzite, 200 to 700 m thick, can be correlated to the upper 5 stages of about 3,000 m of the Tahoshangshan series. The Hsiho series is only 700 to 2,000 m in total thickness. The Wuhangshan series, the correlative of the Kuantung series, is also thin and about 900 to 1,300 m thick. The Nanshan series is absent in this area. There sediments of only a little more than 2,000 meters' thickness accumulated in the early and middle Sinian periods, while on the south side of Yatang bay, the thickness of the sediments attained about 7,000 m. Subsequently the northern area became land by the end of the Sinian period, whereas 1,000 meters' sediments accumulated in the southern area after an emergence between the middle and upper Sinian period.

In the vicinity of Chunghwa in North Korea there are the *Protolenus* beds between the Kuhyeon series below and the *Redlichia* beds above. The three lie one above the other. In the Liaotung peninsula the *Redlichia* beds appear to lie on the Nanshan stage without any sharp boundary.

Near Chinchou in the southern area the *Redlichia* beds seem to be conformable to the Nanshan stage, but the relation of the beds to the upper Wuhangshan series is evidently disconformable in the northern area at the neck of the peninsula. Around the Wuhutsuei basin, it is recognized that the stratigraphic break beneath the *Redlichia* beds becomes larger from the Hsitao to the Chinchia-chengtzu area. For example, the Panlatao limestone at the top of the Wuhangshan series is present in the former area, but absent in the latter (NAKAMURA and SOO, 1942). Southwest of Wafangtien the red conglomeratic shale lies on the undulating erosion plane of the Chiaotou quartzite.

At Sungshu and Teiliszu north of Wafangtien, and in the vicinity of Fuchou north of the Wuhutsuei basin, there is the Yungning sandstone, whose age has been under discussion. This is reddish purple false-bedded sandstone derived from quartzite and granitic rocks. It is a kind of deltaic sediment in which conglomerate is intercalated. Because of its young appearance it was once considered Mesozoic. According to SAITO (1939), the formation consists of two parts. The lower part unconformably overlies the Nanfen shale and marl or gneiss and merges laterally with the Kaochiatun shale and sandstone. The upper part is conformable with the lower, but lies unconformably on the Kaochiatun shale and sandstone. Therefore, the Yungning sandstone must be the remains of a Pre-Cambrian delta on the western margin of the P'yeongbuk massif.

Near Kaiping, further north, only the thin Tiaoyütai quartzite exists. The Hsiho series is best developed in the Taitzuho tributary at its type locality. Because it reveals a cycle of sedimentation, it was once regarded as a minor cycle in the Taitzuho depression, corresponding to the major Sinian cycle in the P'yeongnam geosyncline (KOBAYASHI and KIM, 1931). The Hsiho series is really very thin compared to the tremendous thickness of the Sinian group. Therefore, there is another

interpretation that the Hsiho series is the equivalent of the lower or upper part of the Sinian group. This problem has not yet been solved completely. Nevertheless, it is undeniable that the Hsiho in the Taitzuho valley is so similar in lithic aspects to the so-called Hsiho series at the neck of the Liaotung peninsula that AOJI's correlation between them is now generally accepted.

Whatever this correlation problem may be, it is certain that the subsidence of the geosynclinal zone was as large as that indicated by the group, i.e., about 8,000 m in the peninsula, four times thicker than the group on the P'yeongbuk massif at the neck of the peninsula.

c. Korean Group.

The fossils from the Fuchou series at Changhsingtao which were described by WALCOTT are Middle Cambrian. In the vicinity of Chinchia-chengtzu one can see an excellent Cambrian sequence, from lower to upper, which is provided with numerous fossil horizons, and overlain by the Ordovician. They were studied in detail by ENDO, KOBAYASHI and others, among whom NAKAMURA and SOO (1942) have presented a detailed study of the Cambrian stratigraphy of the Chinchia-chengtzu and Hsitao areas.

The Lower Cambrian, 220 m thick, is chiefly composed of reddish purple shale with some limestone. Above this there is micaceous sandstone at the base of the Middle Cambrian formation. This formation is about 200 m thick. Shale is not uncommon in the lower part, but the middle part consists mostly of limestone and the upper part of slabby limestone and marl. Slabby limestone and intra-formational limestone conglomerate are the leading components of the Upper Cambrian, which is about 170 m thick. Shaly layers are intercalated in the middle part.

At the base of the Ordovician is *Cryptozoon* limestone, which contains a few of brachiopods. This fauna, as noted by KOBAYASHI (1933), is quite different from that of the *Cryptozoon* limestone in the Taitzuho zone. Above this there is slabby limestone which is accompanied by dolomite and intraformational limestone conglomerate. This sequence appears similar to that of the Wanwanian series in the Taitzuho zone, but their correlation is not well endorsed by palaeontological evidence.

The next beds are composed of chert or flint-bearing massive and well-bedded limestone. The lithic aspect reminds one of the Wolungian, but the limestones are unfossiliferous. Actionoceroids and other Middle Ordovician fossils are abundant in the still higher limestone, through which its reference to the Toufangian can be confirmed. The Ordovician formation is about 400 m thick.

The Korean group in the vicinity of Wafangtien belongs mostly, if not entirely, to the Cambrian.

On the south side of Yatang bay, there is a group near Chinchou and Sanshihlipu. According to MATSUSHITA (1930), the Lower Cambrian measures about 350 m, the Middle and Upper Cambrian about 400 m, and the Ordovician about

600 m in thickness. Thus, the total thickness attains more than 1,300 m in the Chinchou area, while it is about 1,000 m in the Wuhutsuei basin. Thus it is thicker here than in the Wuhutsuei basin, but the difference in thickness is much less in the Korean group compared with that of the Sinian group.

In the Chinchou section there is a formation, 350 m thick, beneath the *Redlichia* beds. It is composed mostly of slate and quartzite, but limestone and quartzose sandstone are intercalated in the slates. MATSUSHITA previously regarded it as the basal part of the Cambrian, but now it is taken for the top division of the Nanshan series. This formation is absent both in the Chinchiachengtzu and the Hsitao area. It is noteworthy that the marl of the Kushan stage and the intraformational limestone conglomerate common in the Upper Cambrian of the Wuhutsuei basin are apparently undeveloped in the Chinchou area.

d. Lower P'yeongan Group.

Surrounded by Ordovician ridges, this group occupies the central part of the Wuhutsuei basin and yields the so-called Fuchou fire clay and anthracite. It forms low hills and consists of the Penchi, Yatang and Lioutang series. The Penchi is the approximate equivalent of the Hongjeom series; the Yatang and Lioutang are combined into the Sadong in Korea. The so-called G bed or the fire clay bed at the base of the Penchi series overlies the Toufangian limestone; the Penchi limestones contain Moscovian fossils. The series is 70 to 90 m thick. The limestone at the top is overlain by the fire clay at the base of the Yatang series with erosional unconformity. The clay bed contains angular limestone boulders which were derived from the upper Penchi.

The Yatang series is about 100 m thick. It has a persistent limestone layer in the middle part, and limestone lenses above and below the middle limestone all yield Sakmarian fossils; coal seams are found below the middle limestone bed.

At a point east of Feichiatun, NODA observed that the false-bedded coarse sandstone of the Lioutang series lies on the dark brown shale of the Yatang in clino-unconformity. Nevertheless, the two series are generally conformable. The Lioutang is built up of sandstone, shale, fire clay and coal seams and contains land plants but no marine fossils.

At Tiaohutsu and Chienshihhueiyaotzu near Chinchou and at Tangchiakou, east of Tahoshangshan, there are small areas of the Penchi and Yatang series.

e. Wafangtien Formation.

This is found as small patches east of the town of Wafangtien. Its structure is so complicated that its sequence is difficult to determine. It is composed of shale and sandstone, in addition to conglomerate and coal seams. According to HORIUCHI, it lies on the Lower Cambrian southwest of Wafangtien and Lichiayao and on the Upper Cambrian east of Wafangtien. At Tangchiatun it overlies the Ordovician (?) and Upper Cambrian in clino-unconformity. At Wangchiatun, however, the relation between its basal conglomerate and the Lower Cambrian

is disconformable. It lies unconformably on the Middle Cambrian north of Chatzuyao and disconformably on the Lower Cambrian east of that village. Furthermore, it lies unconformably on the Middle and Upper Cambrian at Taikumiao but disconformably on the Upper Cambrian at Hsiaolinchiatun. It lies unconformably on the Hsiho series at Luchiatun.

Because I visited this area in 1939 in summer when the exposure is at its worst, I could examine only a part of these contacts. The rock facies are quite changeable. Some conglomerates are composed mostly of limestone, but others contain no limestone. Pebbles of these conglomerates are not always very large. They must have originated as a lacustrine sediment in an intermontane basin whose topographic relief and geologic structure were fairly complicated. Jurassic plants therein belong probably to the Daedong flora. In addition, molluscan shells and fish-scales are known to occur but have not yet been studied. *Manchurodon simplicidens* YABE and SHIKAMA discovered at Chatzuyao in a coal seam is a Jurassic mammal in the family Amphidontidae of the Pantotheria.

f. Pulantien Formation.

This covers a large area east of the railway line between Wafangtien and Pulantien, and is quite different from the Wafangtien formation in that the degree of deformation is much less. It reveals the following two cycles:

e. Shale with sandstone and conglomerate, 350 m thick.
d. Sandstone with some conglomerate, 350 m thick.
c. Conglomerate, 500 m thick.
b. Shale and sandstone with some conglomerate, 450–580 m
a. Variegated tuffaceous sandstone and shale with a basal conglomerate, 1,000 m thick.

It lies discordantly on the Pre-Cambrian rocks; the basal conglomerate contains a great deal of quartzite, phyllite and gneiss in addition to some shale, limestone, porphyrite, quartz-porphyrite and volcanic rocks. The boulders of the conglomerate are often large, attaining 80 cm in diameter, and the conglomerate is sometimes interbedded with sandstone. It is probable that the surrounding land was rugged at the beginning of the Pulantien epoch. *Protocedroxylon araucarioides* (GOTHAN) was procured from the variegated tuffaceous beds. *Plicatounio naktongensis* KOBAYASHI and SUZUKI in the next higher bed at Hifumi pass suggests that the lower Pulantien (a-b) belongs to the Naktong series. Accordingly, the upper Pulantien (c-e) is probably a member of the Silla series.

g. Volcanic Rocks.

Diorite, porphyrite and porphyry are found at some places in the eastern gneiss area. On the east side of Tahoshangshan some sheets of granite porphyry are imbedded in the Tahoshangshan series.

On the west side of the Chinchou fault, the igneous rocks intruding the sedimentaries are mostly basic hypabyssals. Sheets of nephrite-like rock are the most common and attain 50 to 100 m in thickness. Basic dykes are found along faults,

or fissures parallel to the faults, and their breadth generally measures several meters, but one near Sanshihlitun is 700 m wide and 1,600 m long.

For dating the most important is the Mesozoic terrain. Andesite and diorite are found at the thrust which disturbs the Lower (?) Jurassic Wafangtien formation. At Kanchiatum, dolerite intruding the Middle Cretaceous Pulantien formation extends N15°–35°E, forming a dyke. From these facts it can be judged that some of the igneous rocks are related to the late Jurassic Taebo disturbance, but others are younger.

While andesite boulders are found in conglomerates of the Pulantien formation, it is mainly tuffaceous and intercalates with a flow of andesite northwest of Sunchiatun and is intruded by andesite dykes at some places. Thus, there are andesites of various ages. At the same time it is certain that volcanic eruption has taken place in the Cretaceous period. It can be inferred also that the intrusion of diabasic rocks along some faults are related to the late Cretaceous or Tertiary block movement.

h. Younger Sediments and Topography.

Remnants of an old flat plane are found in the mountainous region at an altitude of 300 to 400 m. It may be a correlative of the Yukpaeksan plane in Korea. A clear-cut monadnock stands on this peneplain at Tahoshangshan. This cycle of erosion terminated with the middle Tertiary block movement. Subsequently, the piedmont plane, called Konciji (Kuangningszu), came to being in this region. It is mainly rolling hills 120 to 200 m above sea-level. Loess on the slope or in depressions in these hills seldom exceeds 25 m in thickness. Since the plane is covered by loess, it is older than the Malan stage.

Redeposited loess is distributed in the lowlands. Mammoth remains were discovered in a clay bed at Lunwangtang in Talien. Similar clay beds are found in lowlands near Pulantien, Kaiping, Takushan and elsewhere. The low plane at the top is 20 to 34 m high. This is called the *Liaotung peneplain* or the Hishikwa (Pitzuwe) plane and is considered to be the correlative of the Rakuroan (Naknang) peneplain in North Korea.

The present valley carves this plane. Due to the slight subsidance in the near past, peat beds accumulated at places along the coasts of the Pohai and Hwanghai seas. Among these beds the one at Pulantien is famous for the inclusion of *Nelumbo* seeds still capable of budding. Salt fields at Tailen, Wuhutsuei and several other places are intertidal flats, or places where the sea bottom emerged in the final phase of upheaval.

3. The Eastern Part of the Peninsula

The peninsula on the east side of the Chinchou fault is mainly occupied by the ancient basement complex. The Sinian group, however, appears at Pitzuwe and Heitao. A typical display of the Tahoshangshan series is found at Tahoshangshan,

east of Chinchou, whence its name is derived. It forms a monadnock on the high plain and is folded and cut by faults in the Sinian and Korean directions.

At Tangchiakou the lower Pyeongan group, along with the Ordovician formation, is folded and sunken in the form of a graben trending NW. The quartzite of the Sinian group lies on its northeast side and the limestone of the Sinian group lies on the other side of the graben.

It is noteworthy that the overturned folding near Chinchou, of which a lengthy description is given below, becomes vertical and gentle toward the east. This tendency of deformation is suggestive of the folded structure which has existed on the gneiss basement near the south coast of this area.

OGURA (1933) called attention to parallel dykes which he had studied at Liangchiatien, Pitzuwe and Wolungtun. South of Pulantien, for example, are innumerable dykes of quartz porphyry running NNE to SSW. They are independent of the gneissosity in this region in that the leading trend of the latter is equatorial. The dykes are discrepant also with the Chinchou fault in the NNE direction.

4. The Western Part of the Peninsula (see Geol. Map II)

Because the folds and thrusts in this area are cut by a complicated mesh of faults, it is very difficult to restore the original structure. Thanks to MATSUSHITA's elaborate work, however, recumbent folds and thrusts toward the northeast have

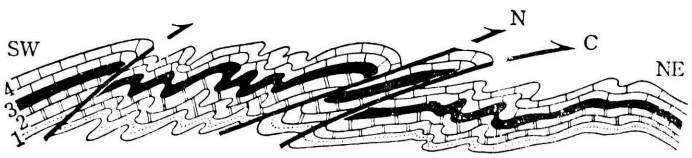


Fig. 15. Generalized Profile of the Liaotung Peninsula (after MATSUSHITA, but modified).

N. Nanshan Thrust
1. Tahoshangshan Series
3. Nanshan Series
C. Chinchou Thrust
2. Kuantung Series
4. Palaeozoic Formations

emerged by elimination of the secondary displacement. This folded zone is composed of the Sinian group, about 7,000 m thick, the Korean group, about 1,300 m thick and the thin lower P'yeongan group, about 200 m thick, or a total of about 8,500 meters of the three sedimentary groups. The gneiss complex at their base is not exposed. Broadly speaking, it is a large synclinorium. Hence the Tahoshangshan series is exposed on the northern and southern peripheries and is especially extensive in the Lüshun projectile west of Talien. This synclinorium, however, is dissected by the Chinchou thrust. One can see the three groups in the northern terrain, while its south side is occupied by the Sinian group. Therefore the large

synclinorium can be divided into the southern anticlinorium and the smaller scale northern synclinorium, which are separated by the Chinchou thrust.

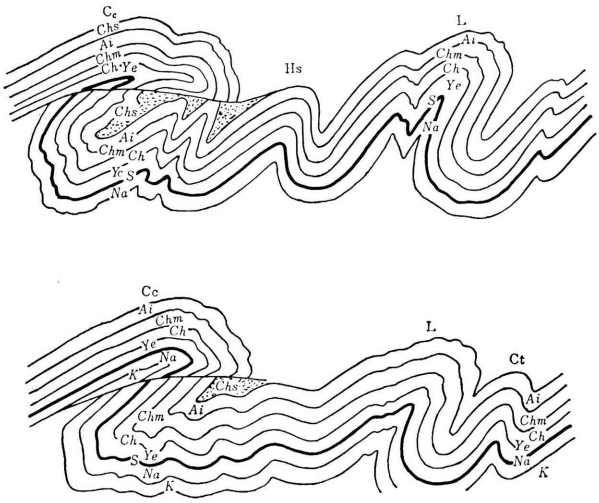


Fig. 16. Two Restored Profiles of Chinchou Area (after MATSUSHITA). (Upper and lower profiles respectively through the western and eastern part of this area).

Chs.	Lower P'yeongan Group	Na.	Nanshan stage
Ai.	Middle Ordovician Formation	K.	Kuantung Stage
Chm.	Lower Ordovician Formation	Cc.	Chinchou Anticline
Ch.	Upper and Middle Cambrian Formations	Hs.	Houshihhueiyaotun Anticline
Ye.	Yenchialu Stage	L.	Lashushan Anticline
S.	Sanshihlipu Stage	Ct.	Chitingshan Anticline

In the northern synclinorium the P'yeongan group is found at Chienshihhueiyaotzu, northwest of Chinchou. Thus, the main axis of the synclinorium is much deviated to the south. The southern anticlinorium is thrust upon this subsided part of the northern synclinorium, the front of the thrusting body being marked by the Chinchou thrust line. The central and southern parts of this synclinorium, to the south of Sanshihlipu, is mainly occupied by the Korean group. The Lashushan homoclinal anticline extends southeast from the Lashushan projection, and divides the Korean group into northern and southern parts. On each side of this principal anticline is an auxiliary anticline, the Chitingshan on the north and the Houshihhueiyaotun on the south. Farther south is the small Chienshihhueiyaotzu syncline, the axis of which is indicated by the P'yeongan group. The northwest side of this area is intensely folded, but the folding decreases southeastward till it results in gentle undulations near the Chinchou fault.

The northern synclinorium is thus quite asymmetrical, having its main axis near its southern margin. The Chinchou anticline within the synclinorium is recumbent and is thrust upon itself, as seen at Lungwangmiao on the western shore. The

major part of this *Decke* is now eroded out, but north of Taiweichiatunhuei, Chienshihhueiyaotun and Yaochiatun, it can still be seen that the Lower Ordovician formation lies on the lower P'yeongan group.

In the stretch between the Chinchou thrust and south Talien, there is an extensive display of the middle and upper Sinian group. On the south side of the Chinchou anticline is the recumbent anticline of Nanshan which is thrust upon the former, forming the Nanshan thrust.

The lower limb of the Nanshan anticline is cut off by thrusting. Its upper or southern limb is indicated by a broad saddle of the Kuantung series which is gently inclined toward the south. Further south are a syncline and an anticline. The latter is the Kuanchingtzu anticline, whose northern limb is cut by the Kuanchingtzu and Haimiaotuotzu thrusts. The northern syncline beneath the Haimiaotuotzu thrust forms a minor anticline near the Chuanshueiyentzu thrust along the northern margin, where it is thrust upon the Nanshan anticline.

The Kuanchingtzu anticline strikes equatorially east of Choushueitzu, but turns abruptly to the north in the west. There it develops into an anticlinorium comprising the eastern and western Yüshan anticlines. This is a narrow fluted zone between the south limb of the Nanshan anticline and the Yuchiatun dome. Further on is the Panchüantzu basin of the Nanshan series on the Pohai coast. The Yuchiatun dome, which is composed of the lower Kuantung series, reveals a northern projection of a large anticlinorium in which the Tahoshangshan series is well developed.

The above mentioned structure is further complicated by three systems of faults. The oldest is the strike fault system (I). NNE to ENE trending faults belong to the next system (II). The last system is represented by the NNW to NW trending faults (III). The first system comprises reverse (Ia) and normal faults (Ib). For example, the upthrust extending southward from the northern limb of the Lashushan anticline belongs to the Ia group. No thrust of the Ia group is found on the south side of the Chinchou thrust. It is a general tendency for the Ib group of faults to have the downthrow on the side of a syncline, instead of an anticline. Among the Ib group of tension faults there are three kinds, as follows:

Ib^1 Those parallel to the thrust, e.g., Chinchou-Tungmen fault.

Ib^2 Equatorial to NE trending faults at Tahoshangshan, Luotuoshan, Chipanme, Lioushutun and other places, and their companion faults, some of which are hinge faults. Some are intruded by diabase.

Ib^3 NW trending fault of Chungkechenpao and WNW trending fault of Taimaoyingtzu, where the former is a hinge fault and the latter has its downthrow on the north side.

The faults of the II group commonly trend in a NNE direction and less commonly in a NE or ENE direction. They are mostly normal faults, but some are hinge faults. Some of them have topographic significance. The most important among them is the Chinchou fault which bisects the peninsula. This fault is indicated by a disturbed zone dipping about 40 degrees, along which the western block has slipped down several hundred meters. A short distance west are some

parallel faults, which as a whole may be called step faults, although a few exceptions have the downthrow on the opposite side. Further west, the terrain is dissected into horsts and grabens by faults of the same trend.

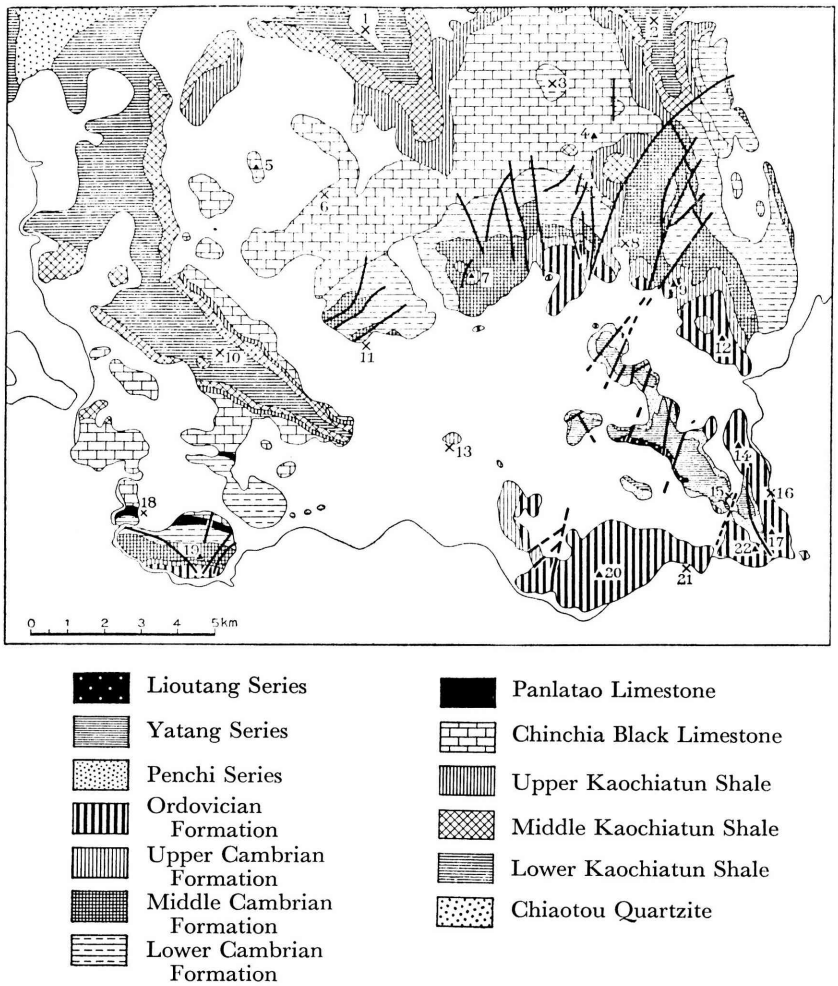


Fig. 17. Geological Map of the Chinchiachengtzu-Hsitao Area (after AJOI, KOBAYASHI, NAKAMURA, SOO and NODA).

1. Laoyufang
2. Hanchiachuang
3. Yuanchiakou
4. Wuhangshan
5. Pachiashan
6. Chientafangshên
7. Mapanshan
8. Chinchiachengtzu
9. Paichiashan
10. Sanchingkung
11. Lienhuashan
12. Taishan.
13. Taipaotzu
14. Loutuoshan
15. Tingchiatun
16. Tunghaimatou
17. Sanlengshan
18. Panlatao
19. Yuntaishan
20. Taitzushan
21. Nanhaimatou
22. Taoershan

The Chinchou fault extends south of the Chinchou thrust. On its west side are the Taifangshen, Chinchoupeimen, Nankuangling, Leishan and Tayüshan faults. The Kechenpao fault which runs meridionally across the interval between the last two faults is intruded by a diabase dyke. The Liangyenching fault on the west side of Tayüshan describes an arc with convexity to the east and is intruded by diabase at Liangyenching, but cuts a diabase dyke at Nankuangling. Therefore it is presumed that the intrusion of the diabase is nearly simultaneous with the block movement.

Finally the faults of the III group trend in a NNW to NW direction in general, but occasionally run a little west of north. The Chinchou fault is dislocated by faults of this kind, which are evidently the products of the diabase intrusion. The Hsiachiahetzu, Yangchuantzu and Chienkuantun faults in the south belong to group III.

5. **Wuhutsuei Basin** (see Geol. Map III)

On the north side of Yatang bay is a large structural basin. On its northwest side beyond the Fuchouho river is the Fuchou syncline with the Cambrian of Tsianghsingtao island along its axis. At the eastern end of Yatang bay is the ancient gneiss of Tawangshan. Through Tientaishan this is linked to the Taipingkou inlier of the pre-Hsiho metamorphic rocks by the Tiaoyütai quartzite. The Wafangtien and Pulantien basins lie on the east side of this anticlinal ridge.

The anticline stands on the eastern wall of the Wuhutsuei basin which is composed of the Sinian group, about 2,000 m thick; the Korean group, about 1,000 m thick; and the lower P'yeongan group, about 200 m thick. Because the basin structure is asymmetrical, the distribution of the Palaeozoic formations is restricted to the southwestern part of the Chinchia basin. This, too, is asymmetrical as is indicated by the P'yeongan group near the southeastern corner of the Chinchia basin. The Ordovician and Upper Cambrian formations are abruptly bent up along the coast of the south sea or Nanhai.

The east side of the basin is delimited by the Wangpashan thrust. The eastern Chiaotou quartzite is thrust at a low angle upon the western Wuhangshan and Cambrian formations along this tectonic line which rises northward from Paochiatao isle. The coast line has a deep indentation north of this isle, forming an inlet called the Tunghai or east sea. There, the folded belt in front of the Wangpashan thrust is submerged, but it is seen in the hills of Waitoushan that the fold axis of the Lower and Middle Cambrian formations has migrated toward the north. The long Hanchiachuang anticline is on its west side.

Along the west side of the Tunghai through Taishan and Mashan the Ordovician formation forms the eastern wall of the Chinchia basin. At Sanlengshan and Taoershan the Ordovician and lower P'yeongan formations change their strike abruptly to form an acute angle where they are partly overturned. From the apex

of this angle the P'yeongan group extends along the bisectrix, forming a low hill where the group lies horizontally.

Although the Chinchia area is cut by numerous faults, it is still a typical basin topographically as well as geologically. The hilly land is surrounded by the ridge-making Ordovician limestone. The Cambrian rocks are distributed on the outer circle. The Wuhangshan series is widely distributed farther northwest, and the Lower Cambrian occurs in the Yuanchiakou basin.

The Chinchia basin and the Pachiashan syncline each measure 6 km in breadth. They are separated by an anticline extending from Laoyufang toward the southeast. A subparallel anticline exists on either side of that anticline. The eastern one is the above mentioned Hanchiachung anticline and the western one is called the Sanchingkung. Both have their axes inclined toward the southeast.

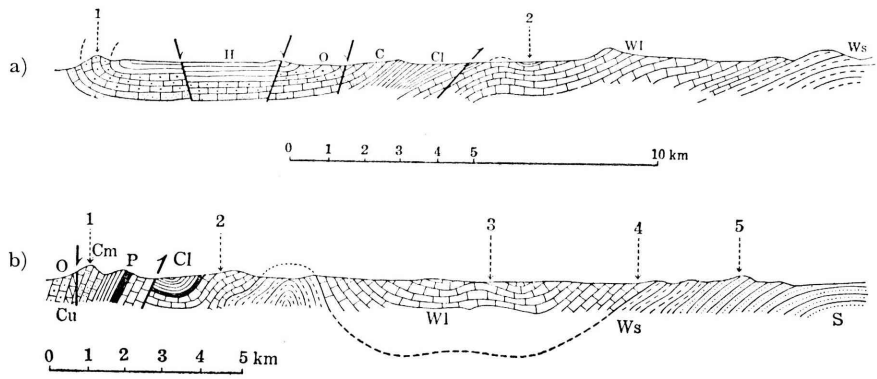


Fig. 18. Profiles of Chinchiachengtzu (a) and Hsitao Area (b) (after NAKAMURA and SOO).

H. Lower P'yeongan Group
O. Ordovician Formation
Cu. Upper Cambrian Formation
C. Upper and Middle Cambrian Formations
Cm. Middle Cambrian Formation
Cl. Lower Cambrian Formation
P. Panlatao Limestone
Wl. Chinchia Black Limestone
Ws. Kaochiatun Shale
S. Chiaotou Quartzite

1. Sanlêngshan
2. Yenchiakou
in the Upper Profile (a)

1. Yuntaishan
2. Hsiaochaochiatun
3. Chientafangshen
4. Chichiafang
5. Taheishan
in the Lower Profile (b)

The Hsitao area is separated from the Chinchia basin by the Sanchingkung anticline, which contains the Panlatao limestone. At Yuntaishan the limestone is overlain disconformably by the Korean group and underlain conformably by the black limestone of Chinchia. They dip to the south and on the north side are thrust upon the Lower Cambrian.

Thus the Hsitao-Chinchia basin suffered thrusting from the south and east sides, with the result that its structure became asymmetrical. While the strata are fluted or steeply inclined near the two margins, they slant gently on the northwest

side; there are some broad undulations, as noted already. On the northeast side there is a centrifugal thrust of Sunchiatun along which the Chiaotou quartzite is pushed upon the Lower Cambrian of Hamakou in the east and the Kaochiatun shale at Sunchiatun in the west.

In the Chinchia basin there are numerous faults. One of them is the Chinchia fault, running from NE to SW through the west side of Chinchiachengtzu. It is a large fault along which the southeastern side has sunken. Most other faults trending NE, NNE, NS or NNW, however, are minor. At Lienhuashan in the southeastern part of the Pachiashan syncline are three step faults downthrown on the NW side.

The area between the Wangpashan thrust and the Tientaishan anticline is called here the Lankushan area. This occupies the outer belt of the Chinchia basin where the Wuhangshan and Hsiho series are widely distributed. Some thrusts toward the east or west are generally found within the Nanfen shale and marl formation. The Chiaoyütai quartzite lying on the gneiss of Tawanshan marks the eastern margin of the large Wuhutsuei basin. In the northern part, the Chiaoyütai quartzite is thrust upon the younger members of the Hsiho series at some places.

Though complicated by undulations and low angle dislocations, it is generally accepted in the Lankushan area that the older formations are developed on the east and the younger ones on the west side. Such meridional zones extend southerly as far as the northern coast of the Yatang bay where they are cut by an equatorial tectonic line. Along the eastern part of the coast the Chiaotou quartzite and the younger formation to the south are thrust upon the Nanfen shale along the tectonic line which takes a meandering course. This is the Yatang tectonic line. It is considered to run across Yatang bay diagonally and reach Chientailientao isle where the Chinchia black limestone slips upon the Chaiotou quartzite.

The line is aligned with the Pulantien fault *en échelon*. They indicate the old and young dislocations of the boundary between the peninsula and its neck. Whether the Yuntaishan thrust of Hsitao occupies the western extention of the Yatang tectonic line, or not is difficult to determine but at any rate they are all products of the thrusting of the southern area upon the northern. The northern area can be divided into the Wafangtien-Pulantien area, the Lankushan monoclinal area and the Chinchia-Hsitao basin by the Tientaishan anticline and Wangpashan thrust line.

6. The Wafangtien and Pulantien Basins (see Geol. Map III)

On the east side of the Tientaishan anticline are the Wafangtien and Pulantien basins, and further on an extensive display of the ancient granitized basement. The Pulantien basin of the Cretaceous formation is delimited by the Pulantien fault on the south. Running along the southern coast of the Yatang bay and passing through the southern side of Pulantien, it extends slightly to the north of east. There the Hsiho series is directly overlain by the Cambrian.

In the Wafangtien basin in the north there are patches and strips of the Jurassic Wafangtien formation. The Cretacous Pulantien formation, on the other hand, occupies the large area of the Pulantien basin in the central and southern parts. These Mesozoic formations afford an indispensable key to analyzing the tectonic development.

As mentioned already, the base of the Jurassic is marked by a remarkable discordance. Therefore it can safely be concluded that before Jurassic sedimentation the older formations were folded, most probably by the Songnim disturbance.

The bedrocks on which the Jurassic formation lies belong mostly to the Cambrian formation. Broadly speaking, its upper part is well developed in the central part of the basin, and so is its lower part around the margin. The Hsiho series is distributed in the further outer side, if the secondary dislocation is eliminated. Therefore the depression of the Wafangtien formation also must have been a structural basin of the Cambrian formation. It is noteworthy that the Jurassic lies on the Cambrian with angular unconformity at some places. This fact, together with the variation among the Cambrian rocks, shows that the basin structure was complicated by local folding to some extent.

This structure was later modified considerably by the Taebo disturbance. Among the thrustings in which the Wafangtien formation plays a role, there are three important elements. One is the Yuntaishan *Pseudoklippe*. The second is the Wafangtien thrusting-sheet and the third the thrusts at Chatzuyao and other places within the basin.

The pre-Hsiho phyllites and dolomites near Chinchangtun are intruded by andesite, and are thrust upon the Jurassic north of Hsiaolinchiatun. This thrust is dislocated toward the south and recurs south of Wangchiatun, southeast of Wafangtien. There a small *Klippe* is found on the Jurassic in front of the thrust.

These metamorphic rocks are overlain by the Chiaoyütai quartzite at Yuntaishan. Southwest of Wafangtien, the phyllites are thrust on the Jurassic or the subjacent Cambrian. Because the pre-Hsiho metamorphics are always in thrust contact with the Jurassic or Cambrian formation, there is a theory that they form an exotic mass transported from a remote place, but there is no root for such a thrusting sheet. In my opinion they form a parautochthonous *Pseudoklippe* which was squeezed out by compression of the Taebo movement.

Northeast of Wafangtien there is a chain of *Klippen* composed of the Chiaotou quartzite. They lie on the Lower Cambrian in most places, but on the Jurassic near Lichiayao. On the west side of the railway line is the autochthonous Chiaotou quartzite which is overlain by the Cambrian, which in turn is overlain by the Jurassic formation. This belt must be the root of the Wafangtien thrusting sheet. Due to the difference of competency for lateral pressure, the rigid Chiaotou quartzite presumably was slipped upon the plastic Lower Cambrian shale and was transported tangentially. The dislocation of the thrusting sheet attains about 4 km at the maximum.

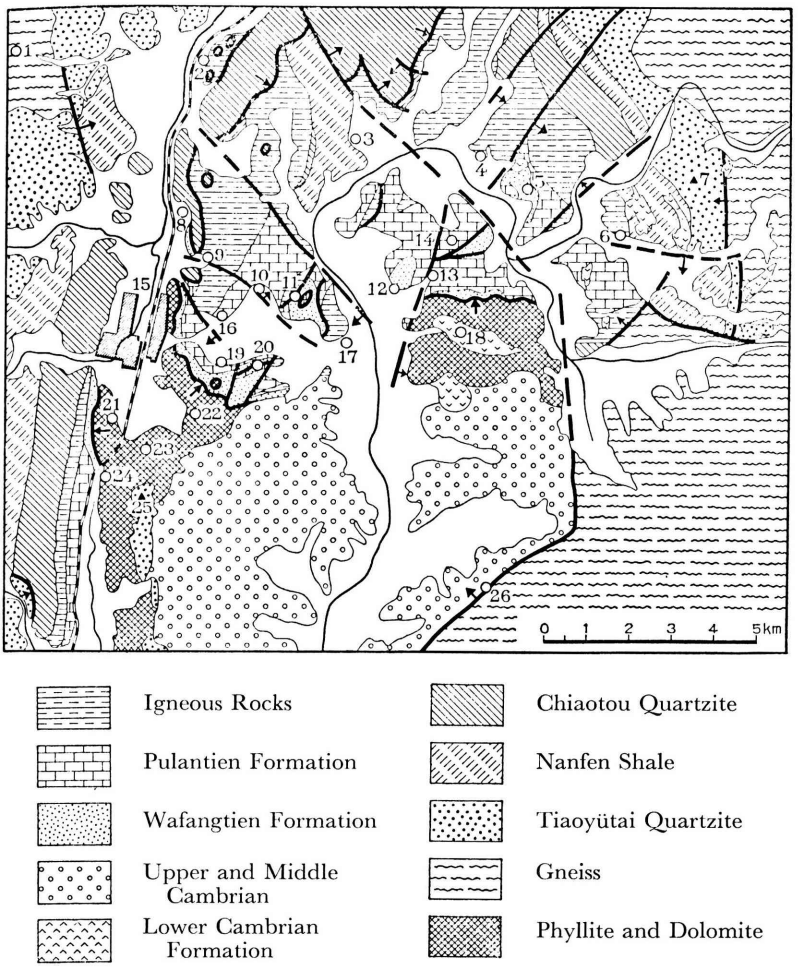


Fig. 19. Geological Map of Wafangtien Basin (after KOBAYASHI, HORIUCHI et al.).

1. Taipingkou
2. Lichiatun
3. Chaochiatun
4. Tailuchiatun
5. Hsiaoyinchiatun
6. Luchiatun
7. Wanchengshan
8. Lichiasueitzu
9. Lichiayao
10. Yangshufang
11. Chatzuyao
12. Takumiao
13. Liuchiatun
14. Hsiaolinchiatun
15. Wafangtien
16. Chuanchüehfang
17. Hsintuntzu
18. Chinchangtun
19. Tangchiatun
20. Wangchiatun
21. Kangtzutien
22. Kanchiatun
23. Chaochiatun
24. Yangshufang
25. Yuntaishan
26. Chunghêtien

The centripetal thrustings from the northwest and south sides caused the Cambrian and Jurassic formations of the Wafangtien basin to be contorted, yielding some thrusts in themselves. At Chatzuyao the Jurassic formation is thrust by the Cambrian on the east side, strongly disturbing the Cambrian on its west side. There is a thrust in the opposite direction within the Cambrian strata which

extend from Kaoshantun to the northeast. It may be an accessory dislocation in front of the Wafangtien thrusting sheet.

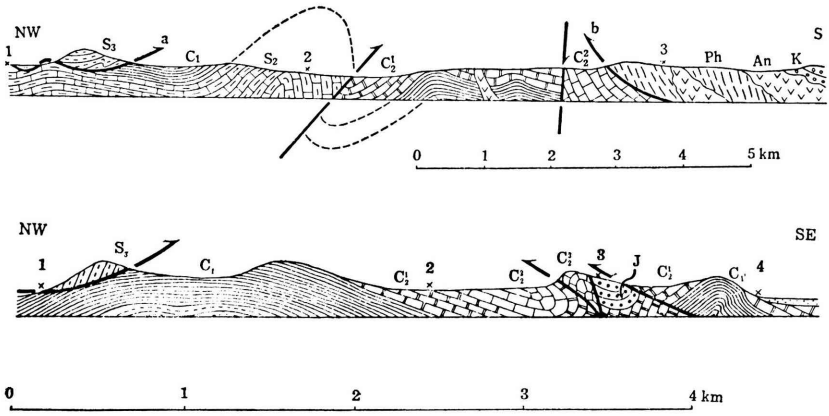


Fig. 20. Two Profiles of the Wafangtien Basin (KOBAYASHI et al.).

K. Pulantien Formation
J. Wafantien Formation
C_2^2. Late Middle Cambrian Formation
C_2^1. Early Middle Cambrian Formation
C_1. Lower Cambrian Formation
S_3. Chiaotou Quartzite
S_2. Nanfen Shale and Marl
Ph. Phyllite and Dolomite
An. Andesite
1. Lichiatun
2. Chaochiatun
3. Chinchangtun
a. Wuchiatun Thrust
b. Chiangchiatun Thrust

in the Upper Profile through the Central Part of the Basin

1. Lichiashueitzu
2. Yangchiafang
3. Chatzuyao
4. Hsinchiatun

in the Lower Profile through the Western Part of the Basin

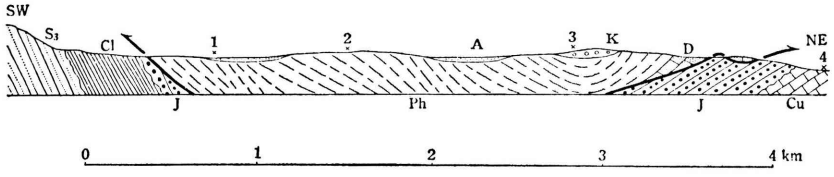


Fig. 21. Profile of the Southwestern Margin of Wafangtien Basin (after SAITO).

A. Alluvium
K. Pulantien Formation
J. Wafangtien Formation
Cu. Upper Cambrian Formation
Cl. Lower Cambrian Formation
S_3. Chiaotou Quartzite
D. Dolomite
Ph. Phyllite
1. Shenyang-Talien Railroad
2. Chaochiatun
3. Kanchiatun
4. Tangchiatun

The basin structure thus intricately disturbed by the Taebo movement was further complicated by vertical dislocations in various directions. The NE to ENE and NW faults are common. They have a tendency to form horsts and

grabens. In addition, there is a large meridional fault running from Wafangtien to the south along the railway line.

The Cretaceous formation is a filling of the post-Taebo basin surrounded by rugged mountains. Judging from its lithofacies, it was deposited immediately after the disturbance. Because it is largely cut by faults on the east and south sides, it is certain that a strong block movement has occurred in the late Cretaceous or Tertiary period.

Cut by the NE fault through Tachengchiatun and Tawangchiatun, the Cretaceous is in contact with the gneiss complex. Because of the lack of any gneiss boulders in its conglomerate, it is presumed that the gneiss basement must have been covered by the Hsiho series before the dislocation. The southern boundary fault of the basin belongs to the same system.

7. Discussion and Summary

In the Liaotung peninsula the pre-Songnim sequence differs remarkable in the northern and southern areas, which are bounded by the Yatang tectonic line. As shown in Table 9, the subsidence was three times greater in the southern than in the northern area. Among the three major stratigraphic units the difference in thickness is especially great in the Sinian group, which shows a remarkable difference in the amount of subsidence between the kratonic mass of P'yeongbuk on the north and the geosynclinal zone of P'yeongnam on the south. The Sinian group is not thinner in the Chaeryeonggang belt of North Korea than in the Liaotung peninsula, but is reduced to less than 2,000 m thick in the central and northern parts of the Daedonggang basin. Nevertheless there is no large break between the Sinian and Korean groups. Therefore this difference must indicate differential subsidence among the parts of the geosyncline. It is certainly noteworthy that the stratigraphical break at the base of the Cambrian system becomes larger from south to north in the Liaotung peninsula. Within the northern area it is larger in the Wafangtien area than in the Wuhutsuei basin. In fact the Wuhangshan series is completely missing in the eastern area.

Table 9. Difference in Thickness of the Pre-Song'nim Sediments on the Two Sides of the Yatang Bay Tectonic Line.

Formation	South Area		North Area
P'yeongan group	Ca. 200 m	Yatang Tectonic Line	Ca. 200 m
Korean group	Ca. 1,300 m		Ca. 1,000 m
Sinian group	— 7,000 m		Ca. 2,200 m
Total Sum	Ca. 9,000 m		Ca. 3,000 m

Farther north is the Yungning sandstone, which indicates a fossil delta wedging

into the Wuhangshan series and expanding toward the west. These facts indicate that the P'yeongbuk land existed in the middle Sinian period. In the latter half of the Sinian period the northern massif was elevated reciprocally to the subsidence of the geosyncline and underwent erosion. The clastic material thus produced was transported from the land to the geosyncline. During this land period the topographic relief of the massif is thought to have been greatly reduced.

In view of the uniformity of thickness of the Korean group and the preponderance of calcareous rocks, it is understood that the differential movement between the two tectonic units was greatly reduced in the Cambro-Ordovician period. After the prolonged Middle Palaeozoic land period, these areas were submerged and the P'yeongan group was deposited, but the local variation of its facies and thickness between the two areas is slight.

The present geologic structure has resulted through repeated crustal deformations. The Yatang tectonic line is an important boundary between the two tectonic units. Another important boundary is the Chinchou fault. From the tectogenetic point of view the Liaotung peninsula can be classified into four kinds of areas as follows:

−A Strongly Subsided Area: .....Distribution of the P'yeongan-Korean Group.
+B Moderately Subsided Area: .....Distribution of the Middle and Upper Sinian Group.
+B Moderately Elevated Area: .....Distribution of the Middle and Lower Sinian Group.
+A Strongly Elevated Area: .....Distribution of the pre-Sinian Basement.

Table 10. Alternating Disposition of Positive and Negative Elements in the Liaotung Peninsula.

−A	+B	−A
	−A	+A
	−B	−A
+B		

When classified and schematized as in Table 10, it is evident that there was a subsiding NW axis as indicated by three minus As. The elevating NE axis through +A, −B and +B crosses the subsiding axis at right angles. When viewed equatorially or meridionally, the positive and negative elements are found to be arranged alternately. They are combined in a checker pattern. More precisely, the northern area can be divided into the western, middle and eastern areas, or the −A, +B and −A elements, by the Wangpashan thrust and the Tientaishan anticline. West of the Chinchia basin there is a moderately subsided area (−B) of Fengningtao and Hsichungtao, while on the east side of the Wafangtien-Pulantien basin there is gneiss terrain (+A).

On the south side of the Yatang line the strongly subsided area (−A) of Chinchou-Sanshihlipu lies in the west and the extensive gneiss terrain (+A) in the east.

Further east is the moderately elevated area (+B) of Pitzuwe-Taichangshantao. On the south side of the above mentioned gneiss terrain there lies the subsided area (−A) of Tangchiakou where the Pyeongan group is encountered. On the south side of the Chinchou-Sanshihlipu area is the Nanshan-Nankuanling area (−B), and to its southwest is the Lüshun or Port Arthur area (+B).

This lineament of the positive and negative elements reveals the total sum of the endogenetic and exogenetic phenomena which have taken place at least since the end of the Palaeozoic era. The amount of erosion differs greatly between the subsided and elevated blocks. Furthermore, the horizontal variation in facies and thickness of the Palaeozoic formation is slight. Therefore it is not difficult to imagine that the Sinian group has been capping the basement to extent, e.g., the gneiss mass east of the Chinchou fault.

It was long thought that the late Mesozoic Taebo disturbance is responsible for the folded structure of the Liaotung peninsula. HORIUCHI, however, pointed out that the base of the Jurassic Wafangtien formation is marked by a strong discordance, where the Jurassic sediments accumulated on the structural basin of the Cambrian formation. It is certain that the quartzites of Tiaoyütai and Chiaotou have resisted against such a compression. In view of the basin structure of these rigid formations on the kratonic mass, it is easy to imagine that the more plastic rocks in the geosynclinal zone have been disturbed more strongly by the same movement.

It is possible that the geosynclinal zone emerged and became a folded mountain range during the Songnim disturbance. The Wafangtien formation is thought to be a lacustrine deposit in the frontal basin of this range. Due to the lack of Mesozoic formations in the peninsular part of Liaotung, the tectonic development of the geosynclinal zone cannot be divided into the Songnim and Taebo phases. The development can be clarified only through the study of tectonics in the Wafangtien basin and by comparison with the geology of the South P'yeongan-do and Hwanghae-do areas in North Korea, which belonged to the same geosyncline. As mentioned earlier, the Songnim disturbance was the principal phase of the crustal movement through which the pre-Songnim formations were strongly folded and thrust. The geologic structure thus produced was further complicated by thrustings and slidings in the Taebo phase.

Judging from the existing structure, a gentle synclinorium and anticlinorium must have been two embryonic folds respectively in the northern and southern parts of the peninsula to the south of the Yatang line. If the southern anticlinorium of the Sinian Sangweon group is compared with that of the Chaeryeong-gang belt, the northern synclinorium corresponds to that comprising the Hwang ju basin and the Chunghwa area in North Korea. In the Liaotung peninsula the synclinorium was asymmetrical, having its subsiding axis in the south upon which the anticlinorium was overturned and developed into a thrusting sheet yielding the Chinchou thrust between them. Later this fundamental structure may have been

deformed, yielding upthrustings and slidings of the Taebo phase, but the destruction by still later faulting was greater in this peninsula.

It is interesting to see that the deformation which the Wafangtien basin has suffered is very similar to what has occurred in the western coal-field of P'yeongyang. The Wafangtien thrusting sheet of the former is comparable with the Kŭmche or the Ch'ebong thrusting sheet of the latter. Likewise, the Kiyang thrust of the latter takes a similar position to the northerly thrusting line of the Yuntaishan *Pseudoklippe* in the former area. The Jurassic and Cambrian formations of the Wafangtien basin were thrust in themselves and folded beneath these thrusting sheets from the two sides, as was the Daedong series of P'yeongyang and Kangseo beneath the similar centripetal thrusting sheets. It may, however, be appropriate to compare the Teoksan thrusting sheet near Samdŭng with the Yuntaishan *Pseudoklippe* which is outlined by the centrifugal thrusts on its two sides. Thus the mode of crustal deformation which the Wafangtien formation suffered before the Pulantien period is essentially the same as that of the Taebo phase in the Daedonggang basin in North Korea.

The series of these thrusts in the two regions are not the dislocations developed from the recumbent foldings but a kind of upthrust or intraformational sliding caused by compressive block movement, although they may take the form of low angled thrusts. Slidings of this kind are seen also along the anticline of Tientaishan where the Tiaoyütai quartzite is thrust up toward the east or west. There are also some *Pseudoklippen*. Farther northwest, as far as the Wangpashan thrust, the Sinian group is dislocated in some places by submeridional thrusts. In North Korea there are some thrusts in a similar trend, the Ap'ari or Suip thrust, for example. There is a tendency for the dislocations of these thrusts in the Lankushan area alternate between east and west and for the quartzite formation to shift up. Therefore these dislocations belong to the same system as the thrusting of the Chiaotou quartzite upon the Cambrian in the Wafangtien area. The dislocation lines of the system are cut by the subequatorial Yatang tectonic line.

Thus, on the north side of the Yatang bay, the embryonic basin structure of the Songnim phase in which there were some sharp foldings was later deformed by the compressive block movement of the Taebo phase. It was astonishingly similar to what has been seen in the P'yeongnam orogenic zone of North Korea.

Along the Yatang line the south side was pushed up toward the north. Although the line to the west of Chientalientao lies concealed below sea-level, the push of the southern side toward the north is clearly indicated by the overturned Ordovician at Taoershan and a similar structure at Yuntaishan in the Hsitao area. It is reasonable to consider that such an upheaval has produced an upthrust toward the south within the Lashushan anticline. These series of block foldings were followed by a tension movement through which strike faults are thought to have come into existence.

This block movement was accompanied by volcanic eruption. The pyroclastic materials accumulated in the Pulantien basin. The Pulantien formation consists

of two cycles of sedimentation, suggesting the rejuvenation of erosion at their transitional interval when the region suffered folding or even tension faulting caused by excessive compression. Thus the Pulantien formation was probably in the making when the late Mesozoic block movement was still going on. It is cut by faults of later ages. In the eastern part of the Kangweondo limestone plateau in South Korea a block movement and related igneous activity took place near the end of the Cretaceous period. Since the late Mesozoic granite is not extensive in the Liaotung peninsula, the block movement may not have been strong.

Generally speaking, the Palaeogene was a tranquil period for Eastern Asia when erosion advanced in Korea and Manchuria. At length the region was levelled to the Yukpaeksan peneplane. Through the Middle Tertiary block movement this plane was displaced. In the Liaotung peninsula the faults in the Sinian trend are more developed than those in the Korean trend, while the reverse is the case in the Daedonggang basin. The Chinchou or Annak faults are respectively the most significant of the former and latter areas. They differ in direction but agree in the low angles of the dislocation planes.

In short, the folded structure of this region, which used to be considered a product of the Taebo disturbance, is not so simple. The tectonic analysis indicates that the fundamental structure which had been established by the Songnim disturbance was to a great extent secondarily modified by the Taebo disturbance. This fundamental architecture started with embryonic domes and basins which were arranged alternately in a checker pattern. In the geosynclinal zone the embryonic fold developed respectively into an anticlinorium and a synclinorium, till at length they became overturned and cut by thrusts. The Songnim disturbance turned the zone into a quasikraton. Together with the kratonic mass in the north it was later deformed by the block folding of the Taebo phase, causing upthrusting and sliding at places. These dislocations occurred in the northern area along various trends, but south of the Yatang bay the upthrust lines run mostly in a direction concordant with the fundamental structures.

IV
The Taitzuho and Yalu Tributaries in South Manchuria and North Korea

1. Introduction

There are many papers dealing with the stratigraphy of this region, in addition to some discussing its geologic structure. Several geological sheet maps and explanatory texts have also been published, but no tectonic synthesis of this region has as yet been attempted.

I have carried out field work in some detail in the Penhsihu and Niuhsintai

basins and the Ch'osan (Sosan) area and have made geologic reconnaissances from Liaotung to Hsiaoshih and from Manp'ojin (Manpochin) to Huch'ang (Kosho). Although these are important areas, my own observations are limited. Moreover, precise descriptions of local geology, published and unpublished, deal only with a small portion of the vast terrain of the two valleys. While the stratigraphy of the Taitzuho or P'yeongan and older formations and rocks is fairly well established, much remains to be studied for the Mesozoic before analyzing this and later movements into phases.

Under these circumstances, the present synthesis cannot help but be preliminary. Nevertheless, intensive studies in some selected areas make it possible to grasp the concept of the regional geology with some accuracy. Therefore it is possible to understand that this geology has characteristics quite distinct from those of the Okch'eon and P'yeongnam zones. The upper Hunchiang and middle Yalu tributaries provide typical examples of kratonic fragmentation, while the Taitzuho river district is an excellent example of quasikratonic deformation.

2. Stratigraphy

From the tectogenetic standpoint the rocks and formations of the Taitzuho zone can be classified into the following three groups:—

A. Pre-Hsiho basement complex.
B. Hsiho series, Korean group and Taitzuho group, all deformed by Mesozoic disturbances.
C. Mesozoic and later sediments and igneous rocks.

a. Pre-Hsiho Basement Complex.

Ancient schists and gneiss are mostly distributed on the north and south sides of basins along the Taitzuho valley. On the south side there is the Liaoho group composed of metamorphic rocks of sedimentary origin. Its sequence with the carbonate facies in the middle part reveals a grand cycle of sedimentation, attaining several thousand meters in total thickness. The Anshan series composed of sericite-schist, quartz-schist, actinolite-schist and so forth, overlies the granites and metamorphics and is intruded by the Kungchangling granite. The field relation between the Anshan and Liaoho formations has not yet been determined. The Shoushan formation, which IMAMURA (1940) considered to occupy the upper part of the Anshan series, consists of tuffaceous sandstone, tuffaceous shale and quartz-trachyte and is overlain unconformably by the Hsiho series.

b. Hsiho Series.

This is divisible into Tiaoyütai quartzite, Nanfen shale and marl and Chiaotou quartzite in ascending order.

(1) The Tiaoyütai quartzite is light brown, gray or white in color and is occasionally conglomeratic near the base. *Dreikanters* are found in the basal conglomerate near Anshan, and hematite layers are contained locally. The thickness of the quartzite varies from 3 to 250 m.

(2) The Nanfen shale and marl formation is 50 to 250 m thick; marl is developed in the lower part whereas shale is common in the upper part.

(3) The Chiaotou quartzite formation comprises some shale and marl and measures more than 250 m at the thickest.

The total thickness of the Hsiho series is 600 m or less in the Taitzuho valley, but the series becomes thicker in the Hunchiang tributary, measuring 1,000 to 2,000 m between the Linchiang and Tzuchengchiang rivers. Near Luohanku, east of Liaoyang, there is a clean-cut river-cliff for a long distance showing that the Chiaotou quartzite is overlain para-unconformably by the Lower Cambrian series. There the contact of the basal conglomeratic sandstone of the Lower Cambrian cuts the banded quartzite beds of the Chiaotou formation with a ratio of 1 to 2 m in a distance of about 1 km.

c. Korean Group.

In the Cambrian system a quartzose sandstone layer of less than 30 meters' thickness is occasionally found near the base. The base is often conglomeratic. Shale, however, is the leading member of the Lower Cambrian series, and limestone is intercalated with it. The Middle Cambrian is built up mostly of limestone, but contains a moderate amount of shale in the lower part; reddish brown sandstone is frequently found in the basal part, and marl occurs occasionally at the top of the series. Platy limestone and intraformational limestone conglomerate are well developed in the Upper Cambrian, but variegated shale or marl is intercalated in its lower and middle parts at places. The thickness of the Cambrian system is about 600 m on the average, but this of course varies to a certain extent.

Table 11. Sequence of the Pre-Song'nim Strata, about 2,000 m thick, in the Taitzuho Valley.

Taitzuho Group About 800 m thick	Permian	Tsaichia Series, 440 m thick
		Lioutang Series, 170 m thick Huangchi Series, 70 m thick
	Moscovian	Penchi Series, 100–120 m thick
Korean Group About 1,000 m thick		Ordovician Formation, 500–700 m thick Cambrian Formation, 600 m thick
Sinian Hsiho Series Less than 600 m		Chiaotou Quartzite, over 250 m thick Nanfen Shale and Marl, 50–250 m thick Tiaoyütai Quartzite, less than 250 m thick

The base of the Ordovician system is marked off by the *Cryptozoon* limestone in many places. Dolomite is common in the lower or Wanwanian series. The larger part of the middle or Wolungian series is occupied by massive limestone, often with patches of chert or flint. Massive limestone is also common in the upper or

Toufangian series, but bedded limestone is not uncommon. Dolomitic spots are frequently seen on them. Limestone conglomerate or so-called *Wurmkalk* is sometimes seen at the base of the Toufangian. The total thickness of the three series is estimated at about 500 to 700 m.

d. Taitzuho Group.

The notable differences between the group in the Taitzuho area and the P'yeongan group of the P'yeongnam and Okch'eon geosynclines are that the limestone occurrences are restricted to the Penchi series and coal measures are intercalated in the Taitzuho area. Fire clay is found in the group at many horizons; the Nogam series is absent. In the Taitzuho area the Taitzuho group is classified into the Penchi, Huangchi, Lioutang and Tsaichia series.

(1) The *Penchi series* lies on the Ordovician, in most places para-unconformably, but in the Hsiaoshih coal-field it is in clino-unconformable relation, indicating the *Hsiaoshih movement*. It is generally 100 to 120 m thick, but attains a thickness of 270 m in the east. It is composed of reddish rocks in the west, but of black shale and gray sandstone in the east; round quartzite pebbles are contained in the basal conglomerate; some limestone lenses or layers and coal measures are found intercalated in most sections.

(2) The base of the *Huangchi series* is generally demarcated by a disconformity, but the clino-unconformity of the *Nanpiao phase* is known in the Hsiaoshih coal-field. This series, about 70 m thick, is the principal coal-bearing series; black and gray colors prevail. It always exists in the western basins, but may be absent in the eastern areas.

(3) The *Lioutang series*, which overlies the preceding conformably, is the upper coal-bearing series, about 170 m thick. In the Hunchiang tributary it is mostly composed of light gray, coarse sandstone.

(4) The *Tsaichia series* is a thicker formation, comprising about 440 m of quartzose sandstone and variegated shale. It appears to lie conformably on the Lioutang, but at some places in the Yentai basin as well as in the Hsiaoshih basin they are in clino-unconformable contact. In the Penhsihu basin the conglomerate of 130 m thickness in the lower part lies disconformably on the Lioutang. In the Hunchang tributary at the top of the series there is false-bedded reddish sandstone, over 300 m thick, a possible equivalent of the Tsaichia series.

In summary it can be said that the Taitzuho group is about 800 m thick in the west, but in the east, where the Huangchi may be missing, it is about 500 m thick.

The Hsiho, Korean and Taitzuho formations altogether give some 2,000 m for the thickness, which is quite thin compared to the pre-Songnim sediments in the P'yeongnam or Okcheon geosyncline.

e. Mesozoic and Later Formations.

A lengthy description of the Mesozoic is given here, because this knowledge is indispensable for any analysis of the tectonic development of this region. According to KOBATAKE (1942), the Mesozoic sequence in the Tienshuaifukou basin is, in descending order, as follows:

(d) Sankeiling cliff-making conglomerate, over 1,000 m thick, containing rounded boulders with diameters averaging 10 cm, or 20 cm at the largest, mostly of quartzite and green siliceous rock, in addition to some black shale, sandstone and quartz-porphyry.

..... Unconformity .....

(c) Tapu coal-bearing formation, over 200 m thick, composed of alternating shale and sandstone in which syenitic porphyrite sheets of various magnitudes are inserted.
(b) Chuanshantzu conglomerate, over 100 m thick, containing unsorted boulders of quartzite and greenish gray siliceous rock; alternation between shale and false-bedded sandstone found in the central and southern parts.
..... Para-unconformity .....
(a) Changliangtzu alternation of black shale and gray micaceous shale, containing subangular pebbles of dark and siliceous rocks; basal sliding often occurs on the Taitzuho or Ordovician formation.

According to SUGAI, the Changliangtzu shale lies on the Ordovician limestone with strong discordance in the eastern part of this basin. All except the Sankeiling conglomerate yield plants. The Chuanshantzu plants and Estherians show some alliance to the Daedong fossils. KOBATAKE collected *Hausmannia* sp. from the Changliangtzu (?) shale west of Yangchikou, 8 km east of Chienchang.

In the Saimaki coal-field the Jurassic coal-bearing formation, more than 1,500 m thick, lies on the Korean group clino-unconformably. According to SUGAI (1942), its sequence is as follows:

I.	Upper coal-bearing formation.	
	Fangniukou sandstone and conglomerate	600 m
	Panchiahsikou coal measures	—650 m
II.	Middle coal-bearing formation	
	Hsinkailing shale	—700 m
	Chuchuankou coal measures	—600 m
	Tientingshan conglomerate	—400 m
III.	Lower coal-bearing formation	
	Hsiaokushantzu coal measures	—200 m
	Changshantzu trachytes	

These conglomerates are all alike; round boulders of fist-size to man's-head-size are most common; some boulders are granitic. The plants which YOKOYAMA (1906) has described were procured from the Hsiaokushantzu coal measures, which are most productive in the southern part of the basin. The three coal measures are all rich in Jurassic plants and common members are *Cladophlebis haiburnensis*, *Coniopteris burensis*, *Elatocladus manchuricus*, and *Neocalamites hoerensis*.

The coal-bearing formations constitute an anticline and two synclines, all having equatorial axes and cut by numerous faults. The most important of these are a hinge fault running from NNW to SSE through the center of the basin and a low angle thrust near its northern margin, along which the pre-Cambrian quartzite rides over the Hsiaokushantzu coal-measures, and the Tientingshan conglomerate, as well as the Korean group on the north side.

Subsequent to this disturbance there took place a primary intrusion of granite. This was followed by an eruption of andesite, presumably in the early Cretaceous period, because *Sphenopteris goepperti* (?) was found in greenish gray sandy tuff in the lower part of the andesite series. Finally, an invasion of granitic magma took place on a large scale. This intrusion may be referable to the late Mesozoic Pulguksa igneous activity.

Table 12. Tentative Correlation of the Mesozoic Formations in the Taitzuho and Yalu-Hunchang Tributaries.

Age		Penhsihu	Tienshuaifukou	Saimaki	Sinŭiju	Tunghua	Fusung	Chungangjin	Series
Cretaceous	Upper	Linchia Cg.	Sankeiling Cg.	Andesite		Tuffaceons ss.	Kutsangkou		Pulguksa
	Middle	Tayü							Silla
	Lower	Penhsihu							Naktong
Malm			Tapu	Upper Coal	Ŭiju	Chienshankou			Jehol
Dogger			Chuangshantzu	Middle Coal		Sanchatzu			
Lias-Up. Trias			Changliangtzu	Lower Coal	Ch'eog-seongjin			Chungangjin	Daedong,

In the vicinity of Penhsihu the Mesozoic formations are distributed on the two sides of the Taitzuho river and around Chiashan, east of Penhsihu. The Penhsihu (Honkeiko) and Linchia formations in the west form a gentle structural basin, steeply inclined near the western margin.

The Penhsihu formation overlies the Taitzuho group unconformably. Its lower 69 to 100 meters are represented by red conglomerate containing various rocks derived from the Taitzuho and older sedimentaries and pre-Hsiho metamorphics, in addition to pyroxene andesite, hornblende porphyrite, diabase and other igneous rocks. They vary in rounding and size to a great extent, the largest boulder being 50 cm in diameter; shaly layers are sometimes intercalated in the basal part. The upper Penhsihu, 300 to 500 m thick, consists of red shale and sandstone, partly tuffaceous or conglomeratic; false-bedding is common.

The Linchia formation, about 50 to 80 m thick, lies on the preceding with erosion unconformity; the facies is easily changeable. The lower part is a conglomerate bed containing large boulders of quartzite, 50 cm across; the upper part consists of alternating beds of quartzose conglomerate, sandstone and vari-colored shale; quartzite, gneiss, sandstone and volcanic rocks less than 5 cm in diameter are also contained in the conglomerate.

Cut by a fault in the Chiashan area, the base of the Miyanohara or Tayü formation is unexposed. Its lower part is composed of variegated sandstone, breccia, and conglomerate. Some pebbles resemble the Taling granite and others look like Nanfen marl. In addition, limestone, quartzite, effusive rocks, vein-quartz and others are found. The middle part is mostly yellowish red tuffaceous sandstone. The upper part consists of tuff, tuffaceous conglomerate and some lava flows, the lowest of which is metabasaltic andesite, the next, meta-andesite, and the third, dacite; the uppermost flow is quartz-trachyte. Thus the change from basic to acidic can hardly be overlooked. The formation strikes N 20°–30° E and dips about 50 degrees to the southeast. The other side is brecciated along the boundary fault.

The Tayü formation in the eastern area forms a structural basin with Kaolifenchu at its center. This formation is intruded by liparite and andesite and is thrust by the metamorphic rocks on the south side of the basin. Although the base is unexposed, it is more than 2,500 m in thickness and its facies variation great. The leading component is red or vari-colored tuffaceous shale, but there are numerous intercalations of sandstone conglomerate, limestone conglomerate, breccia and lapilli-tuff.

The mutual relation among the strata in the three areas is at present unclear. Those in the eastern and Chiashan areas, however, are grouped here in the Tayü formation because they are products of violent volcanic eruptions. SHIMAKURA (1937) identified a fossil wood from the western slope of Chiashan with *Pinoxylon dakotensis* KNOWLTON. Because of its occurrence, INAI (1936) emphasized that its age must be somewhere between Lower Cretaceous and Middle Jurassic.

According to YABE and S. ENDO (1937), *Salvinia* sp. collected at Tayüpaotzu

suggests that the upper Tayü formation is not older than Late Cretaceous. The occurrence of *Plicatounio naktongensis manchuricus* and *Nakamuranaia chinshanensis* in the Mesozoic of Penhsihu has been reported by SUZUKI (1949). Although their exact locality is unknown, it is probable that they were presumably procured from a point 1 km southeast of Hsiwanfen in the Tayü formation. The former pelecypod is known from the Pulantien area and the Yingpan area, east of Fushun. Judging from these fossils the Tayü formation is perhaps Cretaceous in age. The Tayü and Penhsihu formaion represent probably two different parts of the same formation, because they are similar in lithology and structure, although the Tayü contains much more volcanic material than the Penhsihu formation. While the base of the former is unknown, the latter overlies the Taitzuho group unconformably. Therefore it is reasonable to locate the former above the latter.

The change from basic to acidic rock seen in the Chiashan area suggests that the Tayü volcanism corresponds to that of the Silla-Pulguksa series in South Korea. In weighing all of these facts, I am led to the contention that the Penhsihu formation is an approximate correlative of the Naktong series rather than the Jehol series. The Linchia formation lying horizontally on the Penhsihu is the youngest, but still not far removed from the end of the crustal disturbance, as can be judged from its boulder conglomerate. Therefore its age may be late Cretaceous.

At Tungshan, northeast of Hsiaoshih, there is a conglomerate formation, about 50 m thick, in which thin sandstone beds are intercalated. In the conglomerate, rounded or subangular quartzite and other siliceous rocks are cemented by red tuffaceous sandy material; limestone or gneiss pebbles are absent. From its lithology it appears to be a link between the Linchia conglomerate on the west and Sankeiling conglomerate on the east side.

In the upper Hunchiang tributaries east of Huanjen there is a thick vari-colored formation, 1,000 m or thicker, composed of tuffaceous sandstone and shale, tuff agglomerate and breccia containing andesite blocks. Near Pataochiang the Chienshankou coal-bearing strata are unconformably overlain by tuffaceous sandstone and shale. Another formation built up of tuff lies on the Taitzuho group unconformably, but its relation to the coal-bearing strata is undetermined.

Euestheria cfr. *middendorifii* occurs at Huanjen, Yushuchuan near Tunghua and at Sanchatzu, northeast of Tunghua, but the specimens are not preserved well enough to make specific identification. The Mesozoic formation of Kutsangkou can be divided into two parts. Estherians from its lower part bears Neo-Cretaceous aspects (KOBAYASHI and KUSUMI, 1953).

Southwest of Chunggangjin on the middle Yalu river there is a Mesozoic formation, over 1,000 m thick, which overlies the Korean group unconformably. It is composed of conglomerate, sandstone and shale, in addition to coal-seams. Quartzite is common in the conglomerate; its boulders attain a maximum diameter of 60 cm.

Near Sinŭiju on the lower Yalu there is the Cheongseongjin (Seijochin) clay-

slate formation yielding plants of the Daedong (Daido) flora, but its base is unknown. It is overlain unconformably by another Mesozoic formation which consists of the Cheongjudong (Seishudo) conglomerate (600 m), the Paekt'odong (Hakudodo) tuffaceous shale (420 m), and the Yeondaedong (Yendaido) sandstone and conglomeratic sandstone (170 m) in ascending order. The lower conglomerate is rich in porphyrite boulders, but the largest boulder, 1 m across, is a well rounded granitic gneiss. The middle shale yields Estherians and *Lycoptera* typical of the Jehol fauna. Thin coal seams are interbedded with the upper sandstone.

Overlying the gneiss complex is a monoclinal Mesozoic formation near Kanggye which commences with a basal conglomerate, 150–180 m thick. Above it black shale, 300–500 m thick, white sandstone and conglomerate, 150–250 m thick, and black and green shales, over 100 m thick, are accumulated one after another in the order named. In the northern part there are andesite tuff and lava flows below the basal conglomerate. TAKAHASHI (1953) correlated the sequence with that of the Jehol series near Sinŭiju, but no fossil has been found at Kanggye.

Judging from the plants the Cheongseongjin clayslate of Sinŭiju, the Mesozoic of Chunggangjin, the coal-bearing or the lower sediments of Saimaki, and the Changliangtzu shale of Tienshuaifukou belong to the Daedong series, from Lower Jurassic to Upper Triassic in age.

It is certain that the Jehol series of Sinŭiju is Middle and Upper Jurassic. It is probable that the Chienshankou coal-bearing formation of Pataochiang and the Tapu coal-bearing formation and the Chuanshantzu conglomerate of Tienshuaifukou belong to the Jehol series rather than the Daedong.

There is no Tertiary in the Taitzuho and the Yalu-Hunchiang tributaries, but north of the Taitzuho zone there is the Oligocene Fushun series which is in thrust contact with the basement block on the north northwest side. At Inpan east of Fushun is the Cretaceous formation which yielded *Plicatounio*

f. Igneous Rocks.

Andesite, liparite and granitic rocks which intrude these effusives are widely distributed in the Hunchiang tributary, while the distribution of volcanic rocks is extremely small in the Taitzuho basins. As mentioned earlier, volcanic and pyroclastic rocks are intercalated in certain Mesozoic formations. The change of volcanism from basaltic andesite to acidic rock is shown in the sequence of the Tayü formation.

Granitic rocks intruded south of the Hsiaoshih and Tienshuaifukou coal-fields after the folding but before the faulting. West of Huolienchai the Taling granite is intruded into the Cambrian. It may be a product of the same intrusion as the south Hsiaoshih mass, because no Palaeozoic or older Mesozoic granite is known in South Manchuria.

3. The Taitzuho Valley

In this valley are the Yentai-Liaoyang, Penhsihu-Niuhsintai, Hsiaoshih-Tienshuaifukou and other basins aligned from west to east. They are not only topographical but also structural basins, having the Taitzuho or Mesozoic formation at the center. South of this principal chain of basins are the Saimaki basin and a few other sedimentary patches. The principal and auxiliary zones are set off by late Mesozoic granitic rocks, but some sedimentary roof-pendants show that the two zones belong to the same depression. On the north and south side of the principal zone is an extensive display of the pre-Hsiho gneiss and metamorphic rocks respectively.

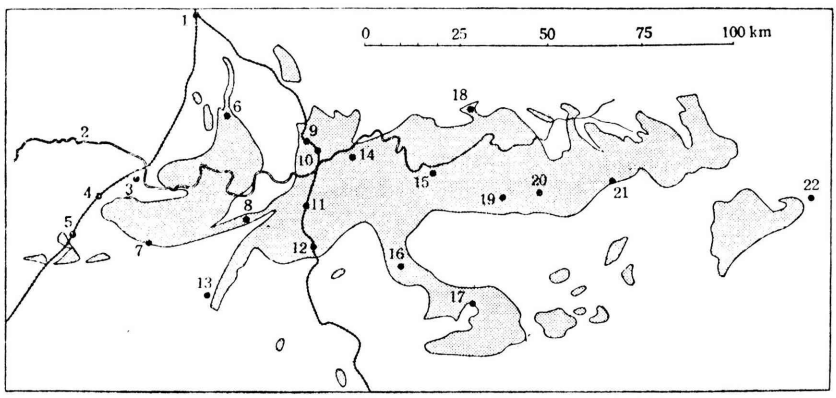


Fig. 22. Distribution of the Hsiho, Korean and Taitzuho Groups in the Taitzuho Valley (after AOJI, HATA et al).

1. Suchiatun
2. Taitzuho
3. Liaoyang
4. Shoushan
5. Anshan
6. Yentai
7. Shangshantzu
8. Hanpeling
9. Huolienchai
10. Penhsihu
11. Chiaotou
12. Nanfen
13. Helankou
14. Niuhsintai
15. Hsiaoshih
16. Tsaohetang
17. Saimaki
18. Chinghecheng
19. Tienshuaifukou
20. Chienchang
21. Szupingkai
22. Huanjen

These basins are not simple basins, however, because their original structure was considerably modified by later movements. The rigid basement was broken into pieces by compression, and the pieces were in turn wedged into the chain of sedimentary basins from the north or south. Further complications were made by the faulting and granitic invasion.

a. Penhsihu-Niuhsintai Basin (see Geological Map IV, Profiles Vb. 5–10). This area is bisected into the Penhsihu and Niuhsintai basins by the northwest

trending Shihchiaotzu fault (e in Fig. 23). The Penhsihu basin has a triangular outline. It is cut by a series of thrusts of Hsintungkou on the west side and by the Pingtingshan upthrust on the south side. In its northern part there is a monocline of the Hsiho series, 230 m thick, which strikes in the NW direction. It is overlain by the Cambrian system, 200 m thick, but syenite dykes or sheets are frequently encountered near the base. The Taling granite intrudes the Middle Cambrian and older formations in the northernmost part. The Ordovician is gently folded and overlain disconformably by the Taitzuho group. Both are sharply bent toward the southwest at the western end. The Honkeiko (Penhsihu) formation on the Taitzuho is also steeply inclined to the east along its western margin, and near Linchiasueitzu is overlain by the horizontal Linchia formation.

This flexure develops into the pre-Hsintungkou upthrust. Behind it is the Hsintungkou thrust (g in Fig. 23), west of which gneiss and granite are exposed extensively. In addition there are some patches of the Anshan series, and also the Hsiho series and the Korean group on the basement complex. The main Hsintungkou thrust along the eastern margin of this rigid mass runs slightly east of north and its branches cut into the mass. As a whole they form a series of imbricated scales. The Hsiho and Korean formations on the basement complex of these scales still maintain the original NW strike on the northern side, but become parallel to the principal thrust on the other side.

YOSHIMURA (1941) noted that the primary tectonic line was a simple thrust which developed secondarily into a series of scales, yielding cracks in the mass. In the course of this imbrication the flexure of the Taitzuho and older formations had increased along the line till at length their strike became parallel to it. In the southern part the Cambrian is thrust upon the Taitzuho group. The western block was later elevated again and pushed upon the basin on the east side, yielding the pre-Hsintungkou upthrust. As a result the Taitzuho group became vertical or even overturned.

Near this upthrust the Penhsihu formation dips 60 to 80 degrees to the east, but soon becomes as gentle as 10 to 15 degrees near the center of the basin.

The Linchia formation lies on the eroded surface of the Penhsihu formation. The leading component of its basal conglomerate is large boulders of quartzite which were evidently derived immediately after the upthrusting from the Tiaoyütai quartzite and Chiaotou quartzite of the western block. The conglomerate is a kind of fanglomerate or deltaic sediment which expanded eastward into the lake. The lacustrine sediment on the conglomerate contains various kinds of rocks, supplied from a greater drainage in mountains of lessened relief and altitude.

The pre-Hsintungkou upthrust is cut at right angles by some faults. The Penhsihu basin is cut diagonally by the Minshankou fault (f in Fig. 23), the downthrow of which is on the southeast side. There the Tayü formation is distributed and is delimited by the Pingtingshan upthrust (h in Fig. 23) from the south. The fault plane dips about 50 degrees toward the southeast and the formation is intruded by quartz-trachyte and quartz-porphyry of the Chiashan area.

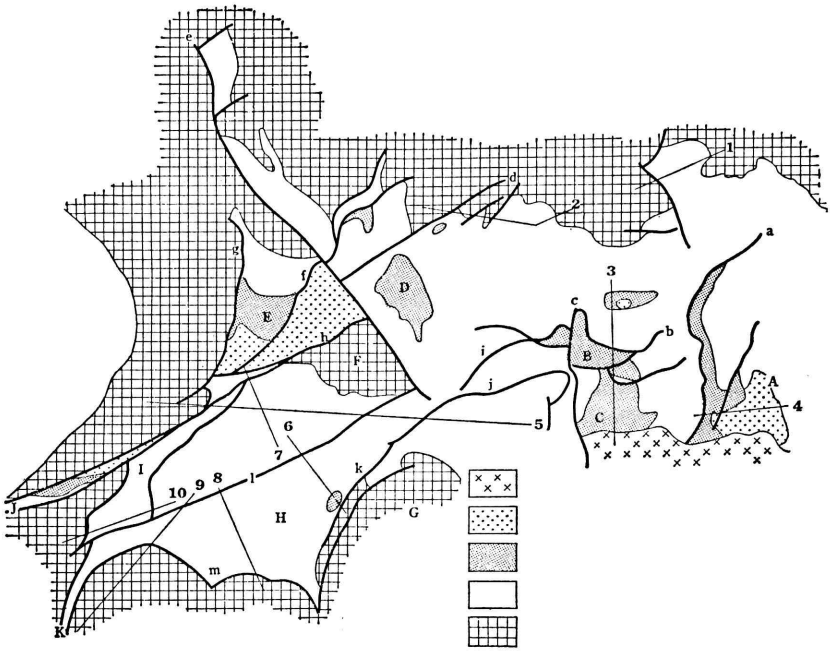


Fig. 23. Tectonic Map of the Middle Taitzuho Valley. See Figs. 24, 25, 29, and 30 for Profiles 7, 6, 3 and 4 and Geol. Map IV and Profile Vb for Profiles 1, 2, 5, 8, 9 and 10 (KOBAYASHI, KOBATAKE, MORISHITA, YOSHIMURA, et al).

A. Tienshuaifukou Basin
B. Hsiaoshih Basin
C. Shanchengkou Basin
D. Niuhsintai Basin
E. Penhsihu Basin
F. Pingtingshan Block
G. Miaoerkou Block
H. Nanfen Area
I. Achiakou Graben
J. Hanpeling Graben
K. Helankou Graben.

a. Papanling Thrust.
b. Yaopao Thrust
c. Hsiaoshih Fault
d. Pienlingpaotzu Thrust
e. Shihchiaotzu Fault
f. Minshankou Fault
g. Hsintungkou Thrust
h. Pingtingshan Thrust
i. Pichiakou Thrust
j. Linchiapaotzu Thrust
k. Miaoerkou Thrust
l. Tiaoyütai Thrust
m. Nanfen Thrust.

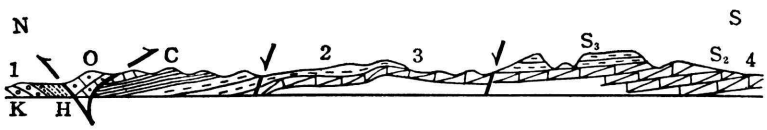


Fig. 24. Profile through the Pingtingshan Block (after MORISHITA), (7 in Fig. 23).

K. Tayii Formation
H. Taitzuho Group
O. Ordovician Formation
C. Cambrian Formation
S_2. Chiaotou Quartzite
S_3. Nanfen Shale and Marl
1. Taitzuho River
2. Fuchinling
3. Chiachiakou
4. Hsiho River

There are strips of the Huangchi series at Tuanshantzu and between Chinfukou and Yaopao along the southern periphery of the Penhsihu basin. It is thrust by the Toufangian series on the south side and the Toufangian in turn is thrust again by the southern mass along the Pingtingshan tectonic line. In the eastern part of this shattered zone there are also the Huangchi and Cambrian rocks, between the Tayü formation and the metamorphic rocks of Pingtingshan. These strips are all by-products of the Pingtingshan upthrust by which the Taitzuho and Korean groups of the Penhsihu basin were sharply bent up and broken.

The Niuhsintai basin northeast of the Shihchiaotzu fault is divided into two parts by the Pienlingpaotzu tectonic line along the Taitzuho river. The southern half-basin is not much deformed, while the destruction of its counterpart is great.

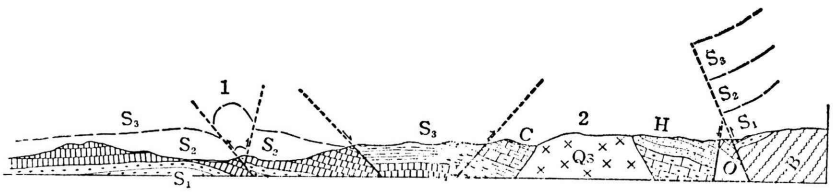


Fig. 25. Profile of the Nanfen Area (after YOSHIKAWA), (6 in Fig. 23).

Qs. Quartz Syenite
H. Taitzuho Group
O. Ordvician Formation
C. Cambrian Formation
S_3. Chiaotou Quartzite
S_2. Nanfen Shale and Marl
S_1. Tiaoyütai Quartzite
B. Basement Complex
1. Santaohetzu
2. Shanchengtzu

In the southern half the major axis of the Niuhsintai brachy-syncline is represented by the hills south of Hunglienkou. Its southwest side is undulating and is inclined steeply, but the other limb is inclined gently. Thus the structure is asymmetrical, and cut by faults in the NW, NE and other directions. The Tsaichia series lies near Shangniuhsintai. The southern margin of the basin is marked by thrusts from the south.

On the north side of the Taitzuho river, the original basin is strongly deformed by thrusting and faulting. Starting from the north, there is a tectonic line extending northeast from Lichiawepeng along which the gneiss complex, capped by the Hsiho series, is thrust toward the southeast. In front of it is a parallel thrust. The thrust sheet in this interval is composed of the Hsiho and younger formations, the youngest of which is the Taitzuho group at Hueishan at the southwestern terminus. On the southeast side is a broad syncline, which is, however, bisected by a tectonic line through Shueiyükou, and the west side is the Taitzuho group which forms a wedge near Yaotzuyü.

Starting from the west end of this northern basin a long syncline of the Hsiho and Korean formations extends to the northwest along the Shihchiaotzu fault as far as Kantaijentun, although it is cut by some NE faults. The Pingtingshan block wedges in between the Niuhsintai and Penhsihu basins from the south side. The

basement complex is exposed extensively in its northern part where the Pingtingshan upthrust and the Shihchiaotzu fault meet at right angles. Because this is a tilted block, it is covered by the blanket formations in the west. The Hsiho series is a gentle monocline, but the Cambrian is moderately undulating with the axes varying from N to NW. Further west the Ordovician is folded to form the graben of Achiakou extending from NE to SW.

The southeast side of the block is limited by the Tiaoyütai upthrust (1 in Fig. 23), which is parallel to the Pingtingshan upthrust. The Nanfen area on the south side is largely occupied by the Hsiho series. There the Taitzuho group is restricted to a small area of Tahuangpaiyü in the east where it lies on the Ordovician. The basement complex in the southeast is pushed up at a steep angle toward the north along the Miaoerkou upthrust. The Hsiho and later formations between this and the Tiaoyütai tectonic line are complicated by thrusts of various directions. Some of them having a WNW trend as well as some others having a NE trend are thrust also toward the south; others having a NE strike are thrusts toward the north. The three kinds of thrusts are each represented by 3 or 4 thrust lines.

In the western part of this area, the southern basement complex is thrust up toward the north. This is the Nanfen upthrust (m in Fig. 23) which describes two large arcs.

The structure at the southwest corner of the Penhsihu basin is rather perplexing.

The granite gneiss of Peitaikou, capped by the Tiaoyütai quartzite, rides over the Cambrian with a low angle at the corner and a *Klippe* lies in front of the thrust. The Achiakou graben is sunken between this granitized mass and the Pingtingshan block. It is occupied by the Ordovician as far as the Hsiho river, but the Cambrian is exposed farther west and at length the Lower Cambrian is thrust by the Hsiho series. This tectonic line extends to the south from Huangchiapaotzu, taking an undulating course.

The Hsiho and the Middle and Lower Cambrian occupy a trapezoidal area which is delimited by the Tiaoyütai thrust on the south side and the Chioukeyü thrust on the northwest. The Chioukeyü thrust is indicated by a thrusting of the granitic block upon this folded area. The granite is covered by the Tiaoyütai quartzite near the eastern margin of the block. Besides the main Chioukeyü thrust there is an auxiliary one on each side. At the northeast corner black schists of the Liaoho group are thrust toward the southwest.

The Chioukeyü thrust, though displaced by the Tiaoyütai thrust, extends southwestward for about 20 km. A narrow straight graben of the Hsiho series between this and the arcuate Nanfen thrust is traceable through the metamorphosed region as far as Helankou (13 in Fig. 22).

Another remarkable graben runs between the granitized masses from ENE to WSW through Hanpeling (8 in Fig. 22). The Ordovician and Taitzuho formations are exposed respectively in its western and eastern part. Also in the eastern part there are porphyrite and tuff which from their lithic aspect may be referred to the Tayü formation. Near the western end, the northern granite mass is overlain by

the Tiaoyütai quartzite of the large Liaoyang-Yentai basin. The Hanpeling shattered zone between the basin and the southern block describes an arc convex to the southeast. Combined with the Hsintungkou tectonic line this zone outlines the large basin and its eastern block.

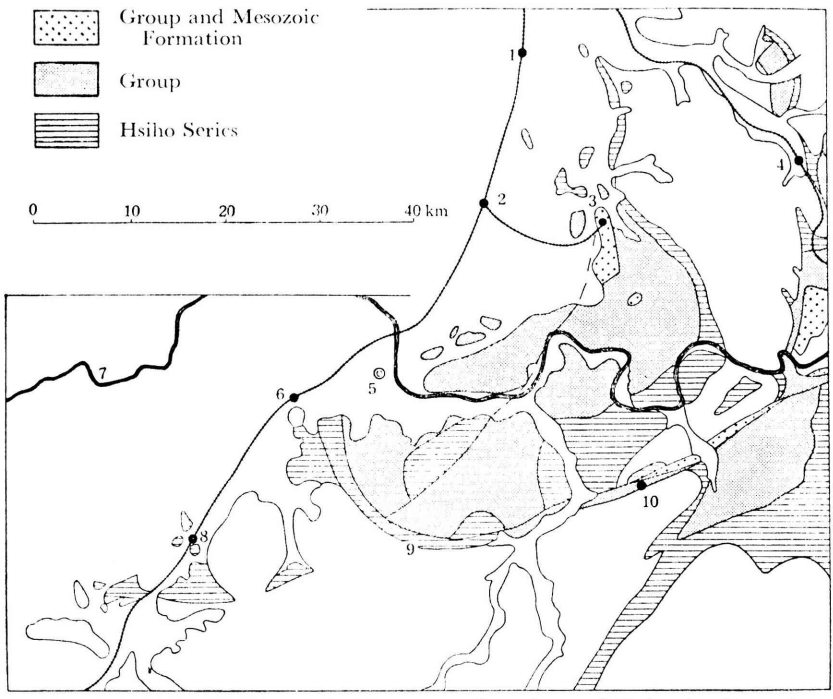


Fig. 26. Distribution of the Rakuroan Complex and Taitzuho Group in the Yentai Basin and its Vicinities (after Aoji and Hata).

1. Shahe,
3. Yentai Station
3. Yentai Coal-Field
4. Shihchiaotzu
5. Liaoyang
6. Shoushan
7. Taitzuho
8. Anshan
9. Shangshantzu
10. Hanpeling

b. Liaoyang-Yentai Basin.

This basin is not as deformed as the preceding. The unconformity between the horizontal Tiaoyütai quartzite and the steeply inclined Liaoho schists seen at Shenwe on the Taitzuho river is such a significant aspect that *Shenwe* was proposed for the pre-Tiaoyütai disturbance. The sequence above the quartzite is simple and regular. The Hsiho series is followed by the Cambrian, and then comes the Ordovician. At length one reaches the Taitzuho group of Yentai.

Near the Yentai coal-field there are some faults with different trends. The southern boundary of the Yentai coal basin is drawn by a ENE fault. At Kangyao, to the southeast beyond the fault, there is a small basin of the Taitzuho group.

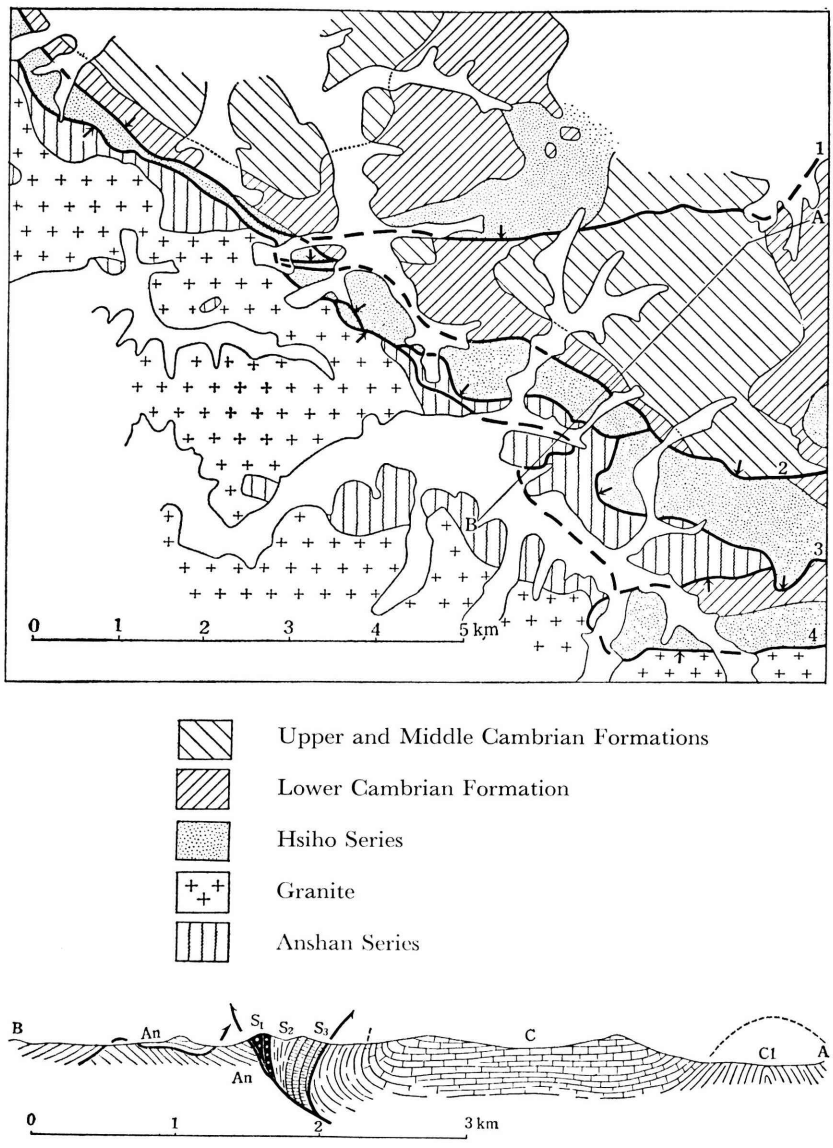


Fig. 27. Geological Map and Profile of the Shangshantzu Area (after SAWATA).

1. Shueichuanstzu Thrust
2. Yatzukou Thrust
3. Weichiakou Thrust
4. Shangshantzu Thrust

C. Upper and Middle Cambrian Formations
Cl. Lower Cambrian Formation
S_3. Chaiotou Quartzite
S_2. Nanfen Shale and Marl
S_1. Taioyütai Quartzite
An. Anshan Series

Most important is the median tectonic line which bisects the Liaoyang-Yentai basin. It runs through the lowland west of Yentai toward Shangshantzu (9 in Fig. 26). To the east of Shahe station on the Shenyang-Talien railway line is a narrow

hill of gneiss. This, together with the eastern gneiss, forms an acute angle where the Yentai-Liaoyang basin is pointed. The southeastern outline of the basin, on the other hand, is broadly arcuate, but as mentioned earlier, there is a shattered peripheral zone due to the Hsintungkou thrust and the Hanpeling graben, which are aligned en échelon. The Ordovician formation in the graben is traceable westward as far as Tangheyen.

Near Shangshantzu in the southwestern part of the basin (SAWATA, 1942) the concentric disposition of the Cambrian and Hsiho formations is strongly disturbed by the Shueichüantzu, Yatzukou and Weichiakou thrusts, which diverge eastward. The north side is repeatedly thrust upon the other along these tectonic lines. The Anshan series and Kungchangling granite on the southern block resisted this movement, but at length they were thrust northward along the Shangshantzu tectonic line, which is generally high-angled, but is low-angled near Shangshantzu. The Shueichüantzu thrust appears to be a part of the median tectonic line diagonally across the Yentai basin, although its whole length has not yet been traced.

The Yatzukou and Shangshantzu thrusts face each other. The graben between them indicates the western extension of the Hanpeling graben. The Hsiho series is strongly contorted in the graben, yielding some diagonal thrustings. A shattered zone lies between the northern basin and the southern block. The Korean group is extensive on the northeast side, whereas the Hsiho series is exposed only along saddles of anticlines.

West of Shangshantzu is an unsurveyed area. In the Anshan-Shoushan area further west (IMAMURA, 1941), the Cambrian, Hsiho and Shoushan-Anshan formations are distributed around the eastern granitic mass. On the south side these formations imbricate toward the southern granite mass.

c. Hsiaoshih-Tienshuaifukou Basin (see Geol. Map IV and Profile Vb 1–4)

To the northwest of the aforementioned Pienling thrust is an extensive display of granite or gneiss. On the other side there are also some thrusts. It is a common habit for the northern mass to thrust upon the south side. Some additional faults have a NW or other trend. At Pienlingpaotzu at the western end of this imbrication is a small Taitzuho exposure.

With respect to the geology of Chinghecheng, YOSHIMURA (1941) mentions that "the Hsiho series and the Cambrian system form a syncline with a NW trending axis, having Tungtataishan, south of Chinghecheng, at its center. Thrust by a granite mass, its western limb is steeply inclined, whereas the eastern one dips gently at 30 degrees or so. Its northern margin is also limited by a thrust. Near Machiakou in the south, the Hsiho series strikes almost equatorially and dips southerly. It is cut by two strike faults. The western end of this faulted zone is cut by a thrust which runs through the west side of Tungtataishan. Cut by equatorial thrusts, the Tiaoyütai quartzite near Mengchiapaotzu, southwest of Chinghecheng, forms narrow belts which are truncated at the western end by a fault in the NNW to SSE direction. Another fault in a similar trend is found in the west of

Hsikou. The Hsiho and Lower Cambrian formations are strongly disturbed in a wedge between these two faults."

South of this area is the Tungshan basin, through which the Taitzuho river flows. The Taitzuho group is at its center, and the main synclinal axis runs from NE to SW. The Tungshan thrust lies on the southeast side, along which the Ordovician and Taitzuho formations are thrust upon the Ordovician. In the west the Taitzuho group slips upon the Ordovician. They are dislocated further by minor NW faults. The Taitzuho group is capped by the Linchia conglomerate in the eastern sunken block.

Southwest of Tungshan there is the Hsiaoshih basin, where the Taitzuho group forms a synclinal basin with its main axis trending WNW. In the Shanchengkou basin to the south, however, the axis of folding is equatorial. In addition to this principal folding there are some rectangular undulations. Between the two basins there is a moderate exposure of Ordovician formation. With respect to the geologic structure, there is some disagreement among YOSHIMURA (1941), SUGAI (1948) and KOBATAKE (1949), but here the description follows the opinion of KOBATAKE.

On the northeastern side of the Hsiaoshih basin, the brachysyncline of the Taitzuho group is thrust by the Mapichiangkou thrusting sheet of the Korean group, and the latter in turn by the Yaopao thrusting sheet of the Upper Cambrian and Ordovician formations. West of the meridional Hsiaoshih fault (IX in Geol. Map IV), a sheet of the Nanfen shale which is considered by KOBATAKE (1949) to be the extension of the Yaopao thrusting sheet is thrust on the Taitzuho group. This Taitzuho syncline is thrust on the south side by the Ordovician of the Pichiakou thrusting sheet (X in Map IV) and this in turn is thrust by the Cambrian of the Niangniangkou thrusting sheet (XI in Map IV). Because the latter is low-angled, its thrust line is noticeably curved. Further south is the Linchiapaotzu thrusting sheet (XII in Map IV), where the Nanfen shale has ridden upon the Niangniangkou thrusting sheet. These thrusts describe arcs convex to the southeast.

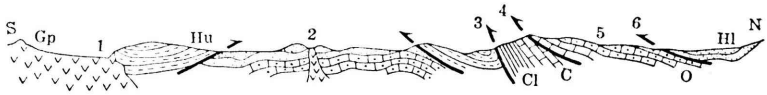


Fig. 28. Profile of the Hsiaoshih Coal-Field (After KOBATAKE), (3 in Fig. 23).

Gp. Granite Porphyry
Hu. Upper Taitzuho Group
Hl. Lower Taitzuho Group
O. Ordovician Formation
C. Upper and Middle Cambrian Formations
Cl. Lower Cambrian Formation

1. Yenchiapaotzu
2. Shanchengkou
3. Mapichiangkou Thrust
4. Yaopao Thrust
5. Taitzuho
6. Tungshan Thrust

Within the Shanchengkou basin is the Lishantaokou thrust, along which the lower Taitzuho group overrides the middle Taitzuho. To the north, the Ordovi-

cian of the Pichiakou thrusting sheet is thrust upon the Taitzuho group. On the east side of the basin is an Ordovician dome. Farther east the Taitzuho group, which forms a basin, is shifted upon the Ordovician along the periphery.

After the thrusting, granite porphyry intruded on the south side. Still later the area was cut by a few faults trending the direction slightly east or west of north.

According to KOBATAKE (1942), the Papanling thrust on the western border of the Tienshuaifukou basin represents double and partly triple thrusts. Near Papanling the Lower Cambrian is thrust upon the Ordovician and the latter on the Taitzuho group. In the northern part, however, an accessory thrust appears in this interval, where the Ordovician is thrust upon the lower Taitzuho or the Ordovician. In addition, in the southern part there is the pre-Papanling thrust along which the Taitzuho group is thrust on the Mesozoic formation or on the Taitzuho group below it. In the eastern part of the Tienshuaifukou basin there is the Kuchiakou thrust from which the Tiehtzushan thrust branches off.

These thrusts toward the east cut the plane along which the Changliangtzu black shale slipped over its basement. This and the later Mesozoic formations are cut by NW and NE trending faults, but the Sankeiling conglomerate is not displaced.

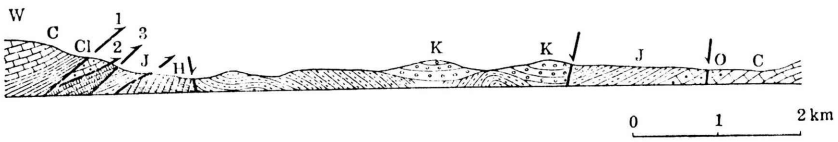


Fig. 29. Profile of the Tienshuaifukou Coal-Field (after KOBATAKE), (4 in Fig. 23).

K. Sankeiling Conglomerate
J. Changliangtzu Shale and Chuanshantzu Conglomerate
H. Taitzuho Group
O. Ordovician Formation
C. Upper and Middle Cambrian Formations
Cl. Lower Cambrian Formation
1. West Papanling Thrust
2. East papanling Thrust
3. Pre-Papanling Thrust

The Mesozoic formation lies on the Taitzuho group in the west, but on the Ordovician in the east, although its base has slipped to some extent. In my opinion it is probable that the incipient basin was a little modified before the deposition of the Changliangtzu black shale. According to SUGAI the black shale overlies the Ordovician in the eastern part with angular discordance. The significance of the Chuanshantzu conglomerate on the tectonic development is not yet well deciphered. It is, however, fairly certain that the deformation of the basin had been almost completed before the Sankeiling conglomerate was laid down.

In short, the deformation of the original basin commenced with the basal sliding of the Mesozoic formation. Subsequently a series of thrustings were repeated toward the east, and the pre-Papaling thrust indicates the final phase of lateral compression. Later block movement dissected the terrain into blocks. Monzonitic porphyry was intruded in the southern part after these structural developments.

4. The Yalu and Hunchiang Tributaries

In the Yalu tributary including the Hunchiang, its branch on the Manchurian side, the ancient gneiss complex is widely exposed. The Mach'ollyong metamorphic group is found as patches near Linchiang, Ŭiju and other places. East of Tienshuaifukou there are still a few other basins, but the chain of basins along the Taitzuho terminates in the vicinity of Huanjen. South of this chain are the Tsaohetang and Saimaki basins. The Santaoyangcha and Putaochiolingtzu coalfields are located in the same zone, but far to the east. Further eastward, beyond the main stream of the Yalu, are the Ch'osan area and several others where the

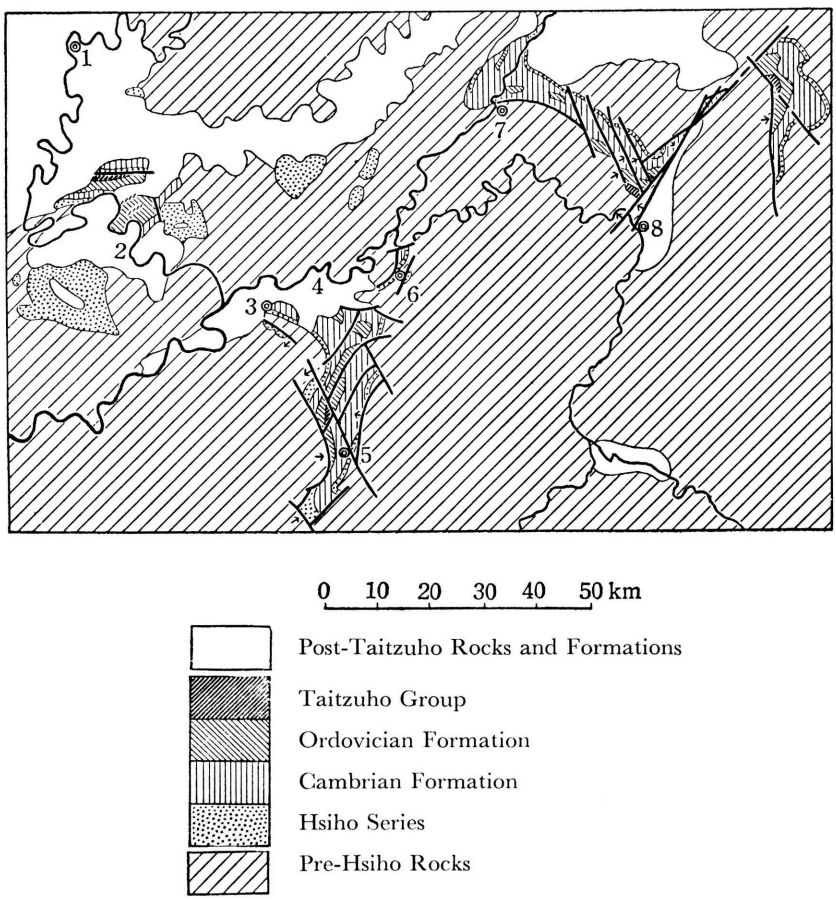


Fig. 30. Distribution of the Rakuroan Complex and Taitzuho Group in the Middle Yalu Valley (After NAKAMURA, AOJI, KOBAYASHI et al.)

1. Huanjen
2. Hunchiang River
3. Ch'osan, (Sosan)
4. Yalu River
5. Kojang, (Kojo)
6. Wiweon, (Igen)
7. Manp'ojin, (Manpochin)
8. Kanggye, (Kokai)

Taitzuho, Korean and Hsiho formations form basins or zones of depression. In the upper Hunchiang there is the so-called Pataochiang *Fenster,* which is actually a narrow graben extending from NE to SW.

In 1884, GOTTSCHE discovered some Cambrian fossils en route from Wiweon to Kojang. Jointly with KIM (1930, 31) and NONAKA (1943) I have investigated the Korean group in the Ch'osan-Wiweon-Kojang area, Kanggye-Manp'ojin area and the Huch'ang area. In the Ch'osan area the group is underlain disconformably by the Hsiho series. The lower part of this series is built up of quartzite, but the basal part is conglomerate; the upper part is composed chiefly of variegated clayslate, which is interbedded with quartzite or alternating marl and limestone at places. The Hsiho series is separated from the *Redlichia*-bearing Lower Cambrian by a wavy erosion surface.

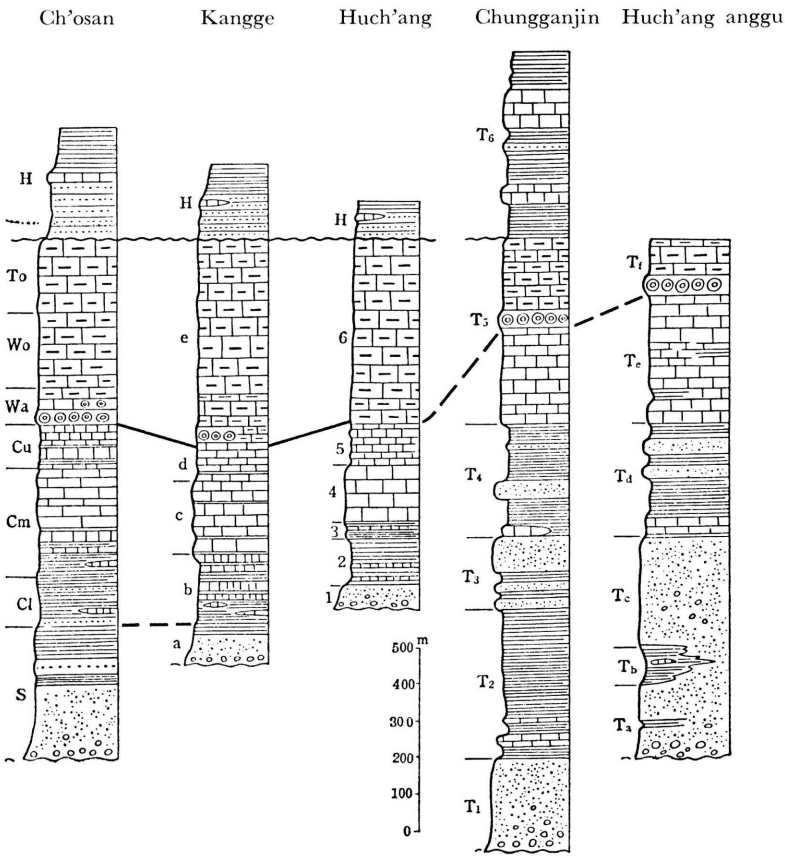


Fig. 31. Columnar Sections of the Rakuroan Complex in the Middle Yalu Valley (after NAKAMURA, KIM and NAKANO, compiled by KOBAYASHI).

H. Taitzuho Group
To. Toufangian Series
Wo. Wolungian Series
Wa. Wanwanian Series
Cu. Upper Cambrian Formation
Cm. Middle Cambrian Formation
Cl. Lower Cambrian Formation
S. Hsiho Series

Redlichia and other Lower Cambrian fossils are unknown from the Kanggye and Huch'ang areas. Whether the quartzite and slate beds in the basal 70 to 100 meters in these areas belong wholly to the Lower Cambrian or the Hsiho series, or whether the boundary between the two formations exists within the basal part is still questionable. It is quite certain, however, that the total thickness of the Palaeozoic and Proterozoic sediments is gradually reduced toward the east through these three areas, as shown in Table 13.

Table 13. Variation of Thickness of the Pre-Song'nim Sediments on the South Side of the Middle Yule Valley.

Thickness in m	Ch'osan (Sosan)	Kanggye (Kokai)	Huch'ang (Kosho)
Taitzuho Group	300	200	100
Ordovician Formation	500	550	500
Cambrian Formation	550	500	450
Korean Group	1,050	1,050	950
Hsiho Series	350	100 (?)	70 (?)
Naknang Complex	1,500	1,250	1,020

Farther northeast are the Linchiang-Chaseong-ganggu, Huch'ang-ganggu and Changpai-Hyesanjin areas. K. NAKAMURA (1942) has referred a formation near Chaseong-ganggu on the Korean side to the Korean group, but judging from the lithology, it seems reasonable to refer the larger part of the lower quartzite and clayslate of the formation to the Hsiho series, as is done for the same formation on the Manchurian side. Taking the *Cryptozoon* limestone as the key to the base of the Ordovician, a tentative correlation is shown in the diagrammatic sections in Fig. 31. Because no Cambrian fossil is known in the Chaseong-ganggu and Huch'ang-ganggu sections, it is difficult to point out the base of the Cambrian, but presumably it lies somewhere within the T_4 beds.

The Hsiho series thus outlined is thicker than 500 meters. The quartzite, especially the basal one, is often conglomeratic, containing quartz and clayslate pebbles, 2 to 3 cm across. In this part of the Yalu valley the clastic facies, especially conglomerate, appears more developed in the southeast than on the other side.

On the Manchurian side of the Yalu river between Changpai and Linchiang SAITO observed that the Cambrian overlies the gneiss and schists directly. The Hsiho series, however, is well developed west of Linchiang. It consists of the Chiaoyütai quartzite and the Nanfen shale and marl and measures 1,000 to 2,000 m in total thickness. In this area as well as in the region east of Tunghua the Chiaotou quartzite is absent. Between Tunghua and Wutaochiang the Nanfen shale and marl formation is seen to be overlain disconformably by the basal quartzite of the Cambrian formation, which contains the Nanfen marl as boulders.

The local variation in facies and thickness suggests that there were lands on the

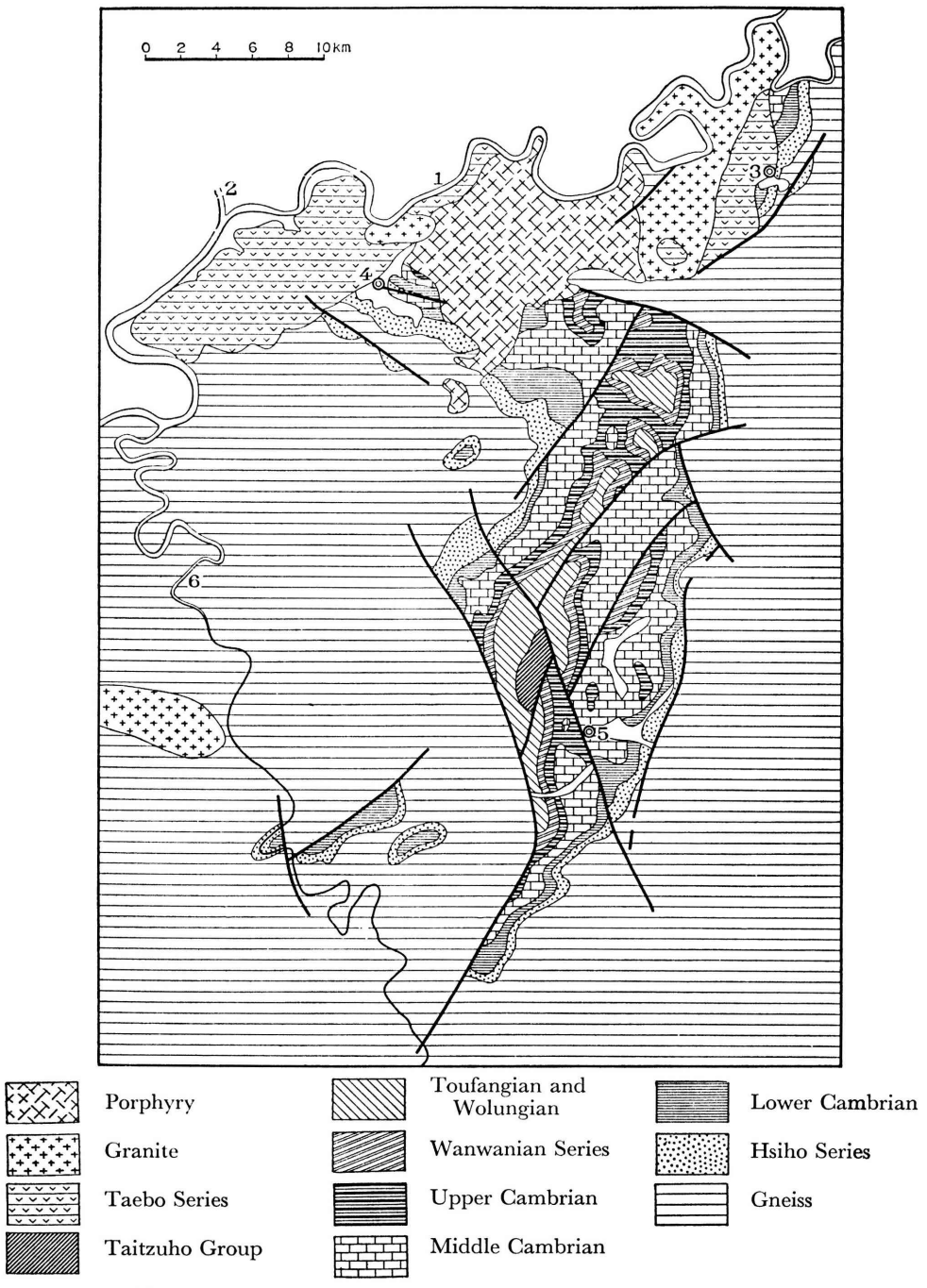


Fig. 32. Geological Map of the Ch'osan (Sosan) Area (after KOBAYASHI, KIM and TAKAHASHI).

1. Yalu River
2. Hunchiang
3. Wiweon, (Igen)
4. Ch'osan, (Sosan)
5. Kojang, (Kojo)
6. Ch'unggang, (Chuko)

east and south sides in the Hsiho period. The conglomeratic facies between the Huch'ang-ganggu and Hyesanjin shows that there was a trough bordered by high lands.

According to INAI and SHIKAMA (1940), the Cambrian and Ordovician formations east of Tunghua are respectively 500 m or less and 600 to 800 m in thickness. They are in discordant relation, as manifested by the fact that the *Cryptozoon* limestone of the latter lies on various horizons of the former.

The Taitzuho group is found in the Tiehchengtzu, Wutaochiang, Pataochiang and other coal-fields. Its basal conglomerate on the eroded surface of the Ordovician limestone is 2 to 5 m thick and contains quartzite boulders of frst-size, or rarely, the size of a man's head. The lower coal-bearing formation consists of shales and sandy shales in addition to Moscovian fusulinid limestone. The upper coal-bearing formation begins with well stratified sandstone succeeded by coal-bearing shale beds, quartzose and partly conglomeratic sandstone beds, and black shale beds.

On the Korean side of the Yalu river a similar limestone containing Moscovian fusulinids (TORIYAMA, 1941) is known to exist at Sinmakdong, Nanmyeon, in the Ch'osan area. Some brachiopods, naiads and plants occur near Kanggye and also in the Huch'ang basin, showing the existence of the Hongjeom and probably the lower Sadong series.

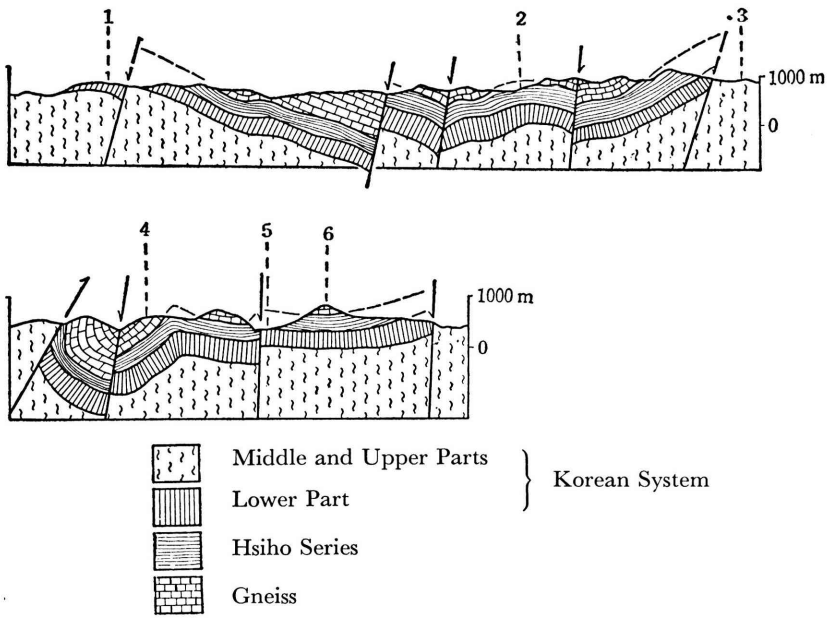


Fig. 33. Two Profiles of the Ch'osan Area (after KIM)

1. Nanhach'ang
2. Ohwadong
3. Mundok-tong
4. Yongdong-dong
5. Kojang, (Kojo)
6. Yondu-bong

In the Ch'osan area the Taitzuho, Korean and Hsiho formations form a synclinorium, the principal axis of which is subvertical and takes a NE trend, but in the northern part an auxiliary axis branches off at right angles and extends to the northwest. This T-shaped zone of folding is cut by NE and NW trending faults, some of which are high angle thrusts placing gneiss upon the sedimentary formations as shown in the profiles in Fig. 33. In addition to the main distribution, there are a few patches still remaining in the gneiss terrain on the west side.

In the Kanggye area these formations form a syncline or monocline, the strike of which takes a U-shaped course. That is, it runs from NW to SE in the middle sector, but at the two ends it is bent at right angles and extends to the northeast. Kanggye and Manp'ojin are located near the two angles. North of Kanggye the gneiss on the south side is thrust upon the lower Taitzuho group at the top of the monocline. The gneiss block is capped by quartzite and clayslate in the northwestern part, which must be a relic of the southern limb of the original syncline. This structure is further complicated by a thrust within the monocline and by NW and NE trending faults.

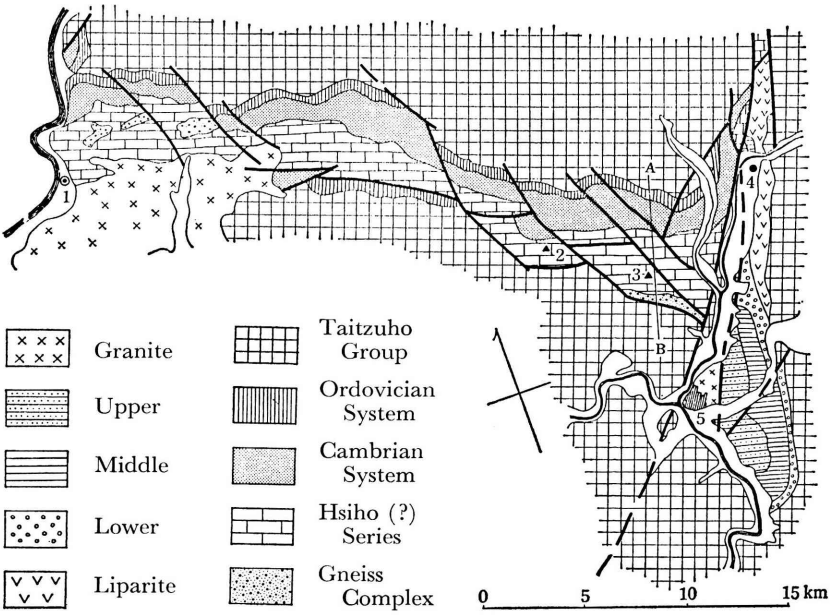


Fig. 34. Geological Map of the Kanggye (Kokai) Area (after Kobayashi, Nakano, et al.), (see Fig. 35 for Profile A–B).

1. Manp'o-jin
2. Sipijup-san
3. Choidok-san
4. Hanjon-dong
5. Kanggye

East of Kanggye there is the subtriangular Huch'ang basin. Quartzite and clayslate of the Hsiho (?) series overlie the gneiss basement on the northeast and southeast sides. It is supposed to have been a quadrate basin with the Hong'jeom series near the center, but it is cut by faults on the west side.

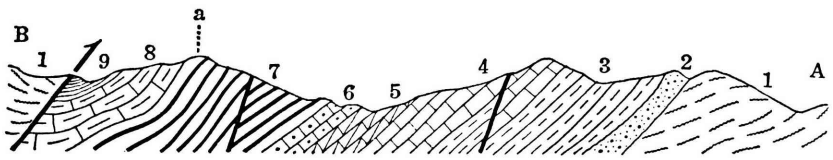


Fig. 35. Profile of the Kanggye Area (after NONAKA), (see Fig. 34 for Points A and B).

1. Paragneiss
2. Quartzite
3. Slate, variegate shale, marl and limestone
4. Purple shale and black limestone
5. White massive limestone
6. Gray limestone and purplish black shale
7. Slabbly limestone and Wurmkalk
8. Dark gray massive limestone
9. Taitzuho Group
a. Choidok-san

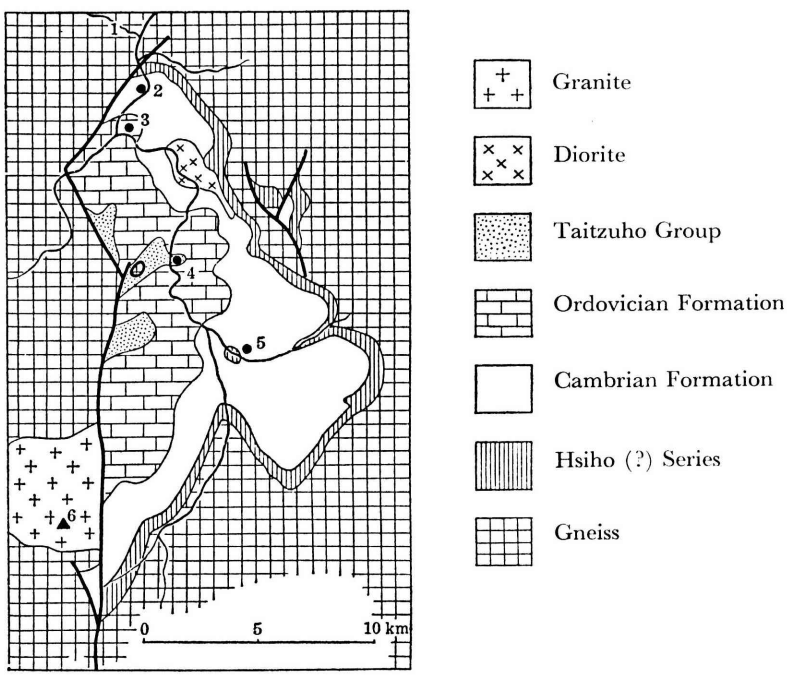


Fig. 36. Geological Map of the Huch'ang (Kosho) Area (after YAMANARI, KOBAYASHI, et al.)

1. Chasoeng-gang, (Jijoko)
2. Uhwa-dong
3. Hwap'yoeng
4. Puhŭng-dong
5. Sobuk-tong
6. Paeksam-bong

The so-called Pataochiang *Fenster* extends from NE to SW along the upper Hunchiang river for about 40 km with a breadth of less than 6 km. This is a *Pseudofenster*, or a kind of graben which consists of Mesozoic, Taitzuho and older formations. The boundary faults on its sides are thrusts of the Korean and Hsiho

formations toward the graben. The Palaeozoic formations were folded in by compression between the thrusting blocks and were diagonally folded and faulted. These Palaeozoic formations are overlain by a Mesozoic formation which is not disturbed as much. Nevertheless, the Mesozoic is capped by several *Klippen* which were probably transported from the two sides. Judging from these facts, it is certain that there were two or more phases of movement. The Mesozoic formation is a filling of the graben produced by the early movement, but it was thrust from the two sides by the later one.

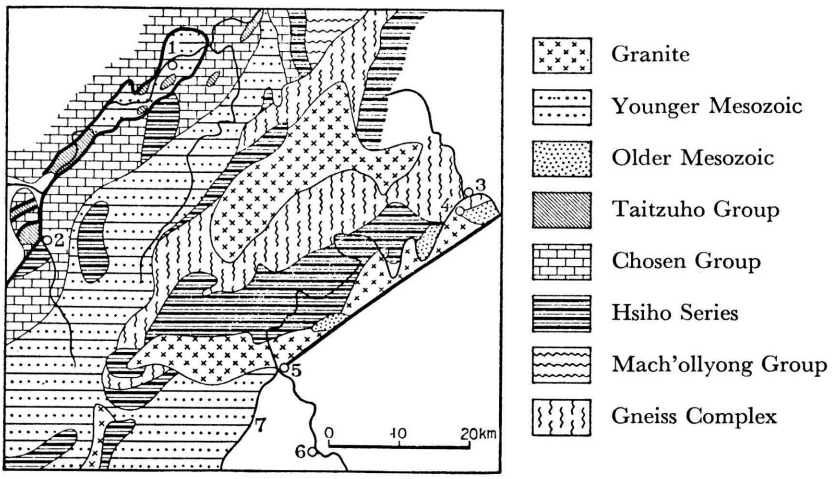


Fig. 37. Geological Map of the Upper Hunchiang Valley.

1. Pataochiang
2. Tiehchengtzu
3. Linchiang
4. Chunggang-jin
5. Chaseong-ganggu
6. Chaseong
7. Yalu River

The sequence of the Mesozoic formations in the Pataochiang graben is as follows:

c. Tuffaceous sandstone and shale formation, 120 m thick.
Alternating sandy shale, sandstone and shale.
Tuffaceous conglomerate, tuffaceous sandstone and tuff, 5–15 m thick.
Sandstone and conglomeratic sandstone, 30 m thick.

..... Unconformity .....

b. Chienshankou coal-bearing formation.
Alternating shale and marl.
Tuffaceous sandstone and coal seams.
Greenish tuffaceous shale.
Tuffaceous sandstone.

.....Base unknown .....

a. Tuff with a small amount of reddish tuffaceous sandy shale and bluish green tuffaceous sandstone, unconformably overlying the Taitzuho group.

Euestheria cfr. *middendorfii* from Sanchiatzu, northeast of Tunghua (KOBAYASHI and KUSUMI, 1953), judging from its locality, is thought to have been collected

from one of these formations in the graben. At Kutsangkou further northeast near Fusung are two formations separated by a disconformity. The lower one, 350 m thick, overlies the Ordovician and older formations unconformably and contains volcanic flows and tuffs. Several species of Estherians collected near the top bear some similarities to the Silla, Laotzukou and Sungari faunas. Therefore the age of the Estherians is considered to be Lower or Middle Cretaceous (KOBAYASHI and KUSUMI, 1953). The upper formation, comprising oil shales and coal seams, may be either Upper Cretaceous or Palaeogene. Thus there are at least two Estherian horizons in this region. Assuming that the Kutsangkou Estherian beds can be correlated with the c formation of the Pataochiang graben, the Estherians of Sanchiatzu were probably contained somewhere in the a–b formations which are the Jehol members.

If this interpretation is correct, the primary phase of the movement must be Liassic or older and the final one Middle Cretaceous or younger.

North of Chaseong the folded Korean group is overlain clino-unconformably by the Daedong series containing plant beds and coal seams. Because its basal conglomerate varies in thickness and contains boulders of up to 60 cm in diameter, it is probably an orogenic sediment. Therefore the movement by which the underlying Korean group was folded is referable to the Songnim disturbance.

Near Sinŭiju the Daedong series is overlain unconformably by the Jehol series. TAKAHASHI (1953) proposed *Gishu* or Ŭiju for the movement indicated by this discordance and referred the Mesozoic formation near Kanggye to the Jehol series, but its reference to the Silla series is no less probable. As mentioned earlier, the Mesozoic formation of Kanggye is monoclinal and cut by a fault at the northeast margin. The Jehol near Sinŭiju, on the other hand, is moderately folded and cut by a mesh of NE and NW trending faults.

The Mesozoic formation near Ch'osan is more than 1,000 m thick. It is composed of porphyrite in the lower, tuff, tuffaceous sandstone and shale in the middle, and an alternation of porphyrite and tuff in the upper part. Conglomerates are found near the base of the middle part. This formation is similar to the Silla series in South Korea. It is intruded by granite and quartz porphyry which belong to the Pulguksa igneous group. In the P'yeongbuk massif there are normal faults of various trends among which NW and NE are more common than the equatorial and meridional trends. The western boundary of the Huch'ang half-basin looks as though it were meridional. Close examination reveals, however, that it consists of a combination of NW and NE trending faults, where the latter faults are penetrated by porphyrite dikes.

In the Kanggye area there are diagonal faults which cut the Mesozoic formation and granite porphyry. In the Ch'osan and Huch'ang-ganggu areas, on the other hand, granite and quartz-porphyry are seldom faulted. Thus there are local differences in the age of faulting with regard to igneous activity.

In the Pukchin area southwest of Ch'osan the Pre-Cambrian gray gneiss is intruded by the Pulguksa igneous rocks. According to KINOSAKI (1933), the suc-

cession of their intrusions and block movements can be analyzed as follows:

1. Pukchin spotted granite laccolith and Ich'eondong (Risendo) granite batholith.
2. Northeast faults.
3. Quartz-porphyry dikes.
4. Meridional faults.
5. Northwest faults.
6. Gold quartz veins and dikes of pegmatite and aplite.
7. Dikes of porphyrite and lamprophyre.

Porphyrite

Mesozoic Formation

Taitzuho Group

Ordovician Formation

Cambrian Formation

Hsiho Series

Fig. 38. Geological Map of the Pataochiang Graben (after INAI and SHIKAMA).

1. Heihsiatzukou
2. Hunchiang
3. Pataokou
4. Hungtuya Hekoukai
5. Yenchiapaotzu
6. Toukoutzu
7. Chitaokou
8. Yehchihpei
9. Chienshankou
10. Tatungkou
11. Laoyehling

Although much remains to be settled with respect to the chronology of the Mesozoic formations, on the basis of the known facts the history of the Mesozoic movements may be analyzed into the following phases:

V. Block movements and Pulguksa igneous activity.
Silla series in Ch'osan and Kanggye areas.

IV. Upthrusting: Late Taebo disturbance.
c formation of Pataochiang; Kutsangkou Estherian beds.

III. Gentle folding: early Taebo disturbance.
b and a formations of Pataochiang; Sanchiatzu Estherian beds; Jehol series of Sinŭiju.

II. Gentle folding of Ŭiju phase.
Daedong series of Ŭiju and Chaseong.
I. Songnim disturbance.

The boulder conglomerate at the base of the Daedong series near Chaseong may be an orogenic sediment deposited immediately after the Songnim disturbance. The distribution of the above mentioned Mesozoic formations appears to be mostly related to the Palaeozoic basins in some way but the sequences in these Mesozoic areas differ greatly. The Pataochiang depression which was brought about by the Songnim or Ŭiju movement was filled with Mesozoic formations (a–c). Later this region was compressed, resulting in the upthrusting of the neighboring blocks toward the depression. As a result, the Pataochiang graben was almost completed.

The Kanggye-Manp'ojin zone was primarily a synclinal depression, but later the southern block was thrust upon the northern limb of the syncline. The monocline thus introduced, however, was faulted probably more than once. The Kanggye Mesozoic was tilted and cut by a strike fault of the block movement in a later phase. In the Ch'osan area there are also some thrusts along which the southwestern block is pushed up. Some others are tension faults. Thus there were tension movements from which the Kanggye Mesozoic suffered, and compressive movements which preceded its deposition. The Jehol series of Ŭiju was gently folded by an earlier movement and cut by the fault mesh of a later movement. In the Pukchin area the faultings are known to have been repeated during the Pulguksa igneous activity.

Because there is no Tertiary, nothing definite can be said of the later modification of the Mesozoic structure. Since there was no strong crustal deformation in the Palaeozoic era, the present structure of the Palaeozoic and Proterozoic formations of 1,000 to 2,000 meters' thickness is the product of a series of Mesozoic and later movements.

The structure in this region is quite different from the preceding tectonic regions. There is no chain of basins as seen in the Taitzuho valley. The structure in the P'yeongnam-Liaotung orogenic zone differs even more. Here these Palaeozoic and Proterozoic formations are much thinner than in other regions. They are folded in between the basement blocks. Their structure may be a monocline, syncline or a synclinorium. Whichever of these three it is, such a depression is often thrust from one or two sides, as exemplified by the Kanggye-Manp'ojin zone or the so-called Pataochiang *Fenster*. The most remarkable tectonic feature of the region is the rectangular bending or branching of such a depressed zone. The Kanggye-Manp'ojin zone is U-shaped and the Ch'osan area T-shaped. They are similar to each other in that the prolongation of the depression is in the NE or NW trend. The Pataochiang *Fenster* as well as the Linchiang-Chaseong zone are elongated in the NE trend.

The syncline of Huch'ang-ganggu extends from east to northwest for 20 km. In the western part it is expanded to a breadth of more than 10 km and intruded by

granite and quartz porphyry. The Huch'ang basin is no less wide. It appears to be cut by a meridional fault on the west side. This boundary, however, is partly composed of NE and NW trending faults. Thus, the diagonal trends are predominant but the equatorial and meridional trends can hardly be overlooked.

The diagonal cracks were brought to being in the rigid basement by the compression from north to south which produced the equatorial chain of basins in the Taitzuho valley. The Palaeozoic and Proterozoic strata which mantled the basement were warped down into the depression or folded in between the blocks. Later they were cut by normal faults. The structure one sees here now is a typical example, though on a small scale, of the kraton fragmentation.

5. Discussion and Summary

The Taitzuho, Korean and Hsiho formations are three major units of blanket strata which constitute the basins and grabens in the Yalu-Taitzuho region. The base of the Hsiho series is marked clearly by the discordance of the Shengwe phase, where the Tiaoyütai quartzite overlies the Anshan series, Liaoho-Mach'bllyong metamorphic rocks or ancient gneiss.

I have noted already that the Yungning sandstone is a deltaic sediment which was accumulated on the western margin of the P'yeongbuk land. The Nanfen marl thins and the clastic sediment increases from the Taitzuho and Hunchiang valleys to the Korean side of the middle Yalu. The conglomeratic facies is well developed in the lower Hsiho series between Hyesanjin and Huch'ang-ganggu. If the source of these terrigenous material is considered, the Taitzuho depression must have been a separate embayment, instead of a marginal part of the P'yeongnam geosyncline.

Assuming that the Hsiho series of the Taitzuho valley can safely be correlated with the so-called Hsiho series at the neck of the Liaotung peninsula, the thickness does not differ greatly between the two areas where it is generally 500 to 700 m, but attains 2,000 m at the maximum. There is, however, a large stratigraphic break in the former which involves the middle and late Sinian periods, while there is a Wuhangshan series in the latter area. The break is indicated by the disconformity at Luohanku and other places. The base of the Korean group cuts the Hsiho series with such a small angle that 1 or 2 meters per kilometer of the Chiaotou quartzite are truncated. In the distance of some 200 km from Liaoyang to the upper Hunchiang valley the dissection reaches the Nanfen shale and marl formation through the Chiaotou quartzite, about 250 m thick. This is proven by the inclusion of the Nanfen marl in the basal quartzite of the Cambrian formation northeast of Tunghua.

In the Korean group, the variations in facies and thickness are quite reduced compared to the Hsiho. It measures 1,100 to 1,300 m in the Taitzuho valley and 950 to 1,150 m on the Korean side of the middle Yalu valley. Not only is the difference in thickness slight, but the lithological sequence is very similar through-

out the whole region. It is mainly a great limestone formation, although shales and sandstones are common in its lower part. As it is a monotonous formation, the Cambro-Ordovician topography is thought to have been simple and flat.

There is a general tendency in this region for the stratigraphic breaks to become large or numerous toward the east. The Redlichian sea, for example, did not flood any further beyond the Ch'osan area (KOBAYASHI, 1966). In the Pataochiang graben, INAI and SHIKAMA noted that the base of the Lower Ordovician formation lies disconformably on various parts of the Cambrian formation.

After a prolonged Middle Palaeozoic land period, the Taitzuho group was deposited on the Ordovician para-unconformably in most places. In the Hsiaoshih coal-field and a few other places, however, a clino-unconformity is observed at the base of the Penchi, Huangchi or Lioutang series. Though it is local, it is noteworthy that the Akiyoshi prorogeny in the Mongolian geosyncline was a stronger influence on this zone than the P'yeongnam geosyncline.

The thickness of the group is some 800 m in the Taitzuho, but diminishes to about 500 m in the Hunchiang and less than 300 m in the middle Yalu valley. The Penchi or Hongjeom series containing the Moscovian limestones and coal seams is distributed extensively. The Huangchi series, which is the main coal-bearing series in the Taitzuho valley, may be absent in the Hunchiang tributary. The Tsaichia and probably the Lioutang formation are apparently absent in the Ch'osan, Kanggye and Huch'ang areas. In the Taitzuho tributary the Lioutang is the upper coal-bearing unit which lies conformably on the Huangchi series in most places. In the Hunchiang region it is represented by a coarse sandstone formation with a disconformity at the base. The Tsaichia formation is a thick variegated formation or a red sandstone formation in the Taitzuho or Hunchiang valleys respectively. KONNO (1949) noted that there is a thick basal conglomerate of the Tsaichia series in the Penhsihu coal-field lying on the Lioutang series. Through the *Gigantopteris* flora the Tsaichia is correlated to the Gobangsan series in Korea. Therefore there is no equivalent of the Nogam series in this region.

The Penchi sea was flooded in the Moscovian epoch as far as Huch'ang and Pataochiang, but the Permian formations are mostly non-marine and the depression was reduced successively through the Chiaotsuo and Tungwu phases of movements, which correspond respectively to the Kanokura and Usuginu phases in Japan.

It was turned completely to land by the Ssuwan or Tate movement. It is interesting to see that the Usuginu phase is indicated by a great increase of coarse detrital sediments, because this reveals the growth of the embryonic geanticline.

The Hshiho, Korean and Taitzuho formations are respectively about 500–600 m, 1,100–1,300 m and 500–800 m in thickness, or a total of about 2,000–2,500 m. This amount does not differ greatly from the 3,000 m in the northern area of the Liaotung peninsula, but corresponds to only about one-fourth of about 9,000 m in the geosynclinal part of the peninsula. The total thickness of the geosynclinal sediments attains more than 10,000 m in North Korea.

Table 14. Stratigraphic Sequence of the P'yeongan Group and Its Relation to the Phases of Crustal Movements.

Age	Korea		South Manchuria			Japan	China
Middle Trias					Songnim	Akiyoshi	Weiyang
Early Trias	P'yeongan Group	Nogam		Taitzuho Group		Tate	Ssuwan
Permian		Gobangsan	Tsaichia			Usuginu	Tungwu
		Sadong	Lioutang			Kanokura	Chiaotsuo
			Huangchi		Nanpiao	Sakamoto	Kunming
Uralian Moscovian		Hongjeom	Penchi		Hsiaoshih		
	Stratigraphic Sequence				Phase of Crustal Movement		

Because the Mesozoic stratigraphy has not as yet been thoroughly established and because the Tertiary formation is absent in this region, the tectonic analysis cannot be quite conclusive. A tentative correlation on the basis of the present knowledge, however, allows one to distinguish five or more phases of Mesozoic movements. The Triassic Songnim disturbance was very important to the destruction of the previous depression. The Changliangtzu shale formation in the Tienshuaifukou basin is a member of the Daedong series. It appears disconformable with the Taitzuho or Ordovician formation, but the relation becomes an angular unconformity in the eastern part. This probably means the dip of these formations increases from the center to the margin of the embryonic basin. The Daedong series near Chunggang-jin begins with a thick boulder conglomerate bed which is suggestive of an orogenic sediment.

Near Ŭiju are the Daedong series containing plants and the Jehol series yielding Estherians and *Lycoptera*. The movement which occurred between them is called the Ŭiju phase. The Jehol series, starting with the boulder conglomerate, attains over 1,000 m in thickness. It was folded by the Taebo disturbance.

In the Penhsihu basin the Penhsihu and Tayü formations were deposited and volcanic eruptions repeated in the Cretaceous period. They were folded gently except along the south and west margins where they are sharply folded, yielding upthrusts.

At Pataochiang the Chienshankou coal-bearing formation, which is probably Upper Jurassic, appears to be separated from the Cretaceous pyroclastic formation by the unconformity of the Taebo phase. The latter, which suffered from the upthrusting of the Sakawa phase, may be correlated with the Tayü formation.

The Linchia formation may have been deposited immediately after this movement. The structure was further complicated by faulting related with the Pulguksa igneous activity.

In looking through the stratigraphic sequence, it is certain that the Palaeozoic and Mesozoic were respectively the ages of crustal stability and mobility for this region. Due to the lack of Tertiary sediments, little is known of the movement of this period. It is, however, certain that the Mesozoic movements were compressive, but became the tension type in the Late Cretaceous and probably in the Tertiary period. The batholithic intrusion of the granitic magma may be most responsible for the change in this tectonic habit.

Although the original structure was later modified to a great extent, the chain of basins is still maintained in the Taitzuho valley. These basins are separated from one another by wedges of the basement complex, the aspect being shown more clearly in the northern than in the southern margin. The ancient gneiss or the Liaoho metamorphic group is well developed respectively on the north and south side of the chain. The Saimaki and other coal basins are aligned further south. Judging from the disposition of the basement complex and blanket formation, the incipient structure produced by the Songnim disturbance is thought to have been composed of the following four elements, listed from north to south:

1. The northern anticline of the ancient gneiss.
2. The principal syncline of the blanket formation.
3. The southern anticline of the Liaoho metamorphic group.
4. The auxiliary syncline of the blanket formation.

As clearly shown by the first and second elements, the anticlines and synclines were the chains of domes and basins which were aligned alternately in a checker pattern.

Compressed repeatedly by the later movements, such positive or negative elements were further elevated or depressed. As a result the plastic blanket was folded and the rigid basement cracked along the boundary between two units of opposing tendencies. Such folds developed into thrusts by further compression. Therefore it is a general tendency for blanket formations to be more strongly deformed from center to margin of a basin. If it is delimited by a thrust, the strata are abruptly bent and even overturned in its vicinity. As noted by YOSHIMURA, it is a general feature of deformation here that the structure is more complicated on the thrust side than on the thrusting side.

Among blanket formations, the Tiaoyütai quartzite is most rigid and resistant to erosion. Therefore it often forms *Pingtingshan,* which means a flat topped mountain like a basaltic mesa. Limestones are on the contrary easily folded. The differential deformation among them is well exemplified on the Pingtinghan block where the Hsiho series is gently inclined, but the Korean group is repeatedly folded.

The Liaoyang-Yentai basin is bisected by a median tectonic line which is a thrust at least near Shangshantzu. Its basin structure is, however, not much destroyed, probably because the compression was released by the dislocation along the Shangshantzu-Hanpeling shattered zone. The Hsiho and Korean formations

are more compressed near Anshan beyond the Chienshan granite mass where they form an imbricated structure.

The middle Taitzuho region is strongly disturbed by thrusts in various directions. Thrusting of the northwestern, western or northern block toward the other side is, however, seen more commonly than the opposite thrust; the latter is found mostly in the southern part.

The Hsintungkou thrust provides an interesting example of fracturing of a rigid block along a boundary tectonic line. The Penhsihu basin was compressed from the west and south sides and the thrust-plane so low-angled at the corner where a *Klippe* is seen. In these aspects, this basin agrees with the Wafangtien basin. Is it accidental that each of these two has a large and simple basin on its west side? The large Wuhutsuei basin is, however, different from the Liaoyang-Yentai basin in the common occurrence of intraformational slidings. The *Klippen* of the Chiaotou quartzite capping the Lower Cambrian of the Wafangtien basin are also relics of the same kind of dislocation.

The differential movement between the two sides recurred along the Hsintungkou thrust as well as the Papanling thrust, yielding an upthrusing toward the east side which incorperated the filling of the Mesozoic basin. This is a kind of *Doppelüberschiebung,* bearing certain characteristics in common with the famous pre-Alpine *Doppelüberschiebung.*

There are many basins of various sizes that are commonly asymmetrical in outline and structure, but most of them are not so compressed as to be called brachysynclines. The outline may be elongated, but there is no definite trend for their major diameters or axes. In these respects this structure is quite different from the basins in the P'yeongnam orogenic zone in North Korea.

The Shihchiaotzu fault appears to be a long normal fault, but it needs further confirmation, because the Pingtingshan, Tiaoyütai and Pienlingpaotzu thrusts are also straight. Tension movement is, however, not well illustrated in this area.

As the Taitzuho zone is similar to the Wuhutsuei-Wafangtien area in the materials which constitute these terrains, their geologic structures have features in common. The basin, composed of relatively thin blanket formations, was later destroyed under the strong influence of the compressive block movements of the rigid basement. In short, it was the destruction of a quasikraton composed of a thin plastic veneer capping a rigid basement.

The structure visible in the Yalu-Hunchiang tributaries is an example of kraton fragmentation and is different from the preceding. Because it is the marginal part of the Taitzuho depression, the blanket formations were not well developed. Their basement is mostly composed of granitic gneiss. This well granitized part of the P'yeongbuk massif was broken into pieces by compression. As it is rigid and homogeneous, cracks were more commonly diagonal than parallel or at right angles to the direction of compression.

If a quadrate block is gradually sunken, a rectangular basin like the one of Huch'ang appears from the down -warping of its veneer, but it is easily eroded

because it is thin. The veneer is better preserved along the boundaries, among blocks. It is thought that it was formed originally in a gentle syncline, but was later deformed in various ways.

If the boundary between the basement blocks is linear and simple, the veneer may become a monocline by the thrusting of one block upon another and by losing a limb of the syncline on the thrusting block. This is the case of the Kanggye area.

If it is a relatively broad zone, a syncline may develop into a synclinorium by further compression, as in the Ch'osan area.

If it is a narrow trough in which later sediments accumulated on the veneer, they may be folded in together between the blocks and suffer from the thrusting up of the neighboring blocks. The so-called Pataochiang *Fenster* is a typical example of such a closed graben.

Though the last one is a narrow zone of infolding, it is quite distinct from the arcuate shattered zone of Hanpeling-Shangshantzu. The Helankou graben and the monocline along the Shihchiaotzu tectonic line, which is partly synclinal, bear greater similarities to the third and first types of structures respectively. They are two exceptional off-shoots from the chain of basins into the areas of the basement complex.

These remnants of the veneer along the boundaries are always straight or nearly straight, as they are controlled by the fragmentation of the P'yeongbuk massif. It may happen that a zone of blanket formations issues an off-shoot or is bent by itself. Then it is expected to form an angle of about 90 degrees, or less commonly 45 degrees, at the point of branching or bending. The T-shaped branching of Ch'osan and the U-shaped bending of Kanggye and Manp'ojin are excellent examples of such deformations.

V
Comparative Tectonics

1. Different Types of Geologic Structures

In discussing the orogenic cycles in Japan in 1941, I pointed out the coincidence in the fundamental design of the architecture between the Sakawa folded mountains and the Alps. Each is an anticlinorium of grand scale having a metamorphosed core. In other words, each of them is a long uniaxial folded zone of high amplitude. They differ, however, in that the tangential dislocation in the Alps is much longer than that of the Sakawa mountains. Overthrusting of the *Oga Decke* for a distance of over 40 km was one of the two interpretations which I have previously suggested; the other explanation of the *autochthonous Pseudoklippe* now seems no less probable.

The *Decken* in the Alps are very complicated in comparison with the structure of Japan. In the history of tectonic development, however, Japan is more intricate than the Alps, because here the orogenic cycles were repeated three times. More precisely, similar mountains were successively built in Japan through the cycles of orogeny, causing a migration of the geosyncline, as shown in Table 15. The Akiyoshi mountains were built on the continental side before the Sakawa mountains, and as discussed in my recent paper (1955), the Oyashima mountains on the Pacific side are still in the making. The Ryukyu, Mariana and Chishima arcs which are intimately related to the Japanese arc are also folded mountains in different stages of growth. All are arcuate and each has a large hinter basin and a narrow deep trench in front.

As noted in my 1941 paper, the folded mountains in the Okch'eon as well as the P'yeongnam zone in Korea are very different from the Japanese type of folded mountains, as the metamorphosed axis is absent. I have already given a detailed description of the Okch'eon type of structure seen in the western part of the Kwangweondo limestone plateau. Between P'yeongchang and Mun'gyong it is a large straight anticlinorium with a small synclinorium on each side. These triaxial folds developed into an imbricated structure, yielding thrust lines which show a remarkable parallelism for a long distance. This aspect reminded me of the imbrication of the ridge and valley zone in the Appalachian mountains. This part is, however, considered at present the frontal nonmetamorphosed zone of the mountain system, instead of the system itself.

The Okch'eon folded zone is about 40 to 60 km in breadth, the P'yeongnam zone is much broader, measuring about 200 km wide in North Korea. No long or persistent axis of folding exists and the zone consists of many brachysynclines and brachyanticlines which are mostly composed of the P'yeongan and Sangweon groups respectively. The Korean group between them often forms disturbed zones, and the basement complex is exposed in some places as domes. The alternate arrangement of positive and negative elements in the P'yeongnam zone corresponds to the Taitzuho type of structure, but is distinct from that type in the presence of short and parallel or subparallel folded axes. The zone bears some features of the Taitzuho zone whereas the structure of the Okch'eon zone is similar to the Chichibu zone of the Sakawa mountains. However, the two zones in Korea are folded zones developed from the geosyncline-like troughs or parageosynclines, while the folded mountains of the Japanese type have grown up from the true geosyncline or orthogeosyncline.

The geologic structure produced in the Yalu region and the Taitzuho zone during Mesozoic disturbances are something other than folded mountains. They belong to kratonic or quasikratonic terrains, and their structures were produced by fragmentation of such rigid terrains. A chain of basins is aligned from west to east along the Taitzuho river. These basins are arranged alternately, with the domes on the two sides. Among them the major axis of the brachysyncline has no definite trend, but the chain of basins as a whole forms an equatorial zone. There

Table 15. Tectonic Lineaments of the Folded Mountains in Japan.

Tectonic Elements		Akiyoshi Mountains	Sakawa Mountains	Yezo Mountains
Hinter Basin		(Monguagai Basin in Ussuri)	Tsushima Basin, etc.	Tokaichi Basin, etc.
Axial Zone	Granitized Zone	Hida Gneiss Zone	Ryoke Gneiss Zone	Hidaka Mountains
	Metamorphosed Zone	Sangun Metamorphosed Zone	Nagatoro Metamorphosed Zone	
Frontal Deformation Zone		Yamaguchi folded Zone	Chichibu Folded Zone	Ishikari Coal-Field, etc.
New Geosyncline		Shimanto Geosyncline	Nakamura Geosyncline	Ishikari Plain

are thrusts, many of which are diagonal to the zone. Thus the basins are nonaxial whereas the whole depression forms a zone.

The Yalu-Hunchiang tributaries which occupy the marginal part of the P'yeongbuk land are not zonal. This massif, chiefly composed of granitic gneiss, suffered from the Mesozoic movements simultaneously with the depressions or troughs. Judging from the equatorial zones of the Taitzuho and P'yeongnam, it is evident that the P'yeongbuk massif was compressed meridionally. As a result it was broken into blocks along straight cracks which were more commonly diagonal than equatorial or meridional. The thin veneer of Palaeozoic and Proterozoic sediments which covered the basement complex was tilted up or folded down between the blocks. Such grabens are narrow and straight, and if branching or bent, often form right angles. This is a typical example of kraton fragmentation caused by compressive block movements.

Thus there are five distinct types of structures in Japan and Koreo-Manchuria, called the Japan, Yokusen (Okch'eon), Heinan (P'yeongnam), Taitzuho and Yalu types for the sake of convenience. *Because these structures were produced by the same Mesozoic orogenies or disturbances, their differences must depend upon the terrain.* The relation of these structures to the original terrains are as follows:

1.	Japan type of uniaxial arcuate mountains	Orthogeosyncline
2.	Okcheon type of a triaxial folded zone	Parageosyncline
3.	P'yeongan type of a polyaxial folded zone	Parageosyncline
4.	Taitzuho type of block folding	Quasikraton
5.	Yalu type of kratonic fragmentation	Kratonic massif

The following gradations can be observed in these structures:

1. From uniaxial through polyaxial folding to non-axial structure.
2. From zonal or parallel structure to areal or diagonal structure.

2. Kraton Fragmentation

Starting with kraton fragmentation, we can compare the characteristics of the geologic structure. The P'yeong'buk massif provides an excellent example of fragmentation. It was broken into minor blocks along straight cracks which were more commonly diagonal than parallel or perpendicular to the direction of compression. Because of this habit of fragmentation the isolated microkratons are often subquadrate in outline. The Colorado plateau, Texas basin, Bohemian massif, blocks of Podolia and Woronez, the Kuznetsk basin, and the sunken block of the Kara sea are similar examples.

The cracks in the Pyeongbuk massif were nearly straight and its veneer, which is relatively thin, suffered from the compressive block movement. This is seen in the *Pseudofenster* of Pataochiang, the U-shaped monocline of the Kanggye-Manp'ojin area and the T-shaped synclinorium of the Ch'osan-Wiweon-Kojang area.

Because of the right angle at the junction or beding point, these T- and U-

shapes are related to the L-shape described by the Red Sea and Gulf of Aden or a part of the zig-zag course of the Great Rift Valley in Africa.

The Huch'ang basin is remarkably truncated by a long meridional fault. This basin is not as compressed as the Eo-Palaeozoic formation near Prag in the Bohemian massif. Its triangular outline consists of two edges of discordance and one of dislocation. Near Huch'ang-ganggu there is a syncline having an equatorial axis. Judging from the facies and thickness of sediments it is probable that there was a narrow Proterozoic trough between blocks. The Arbuckle mountains have also developed from a narrow trough between kratonic masses.

Thus there are more than two kinds of troughs. One is a simple graben or zone of depression in which the blanket formation sank after a movement, and the other has developed from a trough or an embryonic syncline. The latter can be further subdivided into two kinds. One is an old trough like the Arbuckle trough which was primarily brought to being by kratonic fragmentation. The other is the case of the Pataochiang *Pseudofenster*. It was not a trough in the Palaeozoic or Proterozoic period, but must have been some kind of a depression in the Mesozoic period. Such a Mesozoic depression was later thrust from the two sides into the form of a graben.

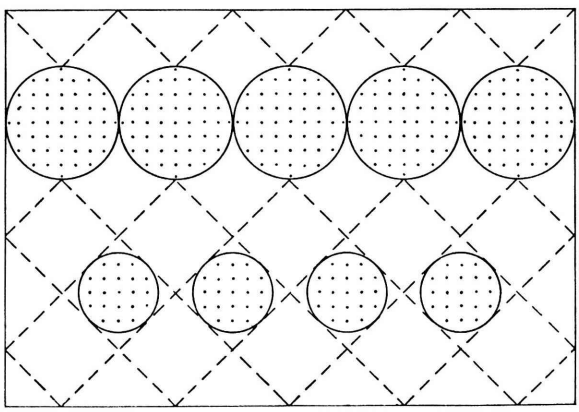


Fig. 39. Chains of Basins (dots), Idealized. Hatching shows the basement block, diagonally cracked.

There is no sharp boundary between the Yalu and Taitzuho types or between the latter and the P'yeongnam type of geologic structure, but there is a great difference in the thickness of the sediments. Accordingly, the differential deformation between these sediments and their basement reveals a remarkable tectonic feature.

In the Taitzuho zone, positive and negative elements which were arranged alternately in a checker pattern can be recognized fairly well. The embryonic folding must have involved the doming up of positive elements and the subsidence of negative ones. At the side of the Taitzuho valley and its neighborhood there

were rows of such domes and basins which were arranged parallel to the Mongolian geosyncline.

It is interesting to see that the arrangement is more or less allied to that of tectonic elements in the Mid-Continent and their relation to the Appalachian geosyncline. In eastern North America the Adirondack dome, Cincinnati arch and Nashville dome correspond to the three arcs of the Appalachian mountains. Beyond the lower Mississippi valley are the Ouachita mountains and the Ozark dome. Northwest of this chain of positive elements are the Michigan, Illinois and other basins, which form a row of depressions. The Sioux quartzite area represents the elevation lying farther from the mountain system. Needless to say, these domes and basins in central North America are incomparably larger and much less deformed than those of the Taitzuho valley. Nevertheless they alternate in a similar manner.

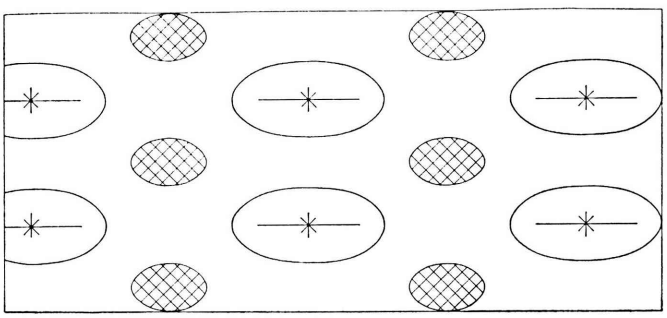


Fig. 40. Brachysynclines Alternating with Domes (crosses).

It is a remarkable fact that the domes and basins in North America bear positive and negative tendencies respectively and grew step by step through the Palaeozoic era. Such tendencies of embryonic folds cannot yet be recognized in the stratigraphic sequence of the Taitzuho region, if each basin is taken as a unit, but it is evident that the region as well as the P'yeongnam geosyncline were two zones of subsiding tendency which were separated by the P'yeongbuk land.

It is interesting that part of Eastern Asia, as exemplified above, reveals various features comparable to those of Laurentia and other megakratons, though on a miniature scale. Therefore it is noteworthy that, insofar as these common features are concerned, *there is no essential difference in the kratonic fragmentation between the mega-and micro-kratons.*

3. Deformation of the Quasikraton

The basins in the Taitzuho tributary are composed of the Mesozoic or P'yeongan formation in the central part, surrounded by the Korean group and then by the Hsiho series. There is a general tendency for their dip to become steeper distally.

Commonly a northern or southern block wedges in between two basins. These blocks and basins are mostly separated from one another by tectonic lines. Among such boundaries the northeastern and northwestern trends are more prominent than the equatorial or meridional ones. Some of the lines are indicated by normal faults, but many others are thrusts, upthrusts or disturbed zones.

Basin structures complicated by thrusts from two or more sides are not uncommon. Such basins may be called *closed basins*. They are caused by centripetal thrusting. The Wafangtien basin, bounded by low angle thrusts from the south and west, is an excellent example of such a basin. It may be said to be doubly closed, seeing that the Wafangtien coal-bearing sediments of Chaotzuyao are folded in between the Korean group on the east and west. The Shanchengkou basin of Hsiaoshih is thrust from the north and west; the Penhsihu basin is thrust from the west and south, but with high angles.

Due to the differential movement among basin sediments, some of them have also slipped outward relative to the underlying part. This type of centrifugal dislocation is sometimes seen within the Sangweon group in the Wuhutsuei basin. Such a basin may be called an *open basin*. The Hwangju basin in North Korea reveals this kind of structure (see Fig. 9). On the south side of the north P'yongnamdo coal-basin centrifugal dislocations are repeated in the Imcheon shale, forming the Seongch'eon imbricated zone (see Fig. 6). The western borders of the Penhsihu as well as the Tienshuaifukou basin are defined by thrusts which are close-set and nearly parallel to one another. Through Papanling on the western margin of the latter basin there are parallel thrusts along which the Korean and P'yongan groups are repeatedly thrust two or three times toward the east. The pre-Papanling thrust is a secondary dislocation along which Palaeozoic formations are pushed upon the Mesozoic. It is noteworthy that all of these dislocation lines among the middle and upper parts of the blanket formations are concave toward the basin.

The pre-Papanling upthrust is a product of a secondary dislocation similar to that of the pre-Alpine *Doppelüberschiebung*. The pre-Alpine *Überschiebung* took place in the culmination phase of the Alpine orogeny. There is some question, however, whether the primary thrusting was soon followed by a secondary one in the Taitzuho valley. In the outer zone of western Japan old and new tectonic lines trending parallel to each other near an important tectonic boundary are not uncommon. In western Shikoku there are the Butsuzo and pre-Butsuzo lines. The former is the boundary thrust between the Chichibu imbricated zone and the Shimanto folded zone in the Sakawa folded mountains. The latter marks the northern boundary of the Neo-Cretaceous formation in the Uwajima basin and must be a secondary tectonic line produced by the Middle Tertiary Oyashima disturbance. Along the eastern margin of the Akaishi mountains, as I pointed out earlier (KOBAYASHI, 1941), there are some parallel tectonic lines which were produced one after another by a similar mechanism.

The amount of dislocation is much larger along the Hsintungkou thrust than

along the Papanling thrust, because the pre-Hsiho basement complex is widely exposed on the west side of the former thrust. Another difference is that the former is convex toward the basin, but the latter somewhat concave. In the course of the thrusting of the western block upon the Penhsihu basin on the east side, the pre-Hsiho basement was cracked and these cracks issued as branches from the main thrust. The pre-Hsintungkou thrust is the secondary product of the repetition of a movement similar to that along the pre-Papanling thrust. I am particularly interested in the peripheral destruction of the western block by branches of the Hsintungkou thrust, because it appears to exhibit a stage earlier than the development into the *Schuppenstruktur* as seen at the two angles of the Chungbongsan block in South Korea.

The Hanpeling-Shangshantzu zone in the Taitzuho valley is a remarkable disturbed zone. It is narrow, long and arcuate, but fairly discordant with the structure of the Yentai basin. The strata in the zone are strongly disturbed, having a strike diagonal to the zone, an aspect which is suggestive of the rotation of the strata within the zone. The Tanagura disturbed zone in the Kwanto region in Japan is straight. Its nature is not yet well known, and its relation to neighboring blocks differs from that of the Hanpeling zone. In the central and western part of the Hida plateau in Japan there is a disturbed zone along the periphery of the Hida gneiss complex. The upper Palaeozoic formations are strongly disturbed and the Middle Palaeozoic formations and metamorphic rocks are wedged into the zone, but it is straight rather than arcuate. Furthermore, the southern boundary of the zone is obscure; I cannot find any example in Japan which is comparable to the Hanpeling-Shangshantzu zone.

4. Grade of Oronization

The mode of deformation of a given orogeny differs in various rocks, formations and terrains. As a rule, the finer the grains of a sediment or the more homogeneous a formation, the easier it is to change the relative position of the grains by compression. Therefore deformation by a crustal movement is stronger for shale than conglomerate, sandstone being intermediate between them.

The sedimentary rocks, when once folded intensely, are not as easily folded or thrust as before, though this is still feasible. The secondary thrusting or the B-type of thrust can clearly be distinguished in North Korea from the primary or A-type of thrust. The former is concordant with folding, while the latter is discordant with the folded structure.

The rocks and formations may be further consolidated by regional metamorphism, but the terrain may not be completely solidified until it is granitized. In other words the oronization, i.e., the consolidation and stabilization of a terrain, can be subdivided into three major grades—deformed, metamorphosed and granitized grades.

The Koreo-Chinese heterogen was largely oronized by the batholithic invasion

of granitic magma in the late Mesozoic period. Because Korea and South Manchuria were granitized almost completely, their subsequent development was unrelated to the previous tectonic lineament. Growth of the Korean peninsula since the latter part of the granitization truncates the P'yeongnam and Okch'eon zones almost at right angles. Such a discordance between the new and old tectonic elements is comparable to that between the Caledonian mountains and the Kareliden in Europe.

5. From Oronization to Anoronization

In looking through the various types of crustal deformations, it can generally be accepted that *the thinner the blanket formation, the greater the influence of its basement upon the deformation of the blanket.* The Yalu, Taitzuho and P'yeongnam types reveal deformation respectively of thin, intermediate and thick blanket formations caused by the same orogeny. These are all compressive deformations and their characteristics have already been pointed out.

The movements which took place in Koreo-Manchuria since the late Cretaceous period were mostly tension rather than compression. I shall not examine this trend of research very deeply here, but the following types of movements are significant:

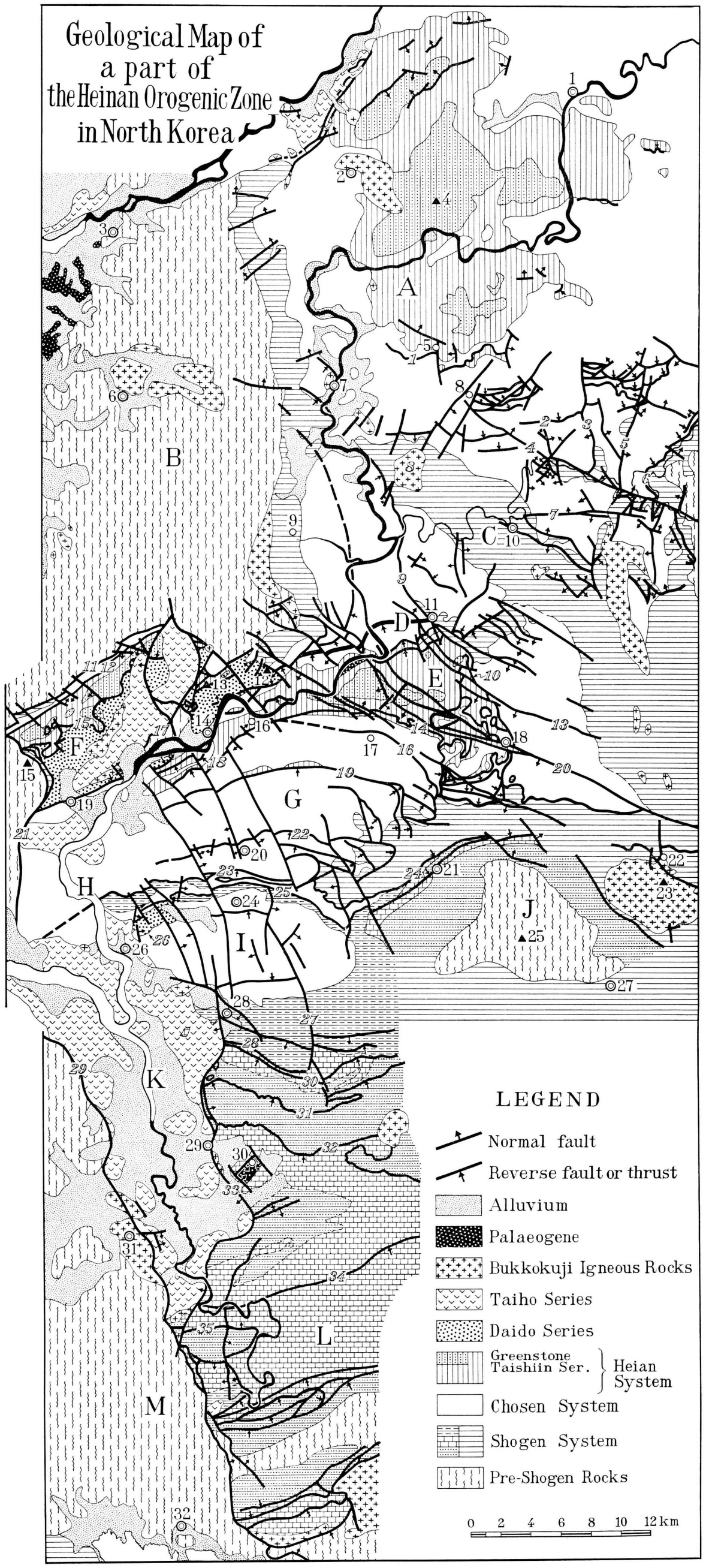
1) The Taebaegsan dislocation zone in Central Korea.
2) The Annak and Chinchou faults.
3) Upheaval of the asymmetrical geanticline indicated by the Yukpaiksan peneplane in Central Korea.
4) Tilting of the Kaema plateau and its peripheral destruction by the Hamgyeong fault system.

The first of these is a zone of faults intimately related to the Pulguksa igneous activity. Although it is difficult to date the faulting, the Annak and Chinchou faults are boundary faults of tilted blocks. They are both long and low angled faults along which the neighboring blocks slipped down. In these characteristics the dislocations are comparable with the sliding of the inner zone along the Median Tectonic Line in the Ichinokawa phase.

The Hamgyeong system is represented by a series of parallel or subparallel faults and the upheaval of the Kaema plateau must have been related in some way to the effusion of basalts or alkaline rocks which occurred before as well as after the principal tilting and faulting.

The geanticlinal upheaval of the Korean backbone appears to be unrelated to either the faulting or the volcanism, but this is not entirely true. It is cut diagonally by the Weonsan-Seoul tectonic valley, which is filled with basalt flows. Furthermore the volcanic rocks are distributed from Mt. Paektu-san to Cheju island through Ullŭng isle, describing an outer circle alone the Korean peninsula. It is clearly seen in Korea that *granitization was followed by culmination or Grossfaltung and volcanism of anorogenic type.*

I. Geological Map of a Part of the P'yeongnam (Heinan) Orogenic Zone in North Korea. (After S. Nakamura, I. Tateiwa, S. Shimamura, T. Shiraki, E. Konno, S. Matsushita, T. Kobayashi, N. Kobatake, K. Saito, T. Watanabe, N. Ikebe, et al.)

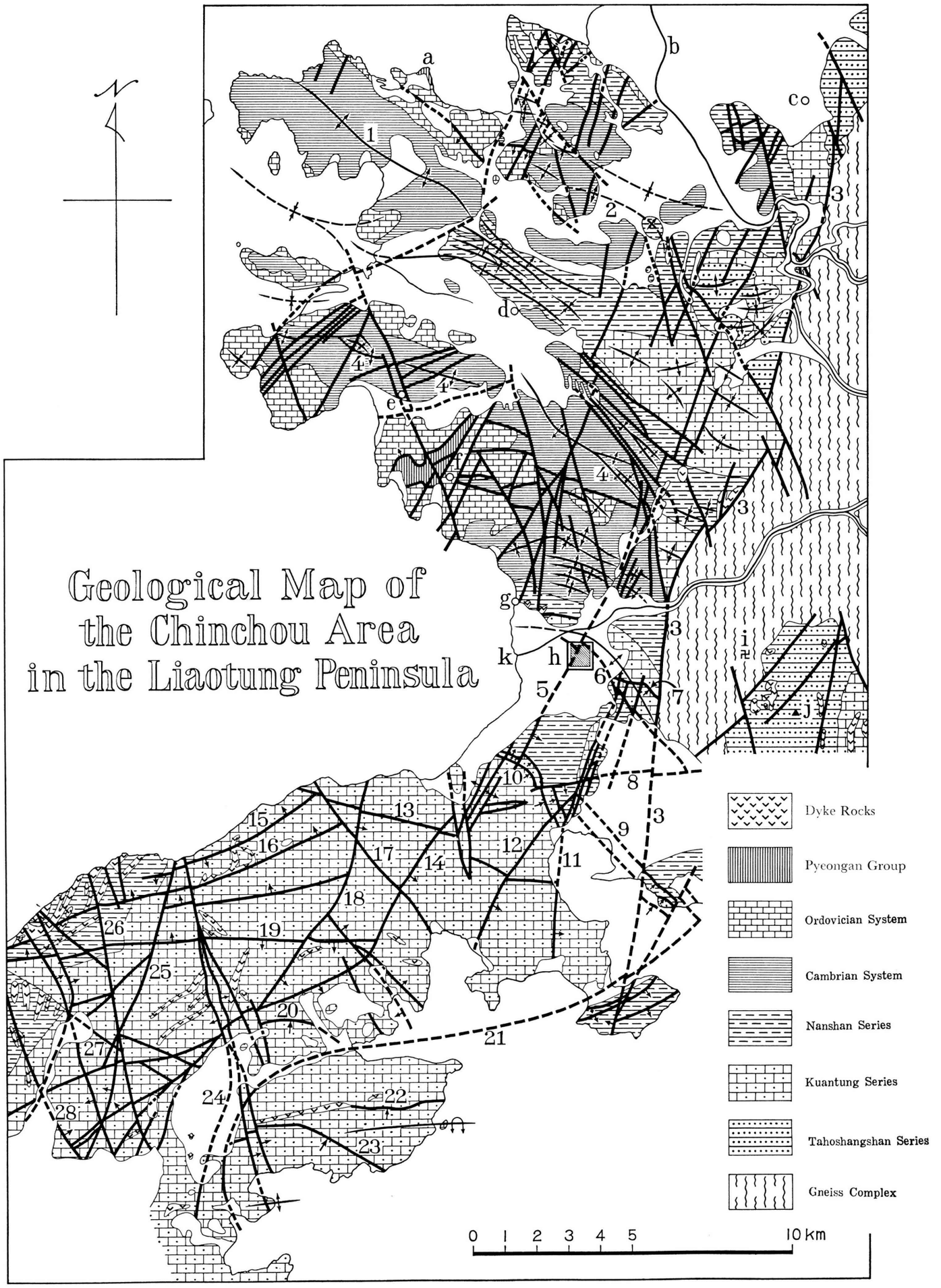


A. North P'eongnam Coal-field
B. P'yeongweon Massif
C. Seongch'eon Disturbed Zone
D. Boundary Tectonic Line between the Northern and Middle Parts
E. Kangtong Coal-field
F. Kangseo Coal-field
G. Chunghwa Disturbed Zone
H. Daedong-gang River
I. Hwangju Basin
J. Chŭngbong-san Dome
K. Chaeryeong-gang River
L. Chaeryeong-gang Disturbed Zone
M. Sinju Massif

1. Teok'cheon
2. Kaech ton
3. Anju
4. Maninbong
5. Ch'eongseong-ni
6. Sukch'eon
7. Sunch'eon
8. Sinch'ang-ni
9. Sainjang
10. Seongch'eon
11. Kangtong
12. Taeseong-san
13. Kambuk-san
14. P'yeongyang
15. Muhak-san
16. Sadong
17. Mandal-san
18. Samdŭng
19. Kiyang
20. Chunghwa
21. Sangweon
22. Holgol
23. Onjin-san
24. Hukkyo
25. Chŭngbong-san
26. Kyeomip'o
27. Suan
28. Hwangju
29. Sariweon
30. Pongsan
31. Chaeryeong
32. Haeju

1. Yeongdaeni Thrust
2. Sadosan Thrust
3. Sakch'ang-ni Fault
4. Changnim Fault
5. Hoeeomsan Fault
6. Pyeolch'angni Thrust
7. Hyangp'ungsan Fault
8. S'ungasan Granitic Mass
9. Ap'ari Thrust
10. Suip Thrust
11. Kŭmche Thrust
12. Changsan Thrust
13. Pongnaeni Fault
14. Teoksan Thrust
15. Taebo Thrust
16. Koyeongsan Thrust
17. Kiyang Thrust
18. Sadong Thrust
19. Post-Sadong Thrust
20. North Samdŭng Fault
21. Muhaksan Fault
22. Chunghwa Thrust
23. Chuyeomjong Thrust
24. Sangweon Thrust
25. Kuhyeonch'i Thrust
26. Songnimni Discordance
27. Tohyeon Fault
28. Toch'i Fault
29. Annak Fault
30. Teongmor Thrust
31. Cheongbangsan Thrust
32. Pongsan Thrust
33. Sariweon Fault
34. Ŭllyong Fault
35. Changsusan Fault

II. Geological Map of the Chinchou Area in the Liaotung Peninsula. (After S. MATSUSHITA)



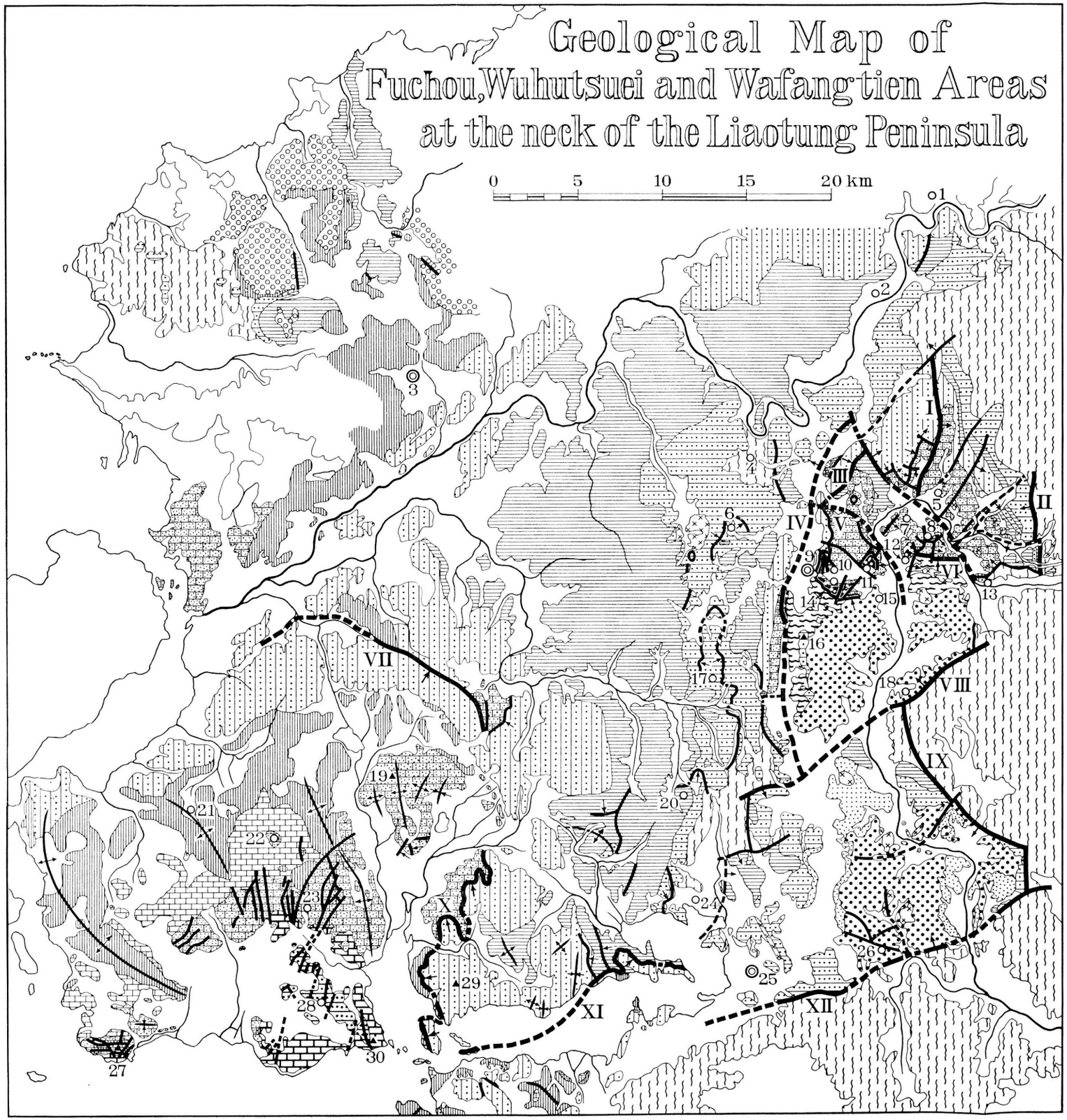
1. Lashushan Anticline
2. Chitingshan Anticline
3. Chinchou Fault
4. Houshihhueiyaotun Anticline
5. Chinchou-peimen Fault
6. Chinchou-tungmen Fault
7. Chinchou Thrust
8. Tahoshangshan Fault
9. Pre-Nanshan Thrust
10. Nanshan Thrust
11. East Tafangshen Fault
12. West Tafangshen Fault
13. Tamaoyingtzu Fault
14. Nankuanling Fault
15. Lashufang Fault
16. Chipanmê Fault
17. Chienkuantun Fault
18. Leishan Fault
19. Luotuoshan Fault
20. Chuanshueiyentzu Thrust
21. Lioushutun Fault
22. Haimiaotuotzu Thrust
23. Kanchingtzu Thrust
24. Liangyenching Fault
25. Tayüshan Fault
26. Panchüantzu Fault
27. Chungkechenpao Fault
28. Hsiachiahetzu Fault

a. Tiaohutzu
b. Sanshihlipu River
c. Sanshihlipu
d. Taweichiatunhuei
e. Houshihhueiyaotun
f. Chienshihhueiyaotzu
g. Lungwangmiao
h. Chinchou
i. Hsiangshueiszu
j. Tahoshangshan
k. Peitaiho

III. Geological Map of the Fuchou, Wuhutsuei and Wafangtien Areas at the Neck of the Liaotung Peninsula.
(After O. Aoji, T. Kobayashi, K. Horiuchi, M. Nakamura, M. S. Soo, R. Saito, M. Noda, et al.)

I. Sungchiatun Fault
II. Wangchengshan Fault
III. Wuchiatun Thrust
IV. Wafangtien Fault
V. Kaochiatun Fault
VI. Chiangchiatun Thrust
VII. Lüchiatun Thrust
VIII. Tawangchiatun Fault
IX. Feichiatun Fault
X. Wangpashan Thrust
XI. Yatang Bay Thrust
XII. Pulantien Fault

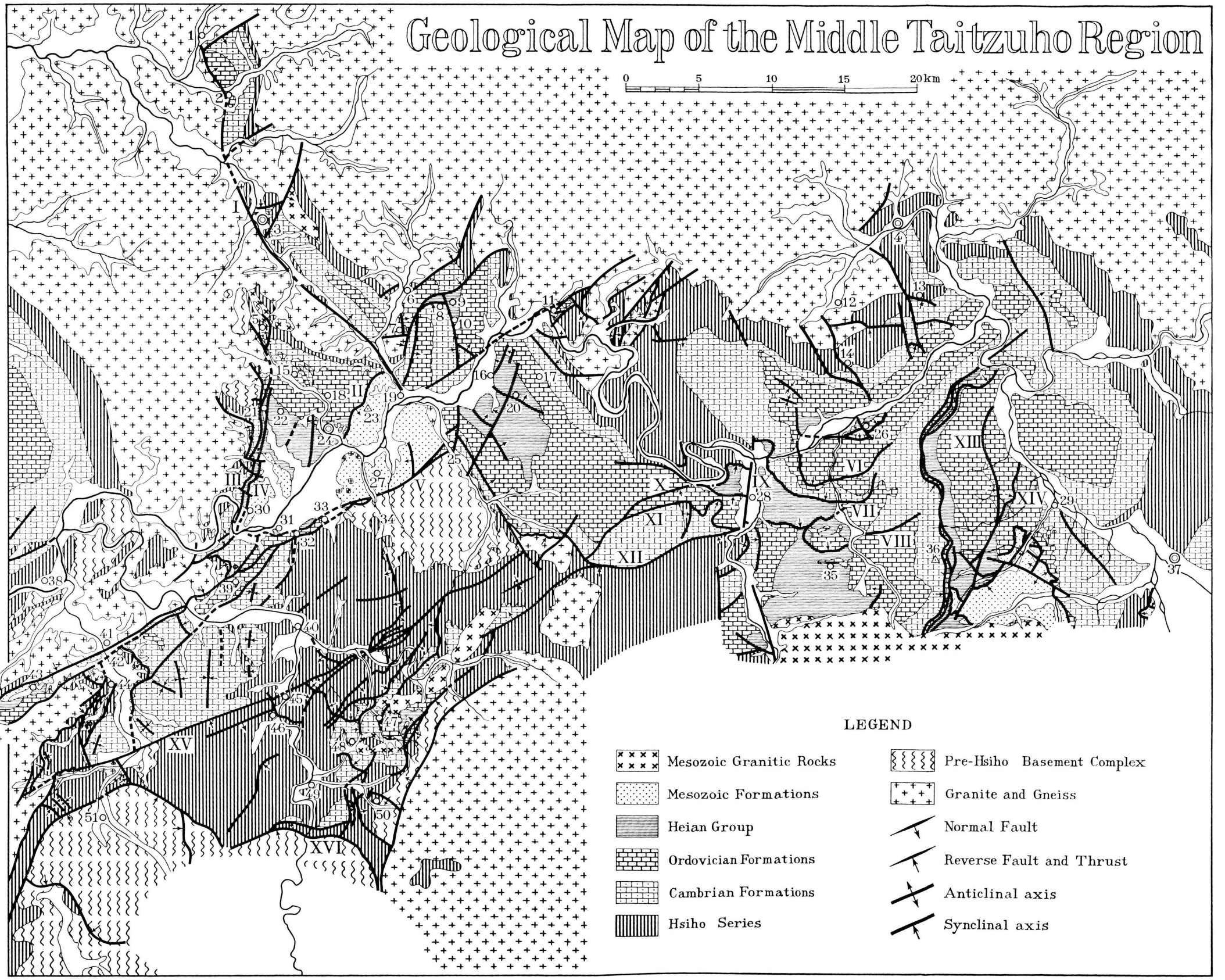
1. Sungshu
2. Teiliszu
3. Fuchou
4. Taipingkou
5. Luchiatun
6. Yinchiatun
7. Talinchiatun
8. Hsiaolinchiatun
9. Wafangtien
10. Chuanchüehfang
11. Chatzuyao
12. Takumiao
13. Tachengchiatun
14. Tangchiatun
15. Sunchiatun
16. Yuntaishan
17. Hêhuawan
18. Tawangchiatun
19. Waitoushan
20. Tsungwangmiao
21. Laoyufang
22. Yuanchiakou
23. Chinchiachengtzu
24. Sankuanmiao
25. Pulantien
26. Pipuhsien, Hifumi Pass
27. Yuntaishan
28. Feichiatun
29. Wangpashan
30. Sanlengshan



LEGEND

- Diluvium
- Pulantien Formation
- Igneous Rocks
- Wafangtien Formation
- Heian Group
- Ordovician Formation
- Cambrian Formation
- Yungning Sandstone
- Chinchia Black Limestone
- Kaochiatun Shale
- Chaiotou Quartzite
- Nanfen Shale
- Tiaoyütai Quartzite
- Gneiss
- Dolomite and Phyllite
- Normal fault
- Reverse fault or thrust

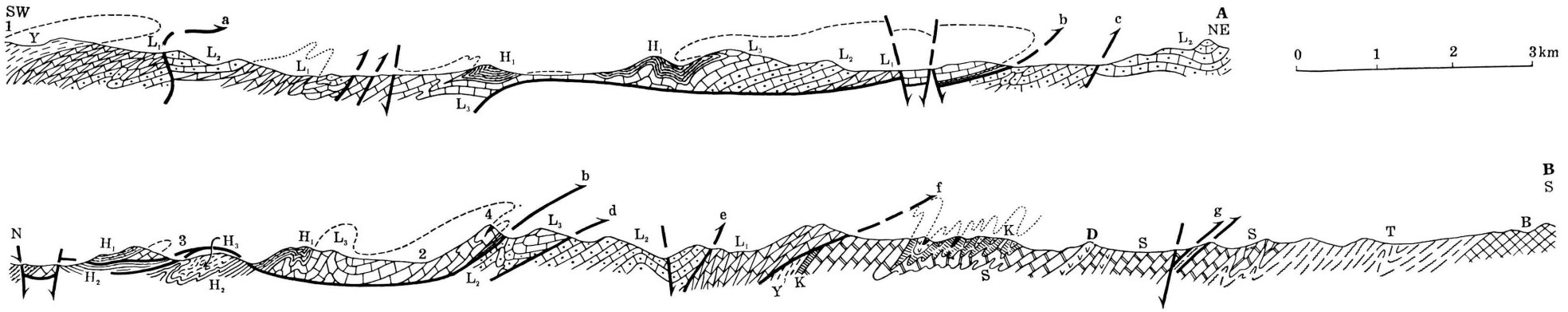
IV. Geological Map of the Middle Taitzuho Region. (After O. AOJI, J. HATA, R. ENDO, T. KOBAYASHI, N. KOBATAKE, M. MORISHITA, Y. YOSHIKAWA, I. YOSHIMURA, et al.)



1. Paihsingchai
2. Kantaijentun
3. Shihchiaotzu
4. Chinghecheng
5. Taling
6. Lichiawepeng
7. Hueishan
8. Houti
9. Yaotzuyü
10. Shueiyaokou
11. Pienlingpaotzu
12. Hsichiapaotzu
13. Machiakou
14. Hsikou
15. Huolienchai
16. Shangniuhsintai
17. Wanwankou
18. Santaokangtzu
19. Weiningcheng
20. Hunglienkou
21. Hsintungkou
22. Toufangkou
23. Chiashan
24. Penhsihu
25. Wolung
26. Tungshan
27. Kaolifenchü
28. Hsiaoshih
29. Tienshuaifukou
30. Linchiasueitzu
31. Tungshantzu
32. Chinfukou
33. Yaopao
34. Pingtingshan
35. Shanchengkou
36. Papanling
37. Chienchang
38. Shenwe
39. Achiakou
40. Chiaotou
41. Kuchiatzu
42. Huangchiapaotzu
43. Hanpeling
44. Chioukeyü
45. Puchiszu
46. Tiaoyütai
47. Taihungpaiyü
48. Hsiaomiaokou
49. Nanfen
50. Miaoerkou
51. Wangchiapaotzu

I. Shihchiaotzu Fault
II. Minshankou Fault
III. Hsintungkou Thrust
IV. Pre-Hsintungkou Upthrust
V. Pingtingshan Upthrust
VI. Yaopao Thrust
VII. Mapichiangkou Thrust
VIII. Lishantaokou Thrust
IX. Hsiaoshih Fault
X. Pichiakou Thrust
XI. Niangniangkou Thrust
XII. Linchiapaotzu Thrust
XIII. Kuchiakou Thrust
XIV. Tiehtzushan Thrust
XV. Tiaoyütai Thrust
XVI. Nanfen Thrust

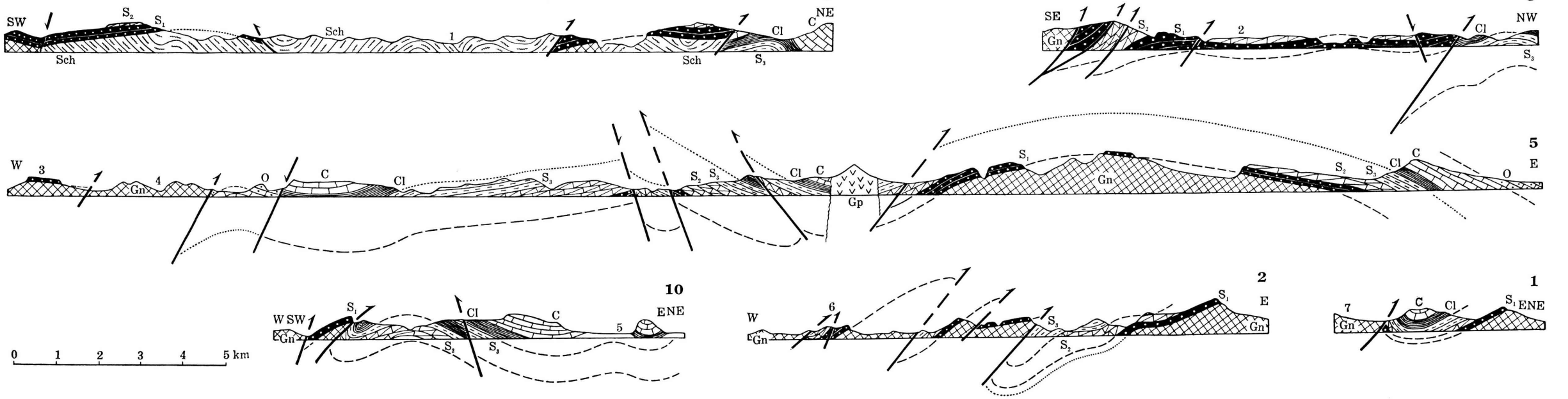
Va. Two Profiles of the Samdŭng-Sangweon Area in North Korea. (After N. IKEBE)



H_3. Gobangsan Series
H_2. Sadong Series
H_1. Hongjeom Series
L_3. Upper Great Limestone Series
L_2. Middle Great Limestone Series
L_1. Lower Great Lime stone Series
Y. Yangdeok Series
K. Kuhyeon Series
S. Sadongmor Series
T. Chikhyeon Series
B. Basement Complex
D. Dyke Rocks

a. Koyeongsan Thrust
b. Teoksan Thrust
c. Suip Thrust
d. Taeyeonni Thrust
e. Sinmadong Thrust
f. Kojeongsan Thrust
g. Sangweon Thrust
h. Chŭngbongsan Dome
1. Koyeongsan
2. Namgang
3. Teoksan
4. Kanjinsan
5. Kojeongsan

Vb. Six Profiles of the Middle Taitzuho Valley (After I. YOSHIMURA)



Gp. Granite Porphyry
H. P'yeongan Group
O. Ordovician System
C. Middle and Upper Cambrian Formations
C_1. Lower Cambrian Formation
S_3. Chiaotou Quartzite
S_1. Nanfen Shale and Marl
S_1. Tiaoyütai Quartzite
Gn. Gneiss
Sch. Schists

1. Lanhe
2. Chinghecheng
3. Peitaiping
4. Nanfen
5. P'ienlingpaoyzu
6. Pingtingshan
7. Wangchiatun

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Cyanite-Andalusite Deposits in the So-Called Okch'ŏn (Yokusen) System

Takao YAMAGUCHI

1. Preface

It was only in the few years following 1939 that cyanite-andalusite deposits were discovered in the so-called Okch'ŏn (Yokusen) System. The deposits are distributed in schistose rocks, just as in other parts of Korea. The cyanites in the deposits are generally very large crystals. The length along the c-axis is generally about 10 cm and occassionally about 50 cm. The so-called Okch'ŏn System has been considered one of the Archean Systems in Korea, but many geologists, including the author, tend to doubt this because of the lack of conclusive evidence.

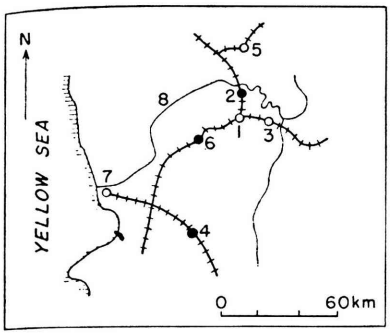
The author surveyed deposits in the three regions as follows:

1. The Okch'ŏn area proper
2. The eastern region of Yŏnsan
3. The vicinity of Chŏnju

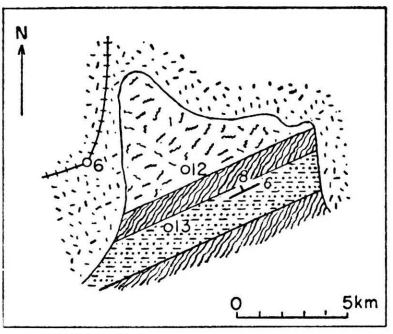
2. Geology and Petrology

1. *Geology of the so-called Okch'ŏn System*: The geological map is shown in Fig. 1. The metamorphic rocks in the three regions are thought to belong to the same geologic system because they have very similar rock layers—mica schist, chiastolite-bearing schist and quartzose schist or granulite. The plane of schistosity and the plane of stratification are thought to be parallel to one another because no evidence to the contrary has been found. The connection between the geological structures of the three regions, therefore, is thought to be a recumbent syncline separated by intrusions of granite (Fig. 2).

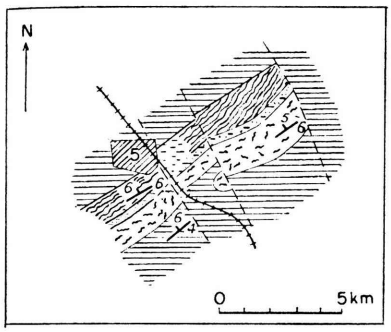
2. *The relationship of granite* (G) *and Gneiss* (N) *to the so-called Okch'ŏn System*: In the Okch'ŏn region and the eastern region of Yŏnsan, the system is intruded by granite (G), perhaps belonging to the Pulguksa Series. The granite (G), therefore, is thought to have intruded after the formation of schistosity in the system. The granite shows almost no thermal metamorphism in the schists even along their contact zones.



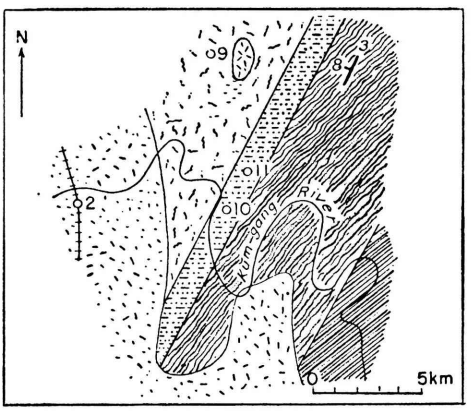
A. Index map



B. Geological map of the eastern part of the Yŏnsan district



C. Geological map of the environs of Ch'ŏngju



D. Geological map of the type localities of the Okch'ŏn system

Fig. 1. Index Map and Geological Maps of Part of Southwestern Korea.

LEGEND

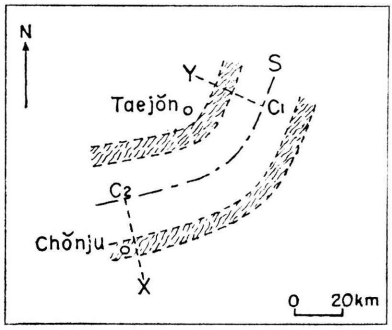
- Conglomeratic phyllite
- Mica-schist
- Chiastolite-schist
- Cyanite andalusite deposit
- Quartzose-schist (Granulite)
- Granite (Pulguksa series?)
- Blasto-mylonitic gneiss
- Strike and dip

NAMES

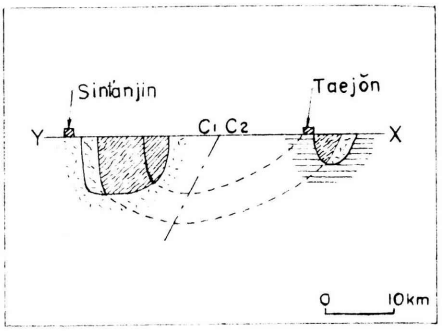
1. Taejŏn
2. Sint'anjin
3. Okch'ŏn
4. Chŏnju
5. Ch'ŏngju
6. Yŏnsan
7. Kunsan
8. Kum-gang
9. Munui
10. Pugong-ni
11. Sansŏ-ri
12. Yangsal-li
13. Tŏngmong-ni

Gneiss (N) is distributed over the Chŏnju region and the plane of schistosity is almost parallel to that of the Okch'ŏn System. The apparent intrusive relationship along the contact zone is disturbed by dynamometamorphism. The gneiss is a blasto-mylonite (Fig. 3) and the "Gefügerelung" of any quartz present shows

the effect of considerable dynamometamorphism (Fig. 4). The original gneiss (granite), therefore, is thought to have intruded before the dynamometamorphism of the system as SHIMAMURA, (1926) and SUZUKI (1926) have ever stated.



A. Horizontal Section showing flexure



B. Vertical section showing recumbent syncline

Fig. 2. Geologic Structure.

LEGEND

- Conglomeratic phyllite
- Mica-schist
- Quartzose-schist (Granulite)
- Granite
- Blasto-mylonitic gneiss

YC_3C_2X Plane of vertical section (B)
S Axis of syncline

STRATIGRAPHICAL SUCCESSION

Upper
- Conglomeratic phyllite (4,000m)
- Mica-schist (8,000m)
- Quartzose-schist (5,000m)

Lower

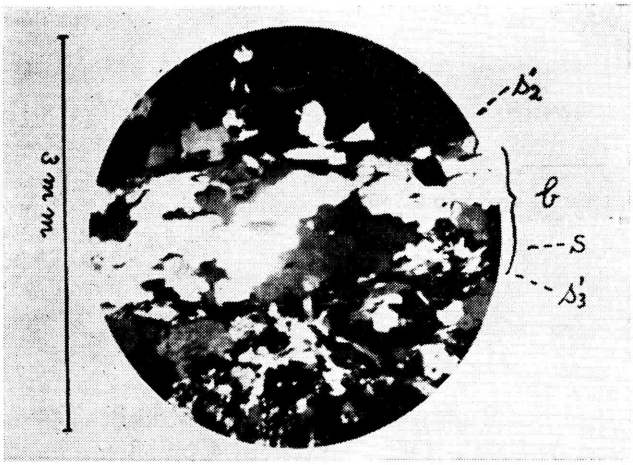


Fig. 3a. Quartzose Band.
(Under crossed nicols)

b Quartzose band parallel to the general schistosity (S)
S'_2, S'_3 Planes of quartz grains showing blasto-mylonitio structure.

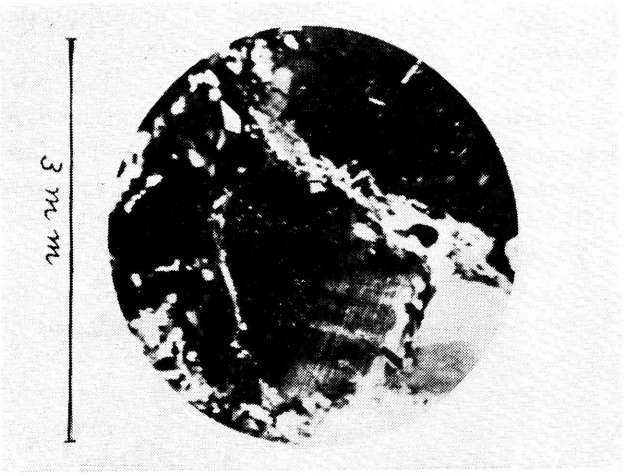


Fig. 3b. Deformed Phenocryst of Plagioclase.
(under crossed nicols)

The phenocrysts of plagioclase show wavy extinction under crossed nicols caused by deformation.

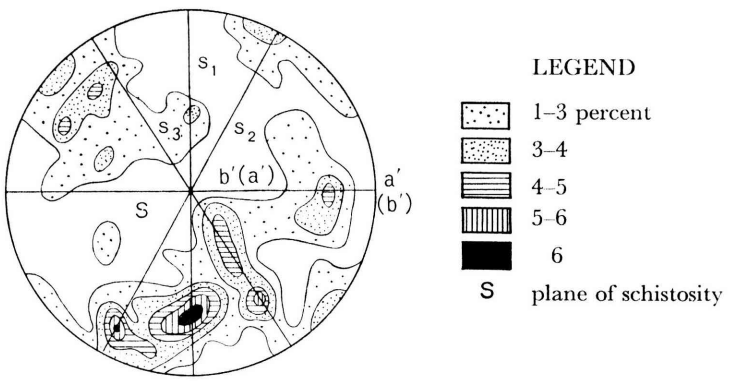


Fig. 4. The "Gefugeregelung" of Quartz in the Quartzose Layer
S_1, S_2, S_3, Latent planes of "Einregelung" (8.5 c-axis)

The field relation between the granite (G) and gneiss (N) was not discovered.

3. *Metamorphic rocks of the so-called Okch'ŏn System*: Metamorphic rocks are generally of a lower grade. According to Eskola's mineral-facies principle, they show chlorite facies~biotite facies. They can be divided roughly into three types: conglomeratic phyllite (P), mica schist (M), including chiastolite-bearing schist (C), and quartzose schist or granulite (Q) (Figs. 1 and 2).

Conglomeratic phyllite (P) The pebbles are derived from quartzite and are relatively sparse. The phyllitic part is composed of chlorite, sericite and quartz. It is similar to the conglomeratic phyllite in the uppermost formation of the so-called

Sangwŏn System to the north of the Yŏnchŏn Metamorphic Group,* but the former has a higher distribution density than the latter.

Mica schist (M), *including chiastolite-bearing schist* (G) The mica schist is composed of biotite-muscovite, together with some chlorite-sericite-quartz schist and chiastolite-bearing graphite. The chiastolite forms large columnar crystals (the length along the c-axis is 1–5cm), which generally tend to crowd one another. The c-axis generally lies on the schistosity plane. In the Okch'ŏn region and the eastern region of Yŏnsan, the cyanite deposits show a very close relationship to the chiastolite-bearing schist. In the mica schist zone, rare cordierite-mica rocks are found (the diameter of the cordierite is as great as 1 cm) along with some garnet-anthophyllite-cordierite rocks.

Quartzose schist (Q) *or granulite* This zone is composed of tremolite or sericite-bearing quartzose schist or granulite, and contains some mica schists and crystalline limestone. Linear schistosity is not found, in general, except at the contact of the sericite-quartz schist and the gneiss south of Chŏnju (Figs. 1 and 4).

3. Cyanite-Andalusite Deposits

Descriptions of the deposits (divided into four groups):

a. Cyanite deposits in the mica schist zone in the Okch'ŏn region
a′. The same as "a" in the eastern region of Yŏnsan
b. Andalusite deposits in the mica schist in the zone of granulite in the Okch'ŏn region
c. Andalusite deposits in the zone of mica schist near Chŏnju

Deposits a and a′ have the same characteristics. "a" and "a′" deposits occur in the chiastolite-bearing schist zone and are closely related to the schist. They are cyanite-bearing veins or pockets which accompany quartz (Fig. 5). In mining, weathered residual blocks are collected. The average cyanite content is about 50 percent. The "a′" deposits are concentrated around Tongmong-ni and the "a" deposits around Sansŏ-ri. The amount of cyanite in the two regions is about 4,000 tons. The "b" type deposit is found near Munŭi. The deposit is an andalusite-bearing vein, accompanied by cyanite, muscovite and quartz, in garnet-biotite-muscovite schist. It resembles the deposits of the Yŏnchŏn Metamorphic Group. The deposits near Chŏnju are andalusite-bearing veins or pockets which accompany quartz and chiastolite-bearing schist in the mica schist zone. The amount of andalusite present may reach 3,000 tons.

Genesis of the deposits—The genesis of deposit "b" is thought to be the same as that in the Yŏnch'ŏn Metamorphic Group. As for deposits closely related to chiastolite-bearing schist (a, a′ and part of c) (Fig. 5), chiastolite is thought to have recrystallized in fissures or cavities. As for deposits in mica schist, the fine needles

* Refer to the author's paper "On the so-called Yŏnch'ŏn System and the Cyanite-andalusite deposit in it".

of sillimanite in the fine veins, composed of sillimanite and chlorite, are the present problems (Fig. 6).

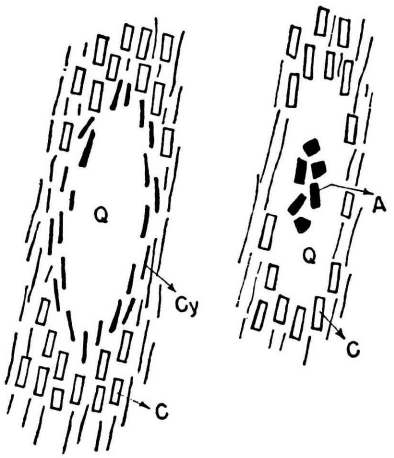


Fig. 5. Sketch of Cynite-Andalusite-Bearing Veins or Pockets in the Chiastolite-Bearing Schist.

Q, Quartz; Cy, Cyanite; A, Andalusite; C, Chiastolite

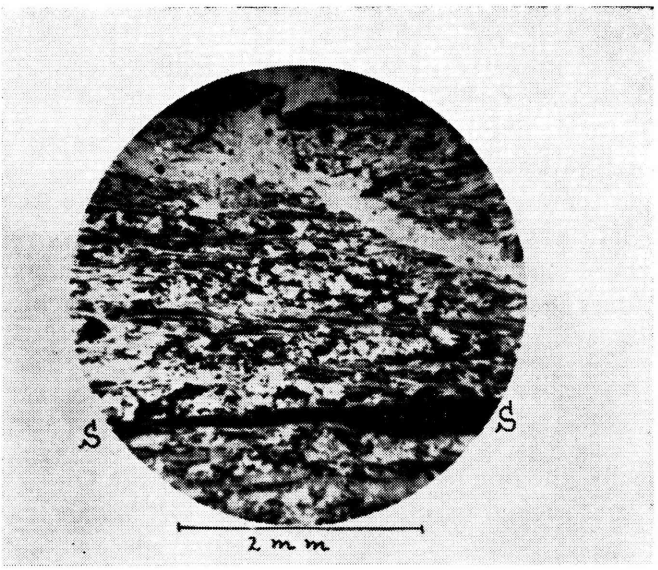


Fig. 6a. Sillimanite-Chlorite Vein.

S, Sillimanite-chlorite vein parallel to the general schistosity. In this vein, many fine needles of sillimanite lie parallel to the vein walls in matrics of chlorite.

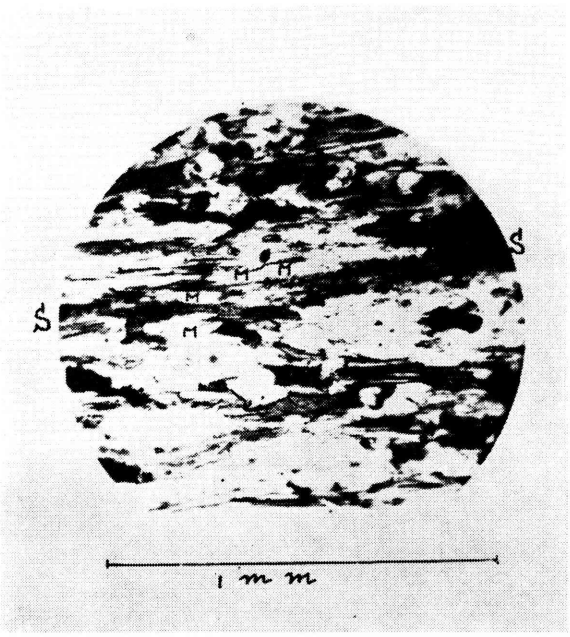


Fig. 6b. Sillimanites after Muscovite.
M, Sillimanite aggregate after muscovite. The sillimanite needles lie parallel to the cleavage planes of muscovite.
S, Sillimanite-chlorite vein.

It seems sure that the fine veins of sillimanite and cholorite were formed by means of a process such as the following:

micas $-K_2O\rightarrow$ sillimanite + chlorite,

where $-K_2O$ means the removal of K_2O.

It is possible that the chiastolite-bearing schist was derived from a mica schist by means of a similar process:

mica schist $-K_2O\rightarrow$ chiastolite-bearing chiorite schist,

even if its original rocks might have been rather rich in Al_2O_3.

The chiastolites are thought to have been formed under dynamometamorphism, because their c-axes lie on the schistosity plane. They were sericitized by the addition of K_2O in a later stage.

4. Summary

1. Chronologically, the original sedimentary rocks of the Okch'ŏn System were formed before the original granite of the gneiss (N), which is older than the granite (G).

2. The dynamometamorphism occurred later than the intrusion of the original granite of the gneiss (N) in the Chŏnju region, and earlier than the intrusion of Pulguksa granite (G).

3. The cyanite-andalusite deposits are divided into two types, according to occurrence: (a) those in mica schist, and (b) those closely related to chiastolite-bearing schist.

4. Genetically, the (a) deposite were formed from mica schist by means of K_2O-removal, and the (b) deposits by means of migration of chiastolite into the fissures or cavities. It is also possible that the chiastolite-bearing schist was derived from the mica schist by means of K_2O-removal.

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2) Suzuki, J. (1926). *Jour. Geol. Sec. of Japan*, v. XXXIII, p. 443.

Boron Mineral Resources in Korea

Takeo WATANABE

Introduction

The unexpected discovery of kotoite, a boron mineral, at the Suan gold mine by the author during his studies on the geology and ore deposits of that mining district in Hwanghae-do, Korea, brought him also to study the boron mineral resources in various districts. About 1938, the stock of boron ore, which had been imported from the North and South American continents, became insufficient for the requirements of Japan. Moreover, later imports did not go smoothly and the question arose whether boron mineral resources within Japan and Korea might be sufficient for use of that time, pure borax and such crude borates as kernite and natural borax of North America, as well as ulexite from Chile and Argentina, were imported. These ores were of relatively high grade, containing 20–35% B_2O_3.

As the imported ore consisted of minerals which were formed on the surface of arid regions such as in California and the Andes, it was evident that similar ore could hardly be found in Japan, Korea or Manchuria. For this reason, even though the ore was not of very high grade, all boron minerals containing any amount of B_2O_3 became the subject of discussion. That is, all localities where tourmaline, danburite, ludwigite, kotoite or szaibelyite occur were investigated. At the same time, new methods of manufacturing borax and boric acid from these minerals were also studied. The manuscript of this report was completed in 1944.

Brief descriptions of the geology and ore deposits of some localities which came to the front at that time are given here. Detailed descriptions of kotoite were published in other paper (WATANABE, 1967).

The author wishes to express his gratitude to the late Professor Takeo Kato, and to Messrs. Iwao Tateiwa, Rokuro Endo and Chuzo Kondo, for their great help and guidance.

1. Boron Minerals and their Uses

More than fifty kinds of natural minerals containing boron are known, but only about ten have been used in the manufacture of boric acid and borax.

Table 1

Important mineral		B_2O_3 (%)	Chief producer
Sassolite	$B(OH)_3$	56.4	Italy
Borax	$Na_2B_4O_7 \cdot 10H_2O$	36.5	U.S.A.
Kernite	$Na_2B_4O_7 \cdot 4H_2O$	51.0	U.S.A. (California)
Colemanite	$Ca_2B_6O_{11} \cdot 5H_2O$	50.8	U.S.A.
Boracite	$Mg_3B_7O_{13}Cl$	62.2	Germany
Hydroboracite	$CaMgB_6O_{11} \cdot 6H_2O$	50.5	U.S.S.R.
Inderite	$Mg_2B_6O_{11} \cdot 15H_2O$	37.3	U.S.S.R.
Szaibelyite	$MgHBO_3$	40–43	U.S.S.R.
Priceite	$Ca_5B_{12}O_{23} \cdot 9H_2O$	49	Turkey

About 1940, the world output of crude ores for manufacturing borax and boric acid had reached 300,000 tons a year, with North America supplying 80 to 90% and the remainder coming from South America (Argentina, Peru and Chile).

Ores from North America consist principally of kernite and natural borax, which occur as stratified deposits in the arid regions of California, Nevada and Oregon. This ore can be easily treated, as it consists of borax, which is relatively soluble in water, and kernite (20–35% in B_2O_3 content), which is soluble in both brine water and weak acid. Some of this ore was imported by Japan and then exported to Korea after being refined to borax and boric acid. Colemanite had been a principal crude boron mineral ore until about 1927, when kernite was discovered, and is not now mined.

Most boron ores from South America are composed chiefly of ulexinite, which is mined in the neighborhood of dried-up and salt lakes in the desert near the Andes Mountain Range. This was also imported by Japan and greatly utilized.

Turkey was the important producer in Europe, where priceite (or pandermite) was mined. In the U.S.S.R., various boron minerals containing magnesia were mined in the neighborhood of Inder Lake, north of the Caspian Sea. In Italy, boric acid was recovered from hot springs. In Germany, B_2O_3 was recovered as a by-product from boracite (or stassfurtite), which occurs in rock salt, and supplied to satisfy the European demand.

As described above, the boron resources mined at that time were only of such minerals as were readily soluble in water, or were easily treated with weak acid. Insoluble magnesium borates and boron-bearing silicates were not thought of as mineral resources.

Minerals such as borax and other crude borates, which are unstable in humid regions, do not seem to have been formed on a large scale in Japan and Korea, probably because of few arid regions even in past times. Thus, the discovery of ore deposits such as the above was thought to be nearly impossible. As a result, other boron minerals came to be considered, and their modes of occurrence minutely investigated.

a. Tourmaline

Tourmalines have a very complex chemical composition, and are divided roughly into the following three.

Table 2

	1	2	3	4	5	6	7	8	9	10
	Sangnong	Sangnong	Sangnong	Sangnong	Tanch'ŏn	Kinsei	Ilgwang	Ilgwang	Haman	Miryang
SiO_2	36.77	38.54	35.34	36.36	35.94	37.59	31.20	35.08	61.25	35.55
TiO_2	1.03	—	—	—	0.31	0.38	0.51	—	0.12	1.51
Al_2O_3	30.70	23.37	36.04	33.70	34.36	34.20	26.81	26.31	8.69	25.62
Fe_2O_3	0.38	13.93	8.54	7.34	0.41	3.64	15.01	14.37	11.58	0.50
FeO	6.62	—	—	—	7.25	8.65	—	—	—	18.21
MnO	0.10	1.37	—	—	tr.	—	0.51	—	0.15	0.14
CaO	2.34	2.49	1.41	1.60	0.39	0.51	1.97	3.74	4.20	0.80
MgO	7.71	5.90	8.40	6.10	5.76	0.29	2.27	4.29	1.63	4.19
B_2O_3	8.34	8.20	10.40	9.03	9.46	6.76	8.05	7.04	0.2	9.15
K_2O	0.84	0.94	—	0.54	0.34	3.74	0.84	4.95	0.44	0.08
Na_2O	2.21		—	2.44	2.55	1.43	1.95		0.60	1.83
H_2O	3.23	3.69	—	2.94	3.02	3.09	2.59	—	3.66	3.38

(1) Magnesium tourmaline (High-grade ore) Sangnong Mine, S. Hamgyŏng; accord. to N. YAMAMOTO
(2) Magnesium tourmaline (High-grade ore) ibid.; analysed by the Takeda Med. Inc. Co.
(3) Magnesium tourmaline (High-grade ore) Korea (Copper ore from Sangnong?). accord. to KANEKO and others.
(4) Magnesium tourmaline (High-grade ore) ibid.
(5) Magnesium tourmaline (Dravite)(High grade ore) Tanch'ŏn. S. Hamgyŏng; accord. to N. YAMAMOTO
(6) Iron tourmaline Kinsei Mine. Kangwŏn; accord. to N. YAMAMOTO
(7) " " Ilgwang Mine. S. Kyŏngsang; accord. to N. YAMAMOTO
(8) Iron tourmaline ibid.; accord. to S. NAGAI
(9) Tourmaline-bearing quartz (Low-grade ore) Haman Mine. S. Kyŏngsang; accord. to N. YAMAMOTO
(10) Iron tourmaline Miryang, S. Kyŏngsang; accord. to N. YAMAMOTO

Elbaite	$Na\ (Al,Li)_3\ Al_6\ (BO_3)_3\ Si_6O_{18}\ (OH)_4$
Dravite	$NaMg_3Al_6\ (BO_3)_3\ Si_6O_{18}\ (OH)_4$
Schorlite	$NaFe^{II}_3Al_6\ (BO_3)_3\ Si_6O_{18}\ (OH)_4$

The constituents average 32–38% SiO_2, 20–40% Al_2O_3, 9–11% B_2O_3, 0.5–1% F and 2–3% H_2O, and sometimes contain alkali, including Na_2O, Li_2O, K_2O, etc. (0–5%), magnesia (0–14%), and iron oxide (1–20%).

Chemical analyses of tourmalines from Korea are tabulated in Table 2. below:

As is obvious in Table 2, tourmalines from Sangnong and Tanch'ŏn in North Korea are of the magnesian variety, while those from various localities in South Korea are mainly of the ferroan variety.

Tourmalines occur most commonly in acidic igneous rocks as granite, especially in pegmatite, aplite and hypothermal quartz veins or iron deposits, as well as in the neighboring contact metamorphic rocks. The richness in magnesia of tourmaline in North Korea seems to be in some genetic relation to the fact that magnesia-rich rocks, including magnesite, dolomite and magnesian pelitic schists are abundantly distributed all over the northern districts of Korea.

The B_2O_3 content of tourmaline is not high, attaining only about 9%. Tourmaline is a relatively stable mineral, making it difficult to recover B_2O_3. Japan, however, succeeded in making boric acid from this mineral, recovering B_2O_3 by treatment with either HCl or H_2SO_4 after heating at high temperature (800°C), or by heating it together with soda ash. Though the process may increase the production cost, at any rate it succeeded in recovering B_2O_3 on an industrial scale. In this process, it became clear that alkali tourmaline and magnesia tourmaline are more easily decomposable than iron tourmaline, and accordingly their treatment is somewhat easier than the latter. This may have been an important reason why the Sangnong tourmaline was investigated.

b. Kotoite

Kotoite is a magnesium borate having the composition $Mg_3B_2O_6$. It was first discovered in the Holgol (or Hol Kol) deposit of the Suan gold mine, Hwanghae-Do, and it occurs in contact metamorphic rock formed through pneumatolytic action. The B_2O_3 content of kotoite is 36.5%; however, the mineral does not occur singly but always with calcite, forming kotoite-marble, in which case the B_2O_3 content is no greater than 9–12%. Although kotoite is difficult to dissolve in water and in dilute hydrochloric acid, in general, it becomes easily soluble in water when heated together with soda ash, enabling one to separate out the boric acid content. Institute of the Hitachi Manufacturing Co. then established factories at Inch'eon and P'yeongyang, and produced borax using the above method. There ore used, so-called Kotoite, was really rock which may be called "Kotoite-marble".

For further details on the mode of occurrence and properties of kotoite, readers are referred to another report (WATANABE, 1967).

c. Szaibelyite

The mineral is a hydrated magnesium borate, $HMgBO_3$ or $2MgO \cdot B_2O_3 \cdot 2H_2O$, containing as much as 40% B_2O_3. It is hardly soluble in water like kotoite and occurs in the contact metamorphic zone in dolomite regions, forming at times massive metasomatic ore bodies. This mineral is also found in Manchuria, near Korea, and other districts, and some occurrences contain a considerable amount of boron, and were actually mined in part. In Korea, it was found in association with ludwigite, but in small amounts.

Some of the rocks with szaibelyite contain 10–15% B_2O_3, and at times, 25% B_2O_3. These ores can be treated, on the whole, similar to kotoite, and may also be treated directly with acids. It is highly possible that the mineral will be found in North Korea in the future.

d. Ludwigite

Ludwigite is a borate mineral having the composition $4MgO \cdot Fe_2O_3 \cdot B_2O_3$, and occurs in pneumatolytically metamorphosed rocks on the contact between dolomite and granite. The ore contains 15–17% B_2O_3, and occurs in association with iron and copper in the deposit. Though it has been found in Namjŏng (Tul mijŏng), Holgol and in the Ŭnsan gold mine, it is small in amount and ore deposits are not large enough to be developed as a of boron in Korea. In Manchuria, ore from Hua-tung-kou and other localities have come to the front sources of boron.

e. Other boron minerals

Although axinite (5% B_2O_3), danburite (28.6% B_2O_3) and datolite (9–11% B_2O_3) are all boron-bearing silicates, little notice was taken of them because of their low boron content and the difficulty involved in treatment. Of them, danburite occurs in abundance at Toroku, in Kyushu, Japan, and was once mined to some extent. In addition, johachidolite, a boron-bearing mineral with fluorine, was found at Sangpa'l-tong, Kilchu-gun, Hamgyŏng-pukto, North Korea, and a mineral called suanite was discovered from Holgol, however, they have no significance as a source of boron.

2. Geology and Ore Deposits

(I) Johachidolite from near Sangp'al-tong

Sangp'al-tong in Changbaeng-myŏn, Kilchu-gun, Hamgyŏng-pukto, is located near the boundary between Hamgyŏng-pukto and Hamgyŏng-namdo. At Sangp'al-tong, nepheline dikes cut the limestone. Recently, a new mineral-bearing boron, named johachidolite, has been discovered in the above dike, but the amount or quality of the ore present has not yet been determined.

(II) Sangnong Mine (Tourmaline)

General view: The Sangnong mine is located near the middle reaches of the

Namdaae-ch'ŏn (river), running through the northeast part of Hamgyŏng-namdo. Gold, copper and cobalt ores had been prospected in this mine for three years prior to 1948, when Keizaburo NAKAMURA, a geologist of the Geological Survey of Korean G.G., found a large amount of tourmaline contained in the country rock of ore deposits in the region. The ore deposit consists of gold-copper-cobalt-bearing quartz veins running nearly parallel to the stratification of tourmaline-bearing schist. The impregnation deposits nearby the veins also contain

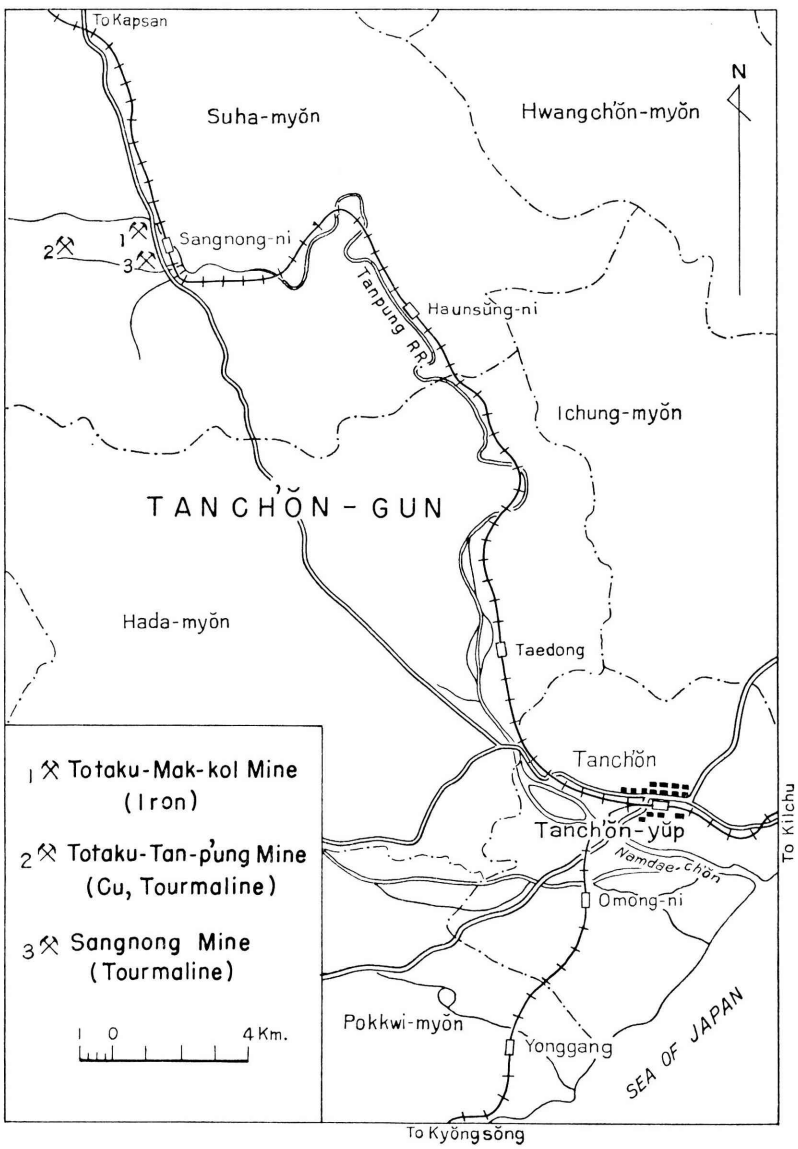

Fig. 1. Map Showing the Location and the Communication of the Sangnong, the Totaku-mak-kol and the Totaku-Tanp'ung Mines, Tanch'ŏn-gun, Hamgyŏng-namdo.

gold, copper and cobalt, but the quality of the ore is not high enough to be worked independently.

The country rock containing tourmaline, which may be called tourmaline schist and locally consists almost entirely of tourmaline, is generally 2–3% in B_2O_3 content. As rock of such quality is impossible to treat as boron ore, the tourmaline had to be concentrated up to 7–8% B_2O_3 ore by means of the flotation method. The reserve of tourmaline schist minable as boron ore was confirmed to be greater than several hundred thousand tons, and a dressing plant which can treat about 100 tons of ore a day was constructed. The adjacent claim to this mine is the Tanp'ung mine (worked by Totaku Co.), where a wider distribution of tourmaline schist is found. Accordingly, the tourmaline resources of this district are very great. If the ore dressing had been successful in treating tourmaline, no anxiety would have been felt about tourmaline resources as far as quantity is concerned. Tourmaline from this region belongs to the magnesia-rich one, and it is said that both the acid and alkali methods are adaptable to the production of boric acid.

Survey and references: The author visited this region in 1943. As for regional geology, Yoshio KINOSAKI of the Geological Survey of Korea carried out sheet mapping in 1937. Cobalt and tourmaline deposits were surveyed by Keizaburo NAKAMURA of the Geological Survey of KOREA.

After that, investigations of tourmaline deposits were made by Shigenori KIMURA of the Tokyo Shibaura Electric Co., and by Toshio ISHIKAWA and Mitsuo FUNABASHI of Hokkaido University. In 1944, Toshiya MIYAZAWA confirmed the wider distribution of tourmaline schist in the area of the Totaku Tanp'ang Mine west of the Sangnong Mine. The present paper is based upon these references, together with the author's own observations.

Claim:

Mine name	Sangnong Mine
Location	Sangnong-ni, Suha-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo
Ownership	Taka-aki OKAGE
Office	Okage Mining Office, Keijo-fu (Seoul), Naka-ku, Eiraku-cho, c/o Eiraku Bldg.

History The mine originated from the discovery of copper ore in a tunnel of the water-way for a power plant under construction. In 1941, the owner started prospecting for copper ore and found the auriferous copper deposit. However, the ore was of low grade and prospecting was continued. In July, 1941, it was found that the pyrrhotite of this deposit contained cobalt, which was in demand in Korea at that time. After examining the cobalt ore, K. NAKAMURA found that a tourmaline schist, recognized as a boron ore, was contained in the country rocks. He then renewed investigation and confirmed the presence of a huge amount of tourmaline schist; at the same time, pegmatites rich in potash feldspar was reported by him from the same claim. After that, tungsten ore was also discovered

within the gold-copper-cobalt ore zone, and was worked later. As a matter of regret, in spite of the many varieties of ore present, no one ore was of high grade and the mine was compelled to adopt a complex method of refining. Responding to the urgent demand for boron in the spring of 1944, the construction of a 100 ton per day dressing plant was being pushed by the Korean Mining Promotion Company.

a. Location and communication

The Sangnong mine was located in the middle reaches of the Namdae-ch'ŏn (River), which empties into the Japan Sea at Tanchi'ŏn in the northern part of Hamgyŏng-namdo. Arriving at Tanch'ŏn by the Kyŏng-wŏn and Hamgyŏng lines from Kyŏngseong, change trains for Sangnong on the Tan-nong line, and leaving the train at Sangnong, one could reach the mine office on foot, which was in the village of Sangnong-ni about 1 km south of Sangnong station. The mine entrance was found on the north bank of the Namsan-ch'ŏn, a branch of the Namdae-ch'ŏn. The road between the station and the mine is level, with easy access.

b. Geology and ore deposit

Rocks in the mine area consist of mica schist, tourmaline-mica schist, tourmaline schist, quartz schist and crystalline carbonate rocks which belong to the pre-Cambrian crystalline schist system or Matenrei system. These formations strike N 70° W and dip 70° S in general, and are intruded by schistose granite, pegmatite and aplite. In this region, dikes of porphyrite, lamprophyre and basalt are also found. The general aspect of the topography in hilly near the deposit, however, along the Namsan-ch'ŏn a wide plain consisting of alluvial deposits and in somewhat higher places, older fluvial deposits are found. The gold-copper-cobalt deposit consists of impregnation zones parallel to the schistosity of the crystalline schists and fine veins running along the bedding plane of country rocks. These were all discovered through tunnel prospecting. The impregnation and vein zones are named the 1st vein (1.5 m wide and more than 50 m long), the 2nd vein 4 m wide and more than 130 m long) and the south vein (2 m wide and more than 20 m long). The 2nd vein, the principal impregnation zone, has been confirmed to continue 180 m in a tunnel; however, judging from the result of other prospecting, it can be assumed to run 500 m or more. Metallic minerals in the impregnation zone consist chiefly of pyrite, chalcopyrite, Co-bearing löllingite and Co-bearing arsenopyrite, which are more or less accompanied by gold. Along the impregnation zone, 2 or 3 bedded veins of varying thickness (between 2 and 20 cm) occur. The veins consist chiefly of quartz, often with sulphides such as arsenopyrite, chalcopyrite, pyrite and pyrrhotite which are quite concentrated in places. These sulphides are replaced by copper-cobalt ore at times, and scheelite accompanies them in rare occasions. The rock, which composes the main part of the impregnation zone, is brown to dark-brown or black schist, which consists chiefly of tourmaline and quartz and shows remarkable schistosity. The tourmaline-rich ore may

be called tourmaline (tourmaline rock) and the tourmaline- poor ore may be called tourma-line-bearing quartz schist.

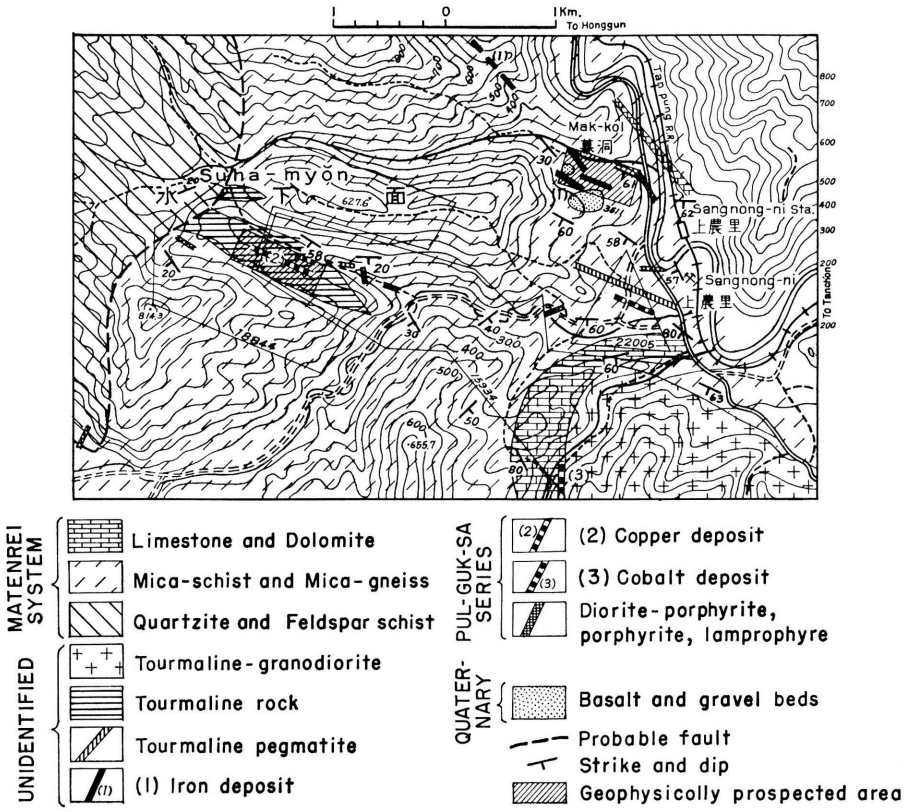

Fig. 2. Geological Map of the Suha-myŏn District Tanch'ŏn-gun, North Korea.
Makkol Mine Fe ⚒ (1)
Totaku Tanp'ung Mine Copper, Tourmaline ⚒ (2)
Sangnong Mine Tourmaline ⚒ (3)

c. Tourmaline deposit

The tourmaline and tourmaline-quartz schist occur as the country rock of the above deposit, chiefly in the vicinity of the sulphide impregnation. As they depart from the sulphide impregnation zone, the rock changes to mica schist. The so-called tourmaline schist consists mainly of quartz and tourmaline, and the tourmaline content reaches 20–30% or 2–3% B_2O_3. Occasionally the amount of tourmaline present reaches 70–80% or 8% B_2O_3; this sort of rock can be regarded as boron ore, however, the amount present is far less than that of the quartz-rich ore. The tourmaline schist contains certain amounts of biotite, muscovite and plagioclase. The tourmaline is deep bluish-brown, and very finely crystallized; it is 0.1 mm in width and 0.2 mm in length in general, and the crystals are commonly

arranged parallel is the direction of schistosity. Sometimes the tourmaline schist is penetrated by finely folded veinlets consisting of quartz and feldspar.

The B_2O_3 contents of the tourmaline schist was measured by K. NAKAMURA as follows:

Table 3

(a)

Rich ore	Tourmaline schist, especially the part concentrated in tourmaline	9.80%
Medium ore	Tourmaline schist with feldspar-quartz veinlets	2.75 – 4.06%
Poor ore	Transitional part between tourmaline schist and mica schist	0.56 – 1.92%

(b)

Ore grade	Locality	B_2O_3
Richest ore	1st vein	9.80%
Rich ore	,, ,,	4.06%
Rich ore	,, ,,	3.85%
Medium ore	,, ,,	2.94%
Medium ore	,, ,,	2.75%
Medium ore	South vein	3.17%
Medium ore	,, ,,	2.25%
Poor ore	1st vein	1.92%
Poor ore	Northern part of the south vein	1.40%
Host rock	Northern part of the south vein	0.56%

As the determination of B_2O_3 content in the tourmaline schist was not carried out by systematic sampling, and therefore no assay map was prepared, it is difficult to estimate the average content. Judging from macroscopic observation as well as microscopic observation of the mineral constituents of the tourmaline schist about 2.5 m wide along the south vein and neighboring pegmatite, and about 1.5 m wide along the 1st vein, the average B_2O_3 content of the rock totaling 4 m in width is estimated at 3%.

General quality of ore: The tourmaline schist generally contains chalcopyrite, arsenopyrite (cobalt-bearing) and scheelite and forms a complex ore. The estimated contents of the rich part are as follows:

Gold, 5 g/t; Silver, 2 g/t; Copper, 0.8%; Cobalt, 0.2%; Tungsten, 0.3%; tourmaline, 3%.

Table 4. Reserves of Boron Ore (tourmaline schist).

K. NAKAMURA (May, 1943)	Width	Length	Depth	Sp. gr.	Reserve	B_2O_3(%)	B_2O_3(t)
Ore deposit	4 m	200 m	100 m	3	240,000 t (probable)	3	7,200
Rich and richest ore	—	—	—	—	48,000 t	4–9	—
K. NAKAMURA	9 m	120 m	85 m	3	275,400 t (probable)	2	5,508
South vein	2 m	(Tunnel)	(Boring)	—	—	—	—
1st vein	1.5 m	—	—	—	—	—	—
2nd vein	5.5 m	—	—	—	—	—	—
	9 m	500 m	200 m	3	2,700,000 t (possible)	2	54,000
T. ISHIKAWA	9 m	240 m	85 m	3	550,800 t (probable)	2 (estimated)	11,016
					1,944,000 t (possible)	2 (estimated)	38,880
WATANABE	5 m	240 m	85 m	3	550,800 t (probable)	2 (estimated)	11,016
					1,944,000 t (probable)	2 (estimated)	38,880
WATANABE	5 m	240 m	90 m	3	324,000 t (probable)	3 (estimated)	9,720
Report of the mine	60 m	450 m	100 m	3	8,100,100 t	Including poor ore	
	10 m	450 m	100 m	3	1,350,000 t		40,500

Development: As stated in articles on prospecting and history, the mine was opened to exploit copper ore which was discovered in a tunnel while constructing a power plant. The copper ore does not reach the surface of the ground. For this reason, tunnel prospecting was carried on from the beginning. That is, a tunnel (the 1st tunnel) was driven N.N.E. into the hill from the north bank of the Namsan-ch'ŏn, but no ore deposit was found until a point about 100 m from the entrance was reached. Then the 1st inclined shaft was sunk northward down to 30 m in the vicinity of the place now called "Dai-ichi kō" (First Deposit), crosscuts were driven northward and southward, each about 50 m from the bottom of the shaft, whereby the presence of tourmaline schist and a copper-cobalt impregnation zone were confirmed. The 2nd shaft is located 200 m WNW of the 1st shaft, or 90 m south of the horizontal tunnel. It was sunk from the older terrace deposit down to 30 m; the tourmaline schist and copper-cobalt deposits were also found in the tunnel at this level. The length and properties of the deposit were confirmed

by driving tunnels roughly parallel to the strike of the impregnation, or the strike of the beds. A crosscut was also driven northward from the principal zone of the deposit, but it did not contact the expected copper-rich ore, and prospecting was abandoned. As the tourmaline schist and cobalt deposit came to the front, the mine prepared a "Main shaft" north of the 2nd shaft for excavation. Furthermore, the mine has carried on two drilling explorations from underground from which the impregnation zone was confirmed to continue at a depth of 88.5 m.

Mining: At the time when the author carried out the survey, excavation had not proceeded properly.

Ore dressing: The mined ore was relatively poor in quality. After breaking large lumps with a crusher, the ores are sorted by hand into copper ore, high-degree tourmaline ore, cobalt-arsenic ore and tungsten ore. The qualities of the hand-sorted ores are as follows:

Table 5

Copper ore of high-grade	Au	40 g/t
	Ag	15 g/t
	Cu	6%
Cobalt-arsenic ore	Au	20 g/t
	Cu	tr.
	Co	1%

At the time when the author visited the mine, a test mill for flotation, about 1 ton a day plant, was being built at the mine for the purpose of studying low-grade ore treating. By the end of spring 1944, the mine had succeeded to some extent in preparing concentrates of copper-cobalt ore and tourmaline ore. Some of this ore was used as test material for making boric acid at the Takeda Medical Industry Co., Ltd., and at the Tokyo Shibaura Electric Co., Ltd.

As the flotation method for tourmaline ore succeeded, the mine began to establish the main mill; it was under construction by the Korean Mining Promotion Co. at the time when the author carried out the survey there, and was scheduled for completion in the spring of 1945.

The capacity of the mill was to be 100 tons a day, the estimated annual production of tourmaline concentrate 8,000 tons and the grade of concentrate about 8% B_2O_3. If recovery was 70–80% and the grade of ore 3% B_2O_3, the annual production would correspond to 560–640 tons of B_2O_3.

Production and retained ore: The mine was still prospecting and had no marked production. In 1943, monthly production was 560 tons of low-grade ore (5 g/t Au, 0.8% Cu, 0.2% Co, 0.3% WO_3 and 3% B_2O_3), 60–70 tons of high-grade copper ore (2% Cu) and 0.5–0.7 tons of high-grade tungsten ore (60% WO_3). Monthly production was scheduled to increase up to about 1,100 tons from 560 tons sometime in 1944.

At the close of December 1943, the following ores were retained at the mine.

Table 6

Copper ore	2%	25 tons
,, ,,	0.6%	3,498 ,,
Scheelite	60% (WO_3)	1.4 ,,
,,	15%	5.3 ,,

(III) Totaku Tanp'ung Mine

Claim: Patent No. 15934

Location: Choga-dong, Sangp'ung-ni, Suha-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo

Ore: Au, Ag, Cu, Tourmaline

Ownership: Totaku Mining Co., Ltd., 195, 2-chome, Kogane-machi, Keijo-fu (Seoul)

Adjacent claim: Patent No. 18844, Au & Cu

Ownership: Fumiya Hori, 1, 2-chome, Chuo-bu, Kanko-fu (Hamhŭng)

a. Location and communication

The mine is located to the west of the Sangnong mine, and the place is of similarly easy access.

b. Geology and ore deposit

The geology and ore deposit are roughly similar to those of the Sangnong mine, but the distribution of tourmaline schist is more widely extended. According to a computation by MIYAZAWA, the tourmaline schist deposit is 1750 m long and 200 m wide, and the possible ore reserves (on a geological basis, tourmaline content 20–70%) reach 42 million tons. The grade of ore inferred is 35% tourmaline, or about an average 3.3% B_2O_3. Where the deposit is exposed a large amount of powdery tourmaline ore occurs. In the tourmaline zone, a copper deposit 0.3–0.5 m wide, 3–4% Cu, is found and was being prospected at the time of the survey.

The mine is a new one, discovered to the west of the Sangnong mine, and the properties of the tourmaline are roughly those found at Sangnong, but the occurrence of a large amount of powdery ore is rather advantageous at this mine. If the flotation method were applied as in Sangnong, it would be easy to obtain tourmaline concentrate. This is the largest tourmaline deposit of this type.

(IV) Utilization of tourmaline schist from near the Sangnong mine

The occurrence of tourmaline schist other than at the Sangnong mine has already been confirmed in the Tanch'ŏn district. Especially from neighboring claims, new discoveries of excellent tourmaline schist have been reported.

Working mines in the vicinity:

Sŏngjon mine (Cu, Co)
Kasin mine (Co)

The tourmaline schist found at these mines is very low grade, averaging about 3% B_2O_3. However, it is characterized by the homogeneity of rock as well as by its great amount, and in addition it occurs in association with gold, copper, cobalt and tungsten. According to recent experimental results, tourmaline can easily be concentrated by using the flotation method. A flotation mill with a 100-ton per day plant was constructed. The concentrate was sent to factories of the Tokyo Shibaura Electric Co. and the Takeda Medical Industry Co., and used in the manufacture of boric acid. In treating ore which contains not only tourmaline but also Cu, Co and W, an attempt was made to make use of these metals, separating them prior to the tourmaline. As the tourmaline schist was thought to be distributed very widely in this district, the ore reserves were considered sufficient to meet the demand at that time.

(V) Holgol (Hol Kol) Mine

General view: The Holgol mine, about 65 km east of P'yŏngyang, was formerly called the Suan gold mine, and was known as one of the three great mines in Korea in older time the present Suan Gold Mine corresponds to the former Namjong gold mine and is now worked for gold, silver, lead and molybdenum under management of the Nippon Mining Co. It is known also for the fact that the mine was once under the management of a non-Asian.
The mine has been continuously worked, and has produced a considerable amount of gold and copper ores.

Since 1930, the author has studied ore deposits in this district, and in 1938 discovered a large amount of magnesium borate in the principal ore body (North ore body) of the mine. The mineral was named kotoite by the author. The boron ore containing kotoite in the North ore body of the Holgol mine attains 8–10% B_2O_3. The mineral occurs in the marginal part of the gold-copper ore of the North ore body, and the mineral reserves are estimated at about 500 thousand tons. A test on the production of borax from this ore was conducted by the Institute of Hitachi Manufactory, and in 1941 the trial manufacture of borax from kotoite was started by the same company at Inch'ŏn. After that, the main mill was established and operated at P'yŏngyang.

From the nature of the ore it is difficult to raise the crude ore above 10% B_2O_3 However, it is easy to obtain concentrate above 10% B_2O_3 by a method of ore dressing.

Investigation and reference: Since 1930 the author has studied the Suan district, including the Holgol mine, 8 times. After the discovery of kotoite in 1938 he visited the mine 4 times, in 1939, 1941, 1942 and 1943, for the purpose of confirming the mode of occurrence of this mineral. During the same period, YAMAZAKI and YAMADA of the Central Institute of Korean G. G. also investigated the mine

and Takao YAMAGUCHI of the Geological Survey of Korea reported drilling prospecting.

Table 7. Main Investigation of Kotoite.

Period	Investigator	Remarks
1939, Sept.	Takeo WATANABE	
1940	YAMAZAKI & YAMADA	Central Inst.
1941, April	Takeo WATANABE	
1942, June	,, ,,	
1943, June–July	Takao YAMAGUCHI	Geol. Surv.
1943, Nov.	Takeo WATANABE	
Claim:		
Mine name:	Holgol (Hol Kol) mine	
Location:	Sugu-myŏn, Suan-gun, Hwanghae-do	
Loc. of office:	Sŏktal-li, Sugu-wyŏn, Suan-gun, Hwanghae-do	
Patent:	7881–7885; 7554	
Ore:	Au, Ag, Cu, W and B	
Ownership:	Pogwang Mining Co., c/o Chosen Seiren Bldg., No. 25, 1-chome, Taihei-dori, Keijo-fu (Seoul)	

History: The mine was opened as early as 100 years ago (in the dynastic age of Korea), and was known as the royal gold mine. Mining and the extraction of gold were carried out by primitive methods. In 1901, Tahei YAMAGUCHI (a Japanese) obtained the mining rights, but was not successful in prospecting. In 1903, the mine again reverted to the royal family. After that, in 1904–1905, the mine was put under the joint control of Japan, Britain and the United States of America. Since 1906, when the Korean syndicate with British capital was established, mining was carried on by the Seoul Mining Company. The company systematically developed the mine, calling it the Suan Mine. That is, the company constructed a coal-power plant at P'yŏngyang, transmitted current to the mine, carried out mining, ore dressing and refining, and the annual production attained 2–3 million yen. Thus the mine came to claim the title of one of the three main gold mines in Korea. However, in 1919, when the mine was deepened at the level now called the 5th old tunnel, the ore was of low grade and became non-profitable. Then, the Suan mine stopped work and transformed its main force to the exploration of the deposit at Namjŏng. Thus the Suan mine was left unworked for a time. In 1928, Ha Tonggyun and several other Koreans obtained part of the non-Koreans' patented mining claim and formed the Holgol gold mining partnership. Then the remaining ore was disposed of and prospecting again continued, and at last an ore body of high-grade-gold-copper ore was discovered north of the formerly worked ore body. The ore body expanded progressively (going down)

and developed to the present great ore body called the North ore body which contains kotoite. In November, 1934, the development of the mine passed to the present owner; thereafter the readjustment of old tunnels and mining of the North ore body proceeded in parallel. Thus the mine has been restored as an important mine in Korea under the name of the Holgol mine.

The first instance of discovery of boron mineral in this mine was that of ludwigite by Shannon, an American, during the period of foreign management, and in 1938 the author noticed the existence of the borate mineral which was named by him as kotoite. An investigation in 1939 made it clear that there was an enormous amount of mineral reserve. After that, at the time when boron material was needed, the kotoite ore was considered as a source of boron. In August 1941, the Hitachi Manufactory made a contract with the Holgol Mine and studied the use of kotoite in the Inch'eon Factory, and at last came to produce borax from kotoite at Inch'ŏn and P'yŏngyang. Meanwhile, in the Holgol mine, the mining of gold, copper and tungsten was continued as before.

Location and communication: The mine office is at Sŏktal-li, Sugu-myŏn, Suan-gun, Hwanghae-Do, and the working places at Pogwang-ni (Holgol) and Soktal-li in the same myŏn. To visit the mine from Kyŏngsŏng, first arriving atP'yŏngyang by the Kyŏng-Ŭi line, take a truck to the mine from Sŏn'gyo-ri station which is located on the south bank of the Taedong-gang (river), running in the southern part of P'yŏngyang, or take a mine truck from Chunghwa station on the Kyŏng-Ŭi line to Yul-li, Hwanghae-do, through Sangwŏn-ŭp, P'yŏngan namdo. The roads mentioned above are relatively even, and one may use a bus between P'yŏngyang and Suan. Though the relief in the area between Yul-li and the mine office is rather steep, the road for truck haulage has already been constructed, and one can now drive 75 km or 60 km, respectively, from P'yŏngyang or Chunghwa to the mine in 5–6 hours. As there is a steep pass reaching 200–400 m in relative height between Yul-li and Sŏktal-li, it is difficult for a car using substitute fuel to get through.

Geology and ore deposit: The mine is in the eastern area, consisting of a pre-Cambrian formation called the Shogen (Sangwŏn) system which is distributed widely over the region from Sangweon, to Yul-li. The Holgol mine is in the contact zone between the Suan granite and the slate and dolomite of the Shogen system. The principal deposit occurs in crystalline dolomite in contact with granite, and can be said to be a gold-copper deposit of the usual contact metasomatic type. As seen on a geologic map near the Holgol mine, the valley running south to north by the village of Holgol is a fault valley; on the west of the fault metamorphosed slate occurs, and in the valley and to the east dolomite of the Sidogu series, Shogen system is widely distributed. At the head of the Holgol valley, there is a small ridge extending east and west which consists of Suan granite and Holgol granite of the aplitic type, and the contact zone is found on the north of the ridge extending east and west. The N-S fault along the Holgol valley (called Holgol fault) dips 55°–60° towards east and a distinct slickenside is exposed on the ridge.

The deposit occurs in the contact zone mentioned above and is divided into two parts; one consists of the East and West ore bodies which have been worked since foreign control, and the other is the North ore body (also called the New ore body) which was discovered when Koreans obtained control. The West ore body is found near the junction of the Holgol fault and granite contact, and is composed of irregular flat-shaped ore bodies arranged roughly along the fault as well as along the granite contact. Two types of deposits are found. One, along the granite contact zone, is a gold-copper deposit of distinct pyrometasomatic type associated with typical skarn minerals such as deopside and phlogopite. The other, along the N-S fault, consists of two deposits—one a high-temperature type with skarn minerals such as garnet and phlogopite, and the other a hydrothermal type without skarn minerals, but consisting of light colored sulphides (chalcopyrite, pyrite, and tetrahedrite) and dolomite, popularly called "Chiaderagi". The principal ore body is a pyrometasomatic deposit extending east to west roughly along the boundary between the dolomite and garnet skarn zone in the eastern part of the granite contact. The North ore body is a large ore-pipe found in dolomite north of the East and West ore bodies, and is a pyrometasomatic deposit containing borate minerals such as kotoite and ludwigite. In this deposit, various minerals are distributed in concentric arrangement; gold, copper and bismuth ores are in the central portion, and a special marble containing kotoite is in the outer zone. The latter contains many small pipe-like and spherical massive gold-copper ores of skarn type. Thus the kotoite-marble, together with the gold-copper-bismuth skarn, form a large ore-pipe.

At the time when the author visited the mine, a large part of the East and West ore bodies had already been exhausted and gold-copper ore and kotoite marble of the North ore body were being mined at the 700 shaku level.

Kotoite occurs mainly in the outer zone of the ore-pipe of the North ore body, and subordinately in the margins of the East and West ore bodies.

In the North ore body, the outer zone between the 1,000 shaku and 600 shaku levels contains relatively few other rocks and forms a homogeneous boron-ore of about 10% B_2O_3. The boundary between kotoite-marble and crystalline dolomite is distinctly observable in tunnels, although it is uneven and irregular. The boundary between kotoite-marble and gold-copper-bismuth-diopside skarn-ore is also distinct, but on occasion the latter is so irregularly distributed in the kotoite-marble that the distribution is difficult to show on a map. In short, the gold-copper ore of the North ore body is a kind of skarn-ore contained in the "Kotoite-marble" ore-pipe and is concentrated in the central portion of the pipe. Therefore, the spot already worked for gold-copper ore in the North ore body corresponds to the portion consisting chiefly of skarn-ore; a large amount of kotoite-marble with skarn ore remains in the outer zone.

Characteristics of the main ore bodies in the Holgol deposit are tabulated below.

Table 8

	Strike shoot dip	Width	Length	Depth	Gangue	Ore mineral
East ore body (Skarn body)	E-W 70–90° S	10–30 m	Max. 90	300 m from surface	Diopside Chondrodite Phlogopite Garnet Datolite Tremolite Kotoite Ludwigite Calcite	Pyrite Pyrrhotite Chalcopyrite Bornite Bismuthinite Native bismuth Native gold
West ore body (A)	E–W 80° S	Flat pipe-like			Diopside Chondrodite Phlogophite Garnet Ludwigite Kotoite Calcite	Pyrite Chalcopyrite Gold Bismuth-bearing minerals
(B)	N–S 55–65° E	Flat		50 m from surface	Dolomite Calcite	Gold Pyrite Chalcopyrite Tetrahedrite Galena Sphalerite
North ore body	50–80° E	Large pipe		300 m from portal level	Diopside Clinohumite Phlogopite Calcite Ludwigite Kotoite	Chalcopyrite Bornite (upper) Cubanite Bismuth-bearing mineral Gold

Tonnage of kotoite-marble: At the time when the author surveyed the mine, it was being worked for gold-copper ore and no prospecting for kotoite-marble was going on. Moreover, in many places gold-copper ore bodies, which are irregular by shape, had been depleted and determination of the exact tonnage of marble present was not easy. The following tonnage was computed on the basis of an underground geologic map, in which case unmined portions were also taken into account (according to an investigation carried out in 1942).

Calculation by Takao YAMAGUCHI *(Aug. 1943)*: From borehole drilling in prospecting for kotoite marble, YAMAGUCHI made a calculation of the tonnage. Through drilling, it became clear that kotoite marble occurs also at the 500 shaku level. First, YAMAGUCHI measured the area of sections in the North ore body from plans for various levels.

Table 9

	Level	Length	Width	Area	Average	Height	Volume	Weight (Sp. gr. - 2.8)
Unmined portions of Au-Cu ore bodies	600 shaku	40 m	25 m	1,000 m²	1,550 m²	30 m	46,500 m³	130,200 ton k(43,400)t
	700	65	30	2,100	1,800 m²	30 m	54,000 m³	151,200 ton
	800	75	20	1,500				k(50,400)t
	(K means tonnage of kotoite-marble. For the mined portions, kotoite-marble is assumed to be 1/3 of the calculated tonnage)							
	800	40	10	400 m²	400 m²	30	12,000 m³	k (33,600)
	900	40	10	400	300 m²	30	9,000 m³	k (25,200)
	1,000	20	10	200				Total K (158,900)
	(K means tonnage of kotoite-marble)							
	Probable reserve of kotoite-marble between the 900 shaku and 800 shaku levels							k (30,000)
	Probable reserve of kotoite-marble in the eastern part at the 1,000 shaku level							k (1,000)
	800	15	5	75		12	9,000 m³	2,520
	600	40	25	1,000	500	30	15,000 m³	42,000 t
	500	0	0	0				k (14,000)
								Total K (206,420)t

East ore body portal level ..... $(0.5 \times 15 \times 6 \times 2.8)$ K(150)
North ore body between portal and 1,000 shaku levels..... $(0.5 \times 2 \times 50 \times 2.8)$ K(5600)
West ore body near 1,000 shaku level..... $(20 \times 10 \times 10 \times 2.8)$ K(5600)
Sum K(6000)

(K denotes tonnage of kotoite-marble)

Remarks: Although the average B_2O_3 content is unknown, it is inferred to be 10%. Therefore, 20 thousand tons of B_2O_3 can be recalculated into 54,800 t. of borax, or 35,600 of boric acid.

Level	Area of section
1,000 shaku	150 tsubo (500 m²)
900 "	400 " (1,320 ")
800 "	470 " (1,560 ")
600 "	800 " (2,640 ")
600 "	130 " (430 ")
500 "	120 " (400 ")
	(inferred)

From the above, the volumes of the ore body between two levels were obtained as follows:

Level	Volume
1,100–1,000	about 5,500 m³
1,000– 900	29,000
900– 800	47,500
800– 700	68,500
700– 600	45,500
600– 500	4,700
	200,700

Thus the total volume of the ore body was calculated at about 200 thousand cubic meters. Assuming the volume of gold-copper ore to be 1/6 of the entire ore body and the specific gravity of kotoite-marble to be 3.0, a reserve of about 500 thousand tons was obtained.

Author's note: Although the gold-copper ore is assumed to compose 1/6 of the entire ore body in YAMAGUCHI's calculation, it should be about ¼ in reality. Moreover, the portions already mined are also contained in the area of section, and must be excluded. An estimate by the mine in 1943 was 400 thousand tons.

Development: The present administrator began mining in December 1934; since then prospecting, mining, dressing and refining have been carried on up to this day. Recent annual production has been 136–270 kg Au, 122–1400 tons Cu (lump concentrate) and 600–800 tons Cu (fine concentrate), attaining more than a million yen per year.

(a) Prospecting is going on at the base of the North ore body and in the unmined part of old tunnels.

(b) Since the country rock is very hard, no supporting timbers were required in mining any ore body, and step-up, step-down methods were adopted, and in part the shrinkage method, in which mined parts are filled with waste, was also supplied. In mining, stopers, jackhammers and light hand drills were used; in part, high-grade ore was mining by hand (drilling). Monthly production was 7,500 tons cude ore, in which 2,500 tons scheelite and copper ores from Namsan near Sŏktalli were included.

(c) Underground haulage: Copper-bearing boron ores from the North ore body and old tunnels are brought up to the horizontal tunnel, and passing through the

Ogiri-ko (main-haulage level) are sent to the crushing plant by mine car of 1-ton capacity. Electric locomotives powered by storage batteries are used.

(d) Transportation; The gold-copper concentrate and part of the boron ore were transported by gasoline-powered trucks from the mine to Yul-li. From there, they were transshipped to cars with substitute fuel to be sent to Chunghwa station on the Kyŏng-Ŭi line. The larger part of the boron ore was sent by cable from the mine to Yul-li, and thereafter sent directly to the P'yŏngyan factory. Both ways, the distance between Holgol and Yul-li is 64 km for which a truck needs 30 liters of gasoline, and the distance between Yul-li and P'yŏngyan is 100 km for which a car using substitute fuel requires 5 bags of charcoal. It is also said that 35 2.5– to 3.0–ton dump trucks were estimated to carry 1,000 tons of ore a month using the road at that time (about 1 ton per day per truck).

(e) Recent production:

(i)	Ore, mined	1942	41,113 t
(ii)	Ore, dressed and refined	"	41,038 t
(iii)	Production		
	Amalgamated gold	362,325 kg	
	Lump concentrate	254,000 t	
	Fine concentrate	666,000 t	
(iv)	Sales in 1942		
	Unrefined gold	166,168 kg	425,325.71 yen
	Lump concentrate	236,251 t	79,107.08 "
	Fine concentrate	638,419 t	477,206.93 "
	Total		981,639.72 yen

The Holgol mine reserves are 200,000 or more tons of boron ore (10% B_2O_3) accompanied by a gold-copper ore deposit. The gold-copper ore of the Holgol mine has been worked for more than 30 years, and annual production still reaches several hundred yen at present. In recent years, however, the mine was worked with the objective of increasing copper production. In mining the boron ore, it was necessary to take care to avoid any serious hindrance in carrying on the mining of gold-copper ore. Fortunately, prospecting for boron ore coincides with that for gold-copper ore, and it is profitable to carry on prospecting simultaneously for both. In mining, it is sometimes difficult to separate the mining-faces of gold-silver-copper ore and boron ore; however, in the case of high-grade ore, they can be mined in their respective faces, and also the hand-sorting of ores can be partly carried out underground. Thus, it was possible to mine both ores selectively and no special mining equipment was required.

The boron content of the ores attained 10–11% B_2O_3 in high grade ore, and 5–6% B_2O_3 in low grade ore, which is mixed with rock materials and gold-silver ore. The latter can hardly maintain 8% B_2O_3 by strict hand sorting. The yield with hand sorting may not be greater than 25–50% if boron concentrate, or kotoite concentrate, could be obtained above 25% B_2O_3 by any method, the

difficulties of transporting and various treatments would be surmounted. The study of ore dressing is an important subject in increasing the production of boron ore. As for truck haulage, in order to send 1,000 tons of boron ore per mouth from the mine to P'yŏngyang (the road for about 80 km was in bad condition), a 2-ton capacity truck must go and return 500 times; one return trip requires 30 liters of gasoline and 5 bags of charcoal. Thus, total expenses come to:

gasoline:	$30 \times 500 = 15{,}000$ li	
	cost: 11.5 yens $\times 500 = 5{,}750$ yen	
charcoal:	$5 \times 500 = 2{,}500$ bags	
	cost: 17.2 yens $\times 500 = 8{,}600$ yen	
		14,350 yen

If the ores could be concentrated into 1/4 the amount, and therefore 25–30% B_2O_3 by ore dressing, the return trips would be reduced to only 125 times; 11,480 yen could be dispensed with or 11,350 liters of gasoline and 625 bags of charcoal a month. Moreover, it was thought that the trucks would be reduced and the yield of the refinery increased.

The boron ore was sent to the Inch'ŏn factory of the Hitachi Manufactory and the P'yŏngyang factory of the Chosen Special Chemical Co., Ltd. The factories were capable of accepting a total of about 1,500 tons of ore a month, or 1,200 tons at P'yŏngyang and 300 tons at Inch'ŏn, and it was imperative that the B_2O_3 content be not less than 8%. The actual yield of the factory treating kotoite was roughly 20% at maximum, and if the hand sorting factor was taken into account, the recoverable B_2O_3 was only 1/10 of the B_2O_3 content of ores.
Improvement in yields, both in ore dressing and in refining, was given attention. In later days, several hundred tons of boron were produced at P'yŏngyang.

(VI) Kinsei (Kŭmjŏng) Mine

The Kinsei Mine is in Ponghwa-gun, Kyŏngsang-pukto. The mine was managed by the Kinsei Mining Co., Ltd., and was one of the greatest gold mines in Korea, However, it is being left unworked at this time. The tourmaline-bearing pegmatites discovered in this mine was once thought of as a source of boron; however, no formal estimates of the ore reserve were made and particulars on the deposit are not known.

(VII) Ilgwang Mine

General statement: This is a copper mine under the management of the Sumitomo Mining Co., and is located northeast of Pusan, Kyŏngsang-namdo. The ore deposit worked is composed of networks of tourmaline-quartz-copper veins in biotite granite. About 150 kg of copper ore is being treated per day by the flotation method, and the tourmaline (0.7% B_2O_3) has been treated as waste. The Sumitomo Mining Co. is said to have recognized the possibility of recovering tourmaline by the flotation method and planned to put it in to operation.

Investigation and reference: Though the author did not investigate the deposit, Hideki IMAI recently surveyed and studied the region.

History: Since 1931, the mine has been managed by the Sumitomo Mining Co., and since 1937 has been worked continuously up to the present time.

(a) Location and communication: The mine is in Ilgwang-myŏn, Tongnae-gun, Kyŏngsang-namdo, and is located about 30 km northeast of Pusan. Traveling from Pusan to Chach'ŏn by train for Kyŏngju the mine may be reached by going west about 2 km by truck or on foot.

(b) Geology and ore deposit: The Keisho (Kyŏngsang) formation of the Mesozoic era is distributed widely in the district, and is intruded by granite, porphyries and porphyrites which are assigned to late Cretaceous intrusives. The ore deposit occurs as stockworks of ore veins in a small intrusive mass of granite about 1 km in diameter. The stockworks are concentrated in the areas which are called the "North body" and "South body" which attain 40–50 m in diameter.

The ore deposit shows characteristics of the high temperature type, containing tourmaline, quartz, garnet, apatite, zirkon, etc., as gangue minerals, and tungsten-bearing and antimony-bearing minerals as ore minerals. The host rocks, or granite, has generally also been altered and, in some places, has suffered severe tourmalinization. The ores mined are rich in chalcopyrite and magnetite and contain 0.6% Cu and 40–50 g Ag; tourmaline is always present also, although the content is less than 10%.

(c) Tourmaline: Tourmaline occurs as black columnar or fibrous crystals, and is the most important mineral among gangues. From the properties, it is considered a kind of iron tourmaline. The tourmaline reserve has not been investigated and no particulars are known.

(d) Development: The mine has been worked regularly by the Sumitomo Mining Co. since 1937. Mining is carried on by the open-pit method where the shrinkage method is used jointly. The ores are treated in a flotation plant of 150-tons-a-day capacity and are concentrated to about 14% Cu. It is said that a flotation plant of 300-tons-a-day capacity is now being constructed in accordance with a plan to increase copper production. As for the tourmaline, a test was made to treat the tourmaline (about 0.7% B_2O_3) contained in the tail of the copper ore flotation, and it is said that concentrate of 8.73% B_2O_3 was obtained from the ore of about 2.3% B_2O_3.

The tourmaline of this mine is contained as a gangue mineral in copper veins as is the case at the Yakuoji mine; therefore, it has heretofore been treated waste. As the tail of copper ore flotation contains 0.7% B_2O_3, if tourmaline concentrate can be obtained from the tail by any suitable treatment (for instance by flotation using sodium oleate), the difficulty of crushing the ore would be done away with and, therefore, the Ilgwang mine would become fairly profitable. The main point was in what yield the tourmaline concentrate of 7–8% B_2O_3 can be recovered from the low grade tailing. If the B_2O_3 content of ore is assumed to be 6.8–1%, and 100 tons of the ore are treated daily, the quantity of B_2O_3 in the ore is 0.8–1 ton.

If 50% of the above B_2O_3 can be recovered, the concentrate of tourmaline obtained daily would contain nearly 0.5 ton of B_2O_3. Then, the amount of B_2O_3 given by the concentrate can be estimated at 150–180 tons a year. When it is recalculated to the amount of tourmaline, it becomes 1500–1800 tons. Thus, obtaining the tourmaline as a by-product of the mine was seen to be important (if the flotation plant of 300 tons a day is completed, the amount of B_2O_3 produced would become more than 200 tons).

(VIII) Haman Mine

The Haman mine, together with the Ilgwang mine, are the important gold-copper mines in Kyŏngsang-namdo, Korea. The mine was under the management of the Showa Mining Co. The ore deposit consists of tourmaline-quartz-copper veins occurring in the Mesozoic formation and granite. The copper veins often contain cobalt-minerals and have been considered also as a cobalt deposit. The ore veins occasionally contain tourmaline and resemble those of both the Yakuoji and Ilgwang mines. The copper ore is treated by the flotation method; however, it is not known how much tourmaline is contained in the tail of copper flotation.

The author surveyed the district in May, 1942, and did not find the tourmaline content of the ore to be very high; the deposit was considered hopeless for the production of boron ore.

3. State of Utilization and Conclusion

The treatment of various kinds of boron mineral was made in several factories by using the different methods tabulated below:

Uses at that time:

(1) Ampoule glass, (2) Optical glass, (3) Vacuum-tube glass, (4) Fire-proof and heat-resist out glass; Chemical glassware, (5) Enamel for ceramicware, (6) For enamelled ironware, (7) For soldering, (8) Medicine; Toilet articles; Photography; Leather-cloth; Uranium pile; For regulating the velocity of neutrons; Antiseptics.

In short, if boron ore which can be easily treated is imported freely from North and South America, tourmaline, kotoite and other boron minerals which are troublesome to treat would be of no value as sources of boron.

Table 10

Ore	Factory	Treating method	Product	Preparation or additon
Tourmaline (Sangnong)	Osaka Indust. Inst.	H_2SO_4 method	Boric acid	$CaCO_3$, H_2SO_4
Kotoite	Hitachi Centr. Inst.	HCl method	,, ,,	HCl
Tourmaline	Aviat. Light Metal Inst. (Toho Sanken)	Alkali method Acid method	Borax, Alumina Boric acid	Soda ash, limestone Limestone, H_2SO_4
Danburite	,,	Alkali method	Boric acid, iron ore	
Kotoite	Nagai Inst., Tokyo Univ.	Acid method	Boric acid	$CaSO_4$, HCl
Tourmaline	,,	Acid method Alkali method	The same as Toho Sanken	
Kotoite	Inch'ŏn and P'yŏng-yang factories, Chosen Sepec. Chem.	Alkali method, less than 300t/month.	Borax	Na_2CO_3 limestone
Tourmaline (Sangnong)	Kanzakigawa fact., Takeda Med. Indust.	H_2SO_4 method	Borax, H_2SO_4	Limestone, H_2SO_4
Tourmaline	Toshiba Chem. Inst.	$AlCl_3$ method	Boric acid, $AlCl_3$	HCl
Tourmaline (Mitsubishi Obira)	Mitsubishi Min. Inst.	H_2SO_4 method		Lime, coal
Danburite	Toshiba, Matsuda Inst.		Ampoule glass	

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Lithia Mica Deposits in Korea with Special Reference to Spodumene and Amblygonite

Hidekata SHIBATA

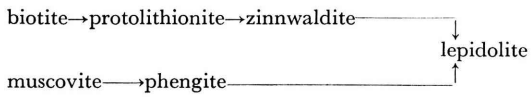
1. Introduction

The author surveyed lithia mica deposits of the Munch'ŏn Mine, Hamgyŏng-pukto, and the Ch'ŏngp'yŏng Mine, Kangwŏn-do, in the autumn of 1944. He was kindly given a few specimens from the collections of Hideki IMAI and of Shinji SATŌ, and after analyzing the specimens, found spodumene and amblygonite. In addition, large blocks of spodumene were found at the Munch'ŏn Mine; the deposit was a large one missed by other surveyors. Lithia micas are found in a pegmatite deposit which resembles the one in Japan.

2. Lithia micas and associated minerals

Varieties of lithia micas include lepidolite, protolithionite, zinnwaldite and lithia phengite. Lepidolite contains much manganese and is pink. Zinnwaldite is commonly pale-brown. Protolithionite is dark-green, pale-green and pale-brown like biotite, and contains little lithia. Lithia phengite is silver-white, like muscovite, and microscopically uniaxial.

There are two series of micas in pegmatites: the biotite series and the muscovite series. Both evolve to lepidolite by parallel growth as follows:



Lithium pegmatite, without exception, contains tourmaline. The tourmaline is colored by the lithia content as follows; black, dark-green, green, indigo, pink and white. One variety contains more than 3% Li_2O. Lithia-tourmaline is found in cleavelandite (lamellar albite) aggregates, and with increase in lithia content goes from black to green and pink. From the Munch'ŏn Mine, beautiful crystals of green tourmaline, which had been mistaken for beryl, were found.

The spodumene is white to grey, and is found near the central quartz.

Amblygonite greatly resembles microcline, and is apt to be missed in rock waste. It is found in the Munch'ŏn and Ulchin Mines in portions rich in lepidolite.

From the Ulchin Mine, an altered product of spodumene was found.

The analyses of these minerals are shown in Table 1.

3. Types of deposits

The ore consists of lithium minerals occurring in pegmatites.

The granite is two mica-granite or biotite-granite, partially porphyritic. It intrudes gneiss and is cut by porphyrite and quartz-porphyry dikes which belong to the Bukkokuji (Pulguksa) Series. Therefore this granite may have formed during the igneous activity of the Bukkokuji Era, or earlier.

Lithium pegmatite may belong to the same age as the one in which columbite was produced, and a small amount of columbite is found in the Tanyang and Munch'ŏn Mines.

Localities in Korea where lithium occurs are shown in Table 2, compiled in December, 1944.

Table 1. Chemical Composition of Lithium Minerals in Korea.

	Amblygonite		Spodumene	Lepidolite		Phengite		Muscovite
	Ulchin Mine	Munch'ŏn Mine	Munch'ŏn Mine	Munch'ŏn Mine	Ulchin Mine	Ulchin Mine	Munch'ŏn Mine	Munch'ŏn Mine
SiO_2	1.89%	1.14%	64.16%	49.18%	49.14%	47.44%	43.24%	41.52%
TiO_2	—	—	—	0.12	0.08	—	0.24	0.28
P_2O_5	46.80	46.77	—	—	—	—	—	—
Al_2O_3	32.31	32.13	26.42	18.85	21.90	25.98	33.90	32.58
Fe_2O_3	—	—	0.22	0.42	0.44	0.56	0.55	0.88
FeO	0.13	0.21	0.12	0.16	0.24	1.31	1.38	0.94
MgO	0.48	0.18	0.09	1.24	0.88	1.41	0.90	0.68
MnO	0.00	none	none	1.77	1.41	0.56	none	none
CaO	2.54	0.18	0.80	0.26	0.96	1.42	0.26	0.10
Na_2O	0.51	1.13	0.52	0.06	0.52	0.86	0.12	0.30
K_2O	0.41	1.33	0.13	10.37	9.82	10.25	10.21	9.60
Li_2O	7.21	9.64	7.48	5.67	5.41	3.02	1.53	1.51
H_2O^+	5.32	5.38	0.76	3.94	3.25	5.02	5.96	6.50
H_2O^-	0.50	0.20		3.86	3.51	2.90	2.36	4.86
F	3.20	3.13	—	5.93	4.61	0.56	0.04	1.02
Total	101.20	101.44	100.70	102.23	102.17	10.022	100.65	100.77
$-F=\frac{1}{2}O$	1.34	1.32		2.49	2.16	0.24	0.02	0.43
	99.86	100.12		99.74	100.01	99.98	100.43	100.34

Analysed by SHIBATA

Table 2. Localities of Lithium Pegmatites and Lithium Minerals.

No.	Locality	Surveyor	Lepidolite	Zinnwaldite	Spodumene	Amblygonite	Lithia tourmaline
1	Ŏbok-tong, Haksŏ-myŏn, Haksŏng-gun, Hamgyŏng-pukto	KINOSAKI, YOSHIZAWA, HARADA	−	+	−	−	−
2	Wŏnp'yŏng-dong, Haksŏ-myŏn, Haksŏng-gun, Hamgyŏng-pukto	,,	−	+	−	−	−
3	Sin-dong, Changbaeng-myŏn, Kilchu-gun, Hamgyŏng-pukto	KINOSAKI	−	+	−	−	−
4	Chikchŏn-dong, Sangp'al-dong, Kilchu-gun, Hamgyŏng-pukto	,,	−	+	−	−	−
5	Ch'ŏnggye-ri, P'ungha-myŏn, Munch'ŏn-gun, Hamgyŏng-namdo	ASANO, HARADA, SHIBATA	+	+	+	+	+
6	Pagam-ni, Nam-myŏn, Ch'unch'ŏn-gun, Kangwŏn-do	TAKAYAMA	−	−	−	−	+
7	Samgul-li, Sŏ-myŏn, Ulchin-gun, Kangwŏn-do	IMAI, MIYAMOTO	+	−	+	+	+
8	Ch'ŏngp'yŏng Mine, Homyŏng-ni, Nam-myŏn, Kapy'ŏng-gun, Kyŏnggi-do	HATANI HARADA, YAGYŪ, SHIBATA	+	+	−	−	+

9	Onjŏng-ni, Chŏgam-myŏn, P'yŏngsan-gun, Hwanghae-do	KINOSAKI, HATANI	+	−	−	−	−
10	Namch'ŏl-li, Posan-myŏn, P'yŏngsan-gun, Hwanghae-do	KINOSAKI, YAMAGUCHI	+	−	−	−	−
11	Oejungbang-ni, Tanyang-myŏn, Tanyang-gun, Ch'ungch'ŏng-pukto	TATEIWA, KINOSAKI, SHIMAMURA, HARADA	+	+	−	−	+
12	Puksang-ni, Tanyang-myŏn, Tanyang-gun, Ch'ungch'ŏng-pukto	KINOSAKI, YAMAGUCHI	+	+	−	−	−
13	Hoesal-li, Tanyang-myŏn, Tanyang-gun, Ch'ungch'ŏng-pukto		−	+	−	−	−
14	Koep'yŏng-ni, Taegang-myŏn, Tanyang-gun, Ch'ungch'ŏng-pukto		+	+	−	−	−
15	Songgye-ri, Hansu-myŏn, Chech'ŏn-gun, Ch'ungch'ŏng-pukto	KINOSAKI, YAMAGUCHI	+	+	−	−	+
16	Sayang-ni, Sŏ-myŏn, Okch'ŏn-gun, Ch'ungch'ŏng-pukto	HATANI TSUDA	+	−	−	−	+
17	Taesal-li, Taesan-myŏn, Sŏsan-gun, Ch'ungch'ŏng-namdo	YAMAGUCHI, ISHIKAWA	+	+	−	−	−

These pegmatites have unusual characteristics due to cleavelandite. This mineral replaced the potash feldspar which formed most of the pegmatite. At the Munch'ŏn Mine, potash feldspar stands perpendicular to the walls and gives the aspect of a ladder structure. However, in the part rich in lithium minerals, structure parallel to the walls as the result of replacement is evident on the weathered surface. Amblygonite, the earliest lithium mineral, is cut by lepidolite-and albite-veins; spodumene, however, was the last lithium mineral formed.

In Korea, zinnwaldite from the Tanyang Mine had been worked and, with lepidolite from the Ulchin Mine, was exported to Japan during the later part of the war. Other mines were being prospected, and exploration had been started.

4. Distribution

As shown in Table 2, pegmatites are distributed from Hamgyŏng-pukto to Ch'ungch'ŏng-namdo. Therse dikes or veins of pegmatites intrude gneiss of the Matenrei and Rensen Series and limestone of the Chosen System.

The granite in contact with the rocks of these Systems is biotite-granite intruded by porphyrite and quartz-porphyry.

5. Mines and reserves

a. Ŏbok-tong, Haksŏng-gun, Hamgyŏng-pukto (HARADA & ISHIKAWA, 1944)

Location: 2.5 km northwest of the Ŏbok-tong Station on the Hamgyŏng Line. The deposit is located 1.5 km north along the highway and 4 km along the road to Onch'ŏn-dong.

Geology: Granite, pegmatite and aplite intruding mica-gneiss, amphibolite and magnesite of the Matenrei System.

Ore: Zinnwaldite crystals, small to 4 cm in size with a Li_2O content of 0.39–3.17 percent. They are thought to be a variety intermediate between protolithionite and lepidolite.

Reserves: The richer portions of the ore contain 10–20 percent zinnwaldite; the average is 2 percent. The reserves of the two main bodies is estimated at 488 tons.

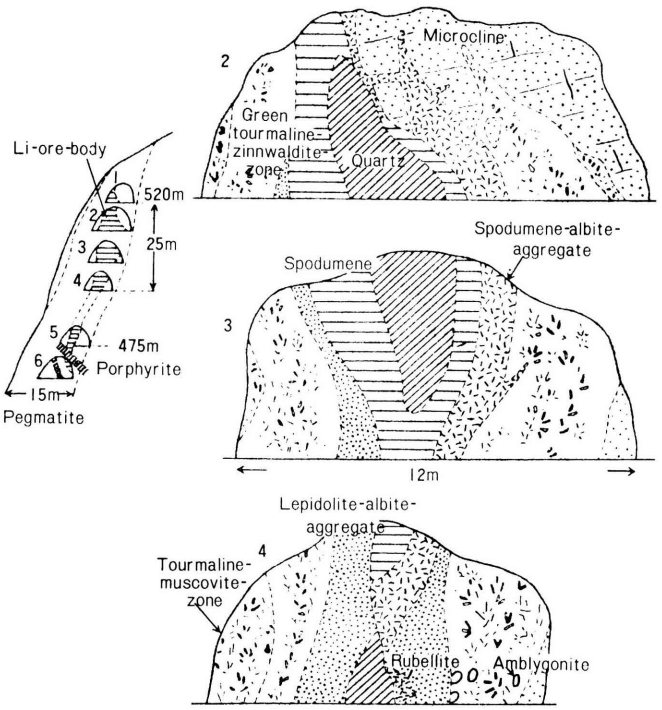
b. Munch'ŏn Mine, P'ungha-myŏn, Munch'ŏn-gun, Hamgyŏng-namdo

Location: 92 km east from Pokkye Station of the Kyŏngsŏng—Wŏnsan Line, through Ich'ŏn, 100 km from Wŏnsan, through Majŏl-lyŏng. The deposit is east of the Ch'ŏnggye-ri Hot Spring.

Geology and deposit: A pegmatite dike starting from the periphery of the granite intrudes biotite-gneiss, augen-gneiss and amphiholite of the Matenrei (Mach'ŏl-lyŏng) System. The dike extends 6 km to the east. The granite is intruded by wolframite-quartz-veins.

The pegmatite is rich in microcline, replaced by albite and is associated with

tourmaline and lithia mica. Tourmaline changes its color from black to green and pink with increase in Li_2O content. Partial replacement has taken place. Spodumene occurs along the margin of the central quartz zone of the replaced portion.



Openings of the West no. 4 Quarry of the Munch'ŏn Mine.

Ore: Micas are muscovite, zinnwaldite, lepidolite and phengite. Li_2O is contained in all the micas.

Spodumene crystals, with a maximum size of 20 cm, are found between the lepidolite zone and the central quartz zone. Also, large blocks of spodumene are found in rock waste and detritus. Fifty tons of ore were to be collected at the time.

Amblygonite crystals up to 5 cm in size are found in the lepidolite albite mass the first lithium mineral. The amount is less than that contained in spodumene, but the deposit should be prospected again. It is produced from West No. 4 and East No. 2 Quarries.

Table 3. Li_2O contents of Micas.

	Muscovite	Zinnwaldite	Phengite	Lepidolite
	Associated with black tourmaline	Associated with green tourmaline		
Li_2O	1.51%	1.53%	4.19%	4.90%

Rubellite crystals are slender prisms in a radial arrangement in the quartz mass, and attain a length of 20 cm. Green tourmaline contains a large amount of Li_2O, which crystallizes as thick prisms like those of beryl.

Table 4. Li_2O Content of Tourmalines.

	Schorl	Green tourmaline	Rubellite
Li_2O	0.05%	0.82%	1.89%

Reserves: The distribution of ores in six quarries along 6 km of a pegmatite dike is shown in Table 5.

Table 5. Ores and Reserves of the Munch'ŏn Mine

Ore mineral	Amount of ore min	Content of Li_2O	Reserves of ore
Spodumene	70%	5%	245 tons
Amblygonite	Not determined	9	Not determined
Lepidolite	50	2	129
Zinnwaldite	100	1.5	5.5
Rubellite	80	1.5	4

Twenty-five tons of lepidolite ore were exported to Japan from Wŏnsan. Thirty tons were retained at the mine.

c. Pagam-ni, Nam-myŏn, Ch'unch'ŏn-gun, Kangwŏn-do

Location: About 16 km from the Ch'ŏngp'yŏng Station of the Kyŏngsŏng—Ch'unch'ŏn Line along the Pukhan-gang (river), through Ch'ŏngp'yŏng Mine and along the Hongch'ŏn-gang (river), and also 15 km south along the Pukhan-gang from the Kap'yŏng Station of the Kyŏngsŏng—Ch'unch'ŏn Line and 4 km along the Hongch'ŏn-gang from the junction of the two rivers.

Geology: Rocks in the vicinity consist of granite-gneiss and metamorphic rocks of the pre-Cambrian System.

Deposit: A pegmatite dike, 4 m wide, intrudes the metamorphic rocks and is exposed for a distance of 20 m. The lepidolite crystals are large, 1–2 cm in diameter, and arranged like petals on a flower.

d. Ch'ŏngp'yŏng Mine, Homyŏng-ni, Nam-myŏn, K'ap'yŏng-gun, Kyonggido

Position: Pegmatites are situated across the Pukhan River and at a spot 4 km from the Ch'ŏngp'yŏng Station of the Kyŏngsŏng—Ch'unch'ŏn Line. It extends 800 m north-south.

Geology and deposit: Pegmatite veins rich in tourmaline intrude gneiss of the Rensen System. There are ten veins on the north side of the river, and two on the

south. They go approximately north and have individual strikes and dips, but may combine below the surface. A vein along a metamorphosed limestone is the largest.

Eight veins on the north side were prospected. No. 2 and No. 5 veins cutting the limestone contain a large amount of lepidolite.

Ore: There are small scales and large crystals of lepidolite. The large crystals are as much as 3 cm in diameter, and accumulate partially in the center of the pegmatite veins. The small ones are found in masses with albite, associated with rubellite.

Reserves: The mine was being prospected. Lepidolite is found in the No. 2, No. 5 and No. 6 veins. The No. 2 vein is the largest, 30 m in length and 2 m in width, and has the highest Li_2O content. The width of the richest part is about 30 cm, and the content of lithium minerals in the ore is 50 percent. The reserves were found to be 67 tons.

e. Tanyang Mine, Tanyang-gun, Ch'ungch'ŏng-pukto (TATEIWA, 1944; HARADA, 1944)

Location: 4 km southeast of the town of Tanyang, Tanyang-gun, west of Kumiri along the Han-gang (River) on the north side of Mt. Sa-bong, 350 m up.

History: This mine was the most exploited, having been discovered in 1934, and became the property of the Japan Rare Metals Company in 1942. The ore was exported to Imajuku, Fukuoka Prefecture, Japan.

Geology: A pegmatite dike intrudes limestone of the Chōsen System; width 2–5 m, length 140 m. The lower half of the vein, which dips 40°–45°, is aplitic and the upper half pegmatitic. The central zone consists of quartz. In the upper selvage of the central quartz, lepidolite is found and on the lower edge, zinnwaldite. In the lower aplitic part, small crystals of zinnwaldite are found. A small amount of columbite and beryl are also present.

Reserves: Principal ore minerals are zinnwaldite and lepidolite. The amount of lepidolite is less than one-fourth that of the zinnwaldite. The lithia mica content is about 2 percent. As the width of the vein is 3 m, the length 100 m and the depth 30 m, the amount of mica present may be 450 tons.

f. Ulchin Mine, Ulchin-gun, Kangwŏn-do

Location: To Samgul-li, Ulchin-gun, it is 110 km by rail from the Yŏngju Station of the Kyŏngsŏng—Kyŏngju Line. The mine is 6 km from Samgul-li and the route passes the copper-pyrite deposit at Wangbi-ri.

Blocks containing large crystals of cassiterite are found at the southwest portion of the property.

Geology and deposit: A lens-like stock of granite intrudes crystalline schists and phyllite of the pre-Cambrian system, which strikes approximately east. Pegmatite veins, No. 3 and No. 4, intrude parallel to the rock—granite contact plane. Pegmatite No. 1 and No. 2 intrude into the strike plane of dolomitic limestone

some distance away. Partial accumulations of zinnwaldite, lithia phengite, lepidolite and amblygonite, altered spodumene and blue tourmaline occur in these veins. No. 1 and No. 2 have a similar character and contain small scales of lepidolite and silver-white lithia phengite, and may be connected underground. Much amblygonite is found in the rock waste. The width of No. 1 vein is 2 m and its length 400 m. In No. 3 and No. 4 veins, large crystals of lithia mica are found in the quartz mass.

Ore: The amount of amblygonite present is larger than that from the Munch'on Mine. It resembles feldspar, but the cleavage is rather indistinct. Spodumene crystals are almost entirely altered, and fresh crystals cannot be found. Three tons per day of ore containing more than 3 percent Li_2O, selected by hand, were sent to Yŏngju. When the flotation plant is completed, 10,000 tons of ore a month from No. 3 and No. 4 veins can be expected. If amblygonite were added to the ore, the amount would be greater.

g. Puksang-ni Mine, Tanyang-gun, Ch'ungch'ŏng-pukto

Location: This mine is located about 4 km southeast of Puksang-ni. A train connects Kyŏngsŏng to Ch'ungju, from where a bus can be taken to the town of Tanyang. The deposit is situated on a hillside of a pass leading to Kasal-li, which is an hour and a half distance by foot.

Geology and deposit: A pegmatite vein, which may belong to the Bukkokuji Series, intrudes limestone of the Chōsen System in the form of a sill or dike. Outcrops are found at three places.

Ore: Protolithionite (dark bluish-green), lepidolite (colorless to deep pink) and zinnwaldite (reddish-brown) are found. They accumulate in coarse graphic parts. The mica content is 2–4 percent. In the finely aplitic parts, the mica content is 0.1–1.0 percent.

Reserves: At the No. 1 deposit, the vein is 1.8 m wide, but decreases to 0.3 m in the gneisses and schists at the summit of the hill. No. 2 and No. 3 veins are 1.0–0.7 m wide and contain about 1 percent mica. No. 1 vein is 14 m long; its depth is unknown.

h. Songgye-ri, Hansu-myŏn, Chech'ŏn-gun, Ch'ungch'ŏng-pukto (Kinosaki, 1942)

Location: About 15 km southeast of Ch'ungju, 9 km south of Hwanggang-ni, Hansu-myŏn, and about 7.5 km northeast from Suanbo-onch'ŏn (hot spring).

Geology and deposit: Biotite-granite, which may belong to the Bukkokuji Series, intrudes pre-Cambrian limestone and slate. Pegmatite, porphyritic granite, spessartite, wolframite-quartz-and fluorite-veins are associated with the biotite-granite.

Pegmatite, containing lithia mica, strikes east through a limestone and dips 60° S. Its width is 30 cm, more or less. Outcrops occur at four places over a distance of 80 m. They consist of blocks of one dike cut by faults running N 40°W.

Ore: Lithia micas and a small amount of rubellite are found. There are two varieties of lithia mica; one is pale violet and the other pale brownish-red. The lithia mica crystals are scales less than 1 cm across. The optical angle of the former is not constant, and there is a uniaxial variety.

Reserves: The content of lithia mica in pegmatite varies from 3 to 20 percent (averaging 6 percent). The horizontal extension of the pegmatite is thought to be 90 m (in one vein). It is 50 m wide and 25 m deep. The entire content of micas appears to be 100 tons.

i. Taesal-li, Taesan-myŏn, Sŏsan-gun, Ch'ungch'ŏng-namdo (HARADA & ISHIKAWA, 1944)

Location: The mine can be reached by train to Hongsŏng, on the Kyŏngnam Line, from Ch'ŏnan Station of the Kyŏngsŏng—Pusan Line and by bus to Sŏsan, by truck 21 km from there and 3 km by foot.

Geology and deposit: The geology consists of metamorphic rocks of the Rensen (Yŏnch'ŏn) System and gneisses of the Shōgen (Sangwŏn) System. The country rock consists of dolomite and at the contact with pegmatite contains diopside.

The pegmatite strikes approximately north in the dolomite, and dips east 45°–60°. Its extension to the south is 5 m, and its width is 5 m. It stretches out on the sand beach and is cut by a fault. Lepidolite, zinnwaldite and beryl are found.

Ore: The principal ore mineral is lepidolite, which is accumulated in the central part. Its size attains 10 cm in diameter and the mass is arranged like petals of a flower.

Reserves: It is divided into five zones (Table 6).

Table 6. Content of Lepidolite in the Pegmatite.

Zone	Width	Percent of lepidolite
A	70 cm	—
B	30	1
C	100	10
D	60	2
E	40	—

The maximum amount of lepidolite present is 10 percent; the average is about 4 percent. The entire amount cannot be known, because of its poor outcrops. It is not found in the selvages.

j. Tajihol Mine, Onjŏng-ni, Chyŏgam-myŏn, P'yŏngsan-gun, Hwang hae-do (TAKAHAMA, 1937)

Location: Onjŏng-ni can be reached by bus for Haeju from either P'yŏngsan or Kŭmju on the Kyŏngsŏng-Ŭiju Line. The mine is on a hill, 100 m high, 1 km southeast from Onjŏng-ni.

Geology and deposit: The country rock consists of biotite-granite, in which xenoliths of dolomite are included and intruded by syenite-porphyry, two veins of pegmatite and a gold-silver-bearing quartz-vein. One vein contact with the upper wall of the gold-vein is 1.5–2 m in width and 300 m long.

Ore: Lepidolite and zinnwaldite, commonly found in large crystals 6 cm in diameter. The content of lithia-micas in the whole deposit is estimated at 1 percent.

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Allanite in Korea

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1. Allanite at P'ano-ri, P'allyung-ni, An'ak-ŭp and Naep'yŏng-ni, Unhong-myŏn, An'ak County, Hwanghae-do[1)]

Allanite is found at a point some 19 km north of the Hwanghae branch of the main tracks between Seoul and Sinŭju. The general geology around the spot where allanite is found is mostly composed of granitic gneiss of pre-Cambrian age and two-mica granite of the Cretaceous period, the latter probably cuts the former and includes not only the main mass but also many intrusions of aplite, pegmatite and even quartz veins. The general strike of these dikes coincides with the schistosity of the granitic gneiss (Fig 1).

Allanite occurs as one of the accessory minerals in dikes of pegmatite and aplite, accompanied by paragenetic minerals such as garnet, hornblende, diopside, zircon, sphene, rutile, ilmenite and various sulphides. General rules, directly related to the origin of the allanite obtained from field observations of the modes of occurrence of this mineral are as follows:

1. No allanite is found in quartz veins which are associated with pegmatite dikes or aplite, but in the latter (dikes) themselves;
2. Dikes of pegmatite or aplite which are associated with allanite are usually found in a granitic gneiss district only, and little allanite is found in dikes which are intruded into the two-mica granite district;
3. The portion which includes some allanite of pegmatite or aplite dikes in the two-mica granite district is limited to xenoliths of the granitic gneiss cited above. The fine-grained crystalline allanite which encircles these xenoliths occurs with paragenetic biotite;
4. Allanite is found only in dikes of pegmatite or aplite in granitic gneiss, and little allanite is found in two-mica granite dikes, which are distributed through both these rocks;
5. Allanite is more numerous and occurs in larger crystals in granitic gneiss which surrounds the dikes rather than in the dikes of pegmatite or aplite them-

* Deceased.

selves. In such cases, the allanite usually accompanies large crystals of biotite, one paragenetic mineral;

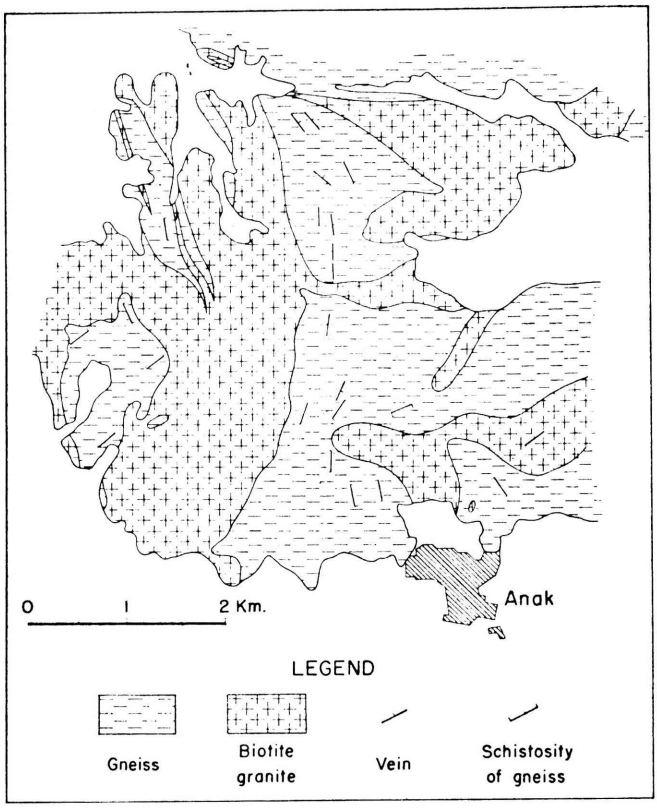

Fig. 1

6. There are three types of combinations of allanite and paragenetic minerals: a) allanite accompanied by biotite, garnet and some sulphide minerals, such as pyrite, chalcopyrite, pyrrhotite, etc.; this type is most common and contains small crystals of allanite particularly embedded with swarms of garnet and biotite; b) a combination of allanite with zircon alone, containing neither garnet nor sulphides; c) a combination of allanite with epidote, grossularite, hornblende, zircon, etc., as contact minerals in the zone between aplite dikes and granitic gneiss, the former of which give contact metamorphism to the latter; in this case, the allanite occurs intimately mixed with zircon;

7. Dikes which contain some allanite in this district are mostly fine-grained, rather compact in nature and differ from common pegmatite dikes. The plagioclases, which form the principal constituents of the pegmatite contain An 12–30 and microcline, which is rather uniformly distributed in ordinary dikes, is scarcely

found. In addition, the nature of these plagioclases tends to be basic. Moreover, considerable traces of hydrothermal metasomatism are seen in the dike, but no traces at all of pneumatolytic metasomatism occur in the same dike.

From the results of general field observations, the existence of gneiss is thought to be one of the principal reasons for finding crystal of allanite. That is, the allanite is believed to be a product of hybridization between the pre-existing gneiss and pegmatitic magmas. It is also thought that the allanite is found (a) in the contact zone between the gneiss and the dikes, (b) around the zenoliths of gneiss in the pegmatite and (c) in the fissures of the gneiss, into which the pegmatitic magmas, were injected.

It is inferred that allanite and biotite are contemporaneous products; Fe and Ca in the former were supplied principally from gneiss, while the rare elements were furnished by pegmatitic magmas.

Physical properties

Allanite has a hardness of 5–6 and is black. It has a resinous luster on a fresh surface and gives a bluish green streak. The specific gravities of the following two allanites were obtained by means of a pycnometer.

1. Allanite paragenetic with minerals such as biotite, garnet and sulphides;
2. Allanite paragenetic with minerals such as common hornblende, diopside, zircon, sphene, etc. Results obtained;

(1) G $(\frac{2°}{4°})=4.076$

(2) G $(\frac{2°}{4°})=3.915$

Only one crystal of allanite showing three plane faces of a(100), c(001) and δ(103) has been found at Naep'yŏng-ni, Ŭnhong-myŏn; most of the allanite is massive and rarely crystalline, and even though some plane crystal faces are sometimes found, they are usually uneven.

The interfacial angles of an allanite crystal obtained at Naep'yŏng-ni were measured. The results were as follows:

	Found results	*Dana's values*
a∧c	65° 00′	64° 59′
c∧δ	22° 06′	22° 19′
a∧δ	87° 26′	87° 18′

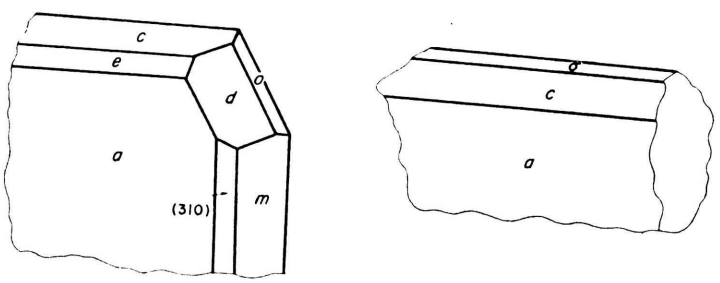

Fig. 2

According to KINOSAKI[2,3], the following crystal faces were found (Fig 2).

m(110), c(101), 1(201), o(011), d(111) and ?(310)

The results of microscopic tests on an allanite section cut parallel to the plane (001) are as follows: The plane of the optic axis is usually parallel to the (010) plane, and is optically negative, biaxial, $2V=55°-51.4°$ and $C \wedge X=57°$ 1'; pleochroism is strong; color along the X axis is slightly brown, but sometimes colorless; Y is brown while Z is light brown; however, sometimes parts of both the Y and Z axes are deep brown. The deepness of the brown color also varies, that is, it is deep in the center and light on the periphery of the crystal.

This variation in color sometimes changes gradually from one place to another, but the color boundary is also sometimes clear. The index of refraction of the part with the deep-brown color is greater than that of the part with the light-brown color, but double refraction is less in the dark part than in the light. Such a phenomenon depends mostly upon the difference in chemical constituents between the center and periphery of a crystal of allanite, which is caused largely by the degree of decomposition of that mineral by weathering, according to Winchell, but we could not determine whether this is true or not. KINOSAKI described the results of his examinations of the refractive index of Korean allanite in this locality as follows:

$$Np=1.765,\ Nm=1.768 \text{ and } 1.774<Ng<1.779.$$

Chemical properties

Two kinds of allanite which were used in the specific gravity measurements by means of the pycnometer, were also chemically analysed.

The results of these tests are as follows:

Columns (3) and (4) in Table 1 contain results on Korean allanites reported by NAKAI[4] and MIZUMA[5], respectively, and are listed for comparison:

Samples (1) and (2) used for chemical analysis vary little in their constituents, although their modes of occurrence were quite different. The differences in the results of the chemical analysis of No. (3) show that it is higher in Fe_2O_3, $[Ce]_2O_3 + [Y]_2O_3$ and H_2O^+) and is somewhat less in Ce_2O_3 as compared with (1) and (2), but the amounts of other constituents do not differ very greatly.

We must pay attention to the smaller amount of H_2O present in samples (1) and (2). It is rather common for 1.5%–2.0% water to be present in allanite crystals previously discovered in Manchuria, Korea and Japan, but these specimens contain much less water. This smaller amount of water in the crystals of allanite indicates that they are more resistant to weathering.

Allanite crystals are often covered with a weathered product on their surfaces, like a fairly thick skin that resembles limonite, which shows that they are, in general, easily weathered.[6] Accordingly, it is rather common that much water is added to the crystals secondarily, although they look fresh after stripping off the so-called weathered skin of the crystals. Allanite crystals obtained in this locality have a strong durability against weathering and have no limonite-like skin on their black

faces at all, and their constituents do not change between the surface and the inside of the crystals. They might be called "Bucklandite", a name given by HERMANN for such strong allanites, which contain less water, as shown in the Table 2.

Table 1. Chemical Analyses of Allanite.

Constituent	(1)	(2)	(3)	(4)
SiO_2	32.99	33.00	31.23	30.60
Al_2O_3	14.68	17.04	15.67	21.96
Fe_2O_3	1.85	2.82	4.65	7.43
FeO	12.53	10.01	10.83	7.46
CaO	10.03	11.62	10.60	3.90
MgO	0.77	0.92	1.11	1.23
MnO	0.82	0.66	1.28	—
ThO_2	0.57	0.44	0.60	—
Ce_2O_3	12.06	10.61	6.78	12.54
$[Ce]_2O_3$	11.20	9.41	15.63	
$[Y]_2O_3$	0.47	0.91		
TiO_2	1.35	0.73	—	—
$H_2O^{+)}$	0.42	0.70	1.54	0.44
$H_2O^{-)}$	0.49	0.53	—	—
Total	100.23	99.40	99.92	85.56

An X-ray analysis of sample (1) was conducted using a spectroanalytic camera of the Siegbahn type, and the distribution of Lanthanide elements determined. The results of these examinations are given in Table 2.

Table 2. Chemical Analyses of Allanite.

No. of atoms	Element	$\alpha 1$	$\alpha 2$	$\beta 1$	$\beta 2$	$\beta 3$	$\beta 4$	$\gamma 1$	$\gamma 2$	$\gamma 3$	4
57	La	2659.7	2668.9	2453.3	2298.0	2405.3	2443.8	2137.2	—	—	—
58	Ce	2556.0	2565.1	2352.3	2204.0	2306.1	2345.2	2045.5	1956.1	1951.5	1895
59	Pr	2459.7	2467.6	2253.9	2114.8	2212.4	—	—	—	—	—
60	Nd	2365.3	2375.6	2162.2	2031.4	2122.2	—	1873.8	—	—	—
61	Il	—	—	—	—	—	—	—	—	—	—
62	Sm	2195.0	2205.4	1994.8	—	—	—	—	—	—	—
63	Eu	2116.3	—	—	—	—	—	—	—	—	—
64	Gd	2041.9	—	—	—	—	—	—	—	—	—

The results of X-ray spectroanalysis clearly show the existence of elements such as La, Ce, Pr, Nd, Sm, Eu and Gd; moreover, the order of abundance of these elements was determined as follows:

Ce, La, Nd, Pr, Sm, Gd and Eu

This order depends entirely upon the relative intensity of the La spectra in each element. The results concerning the amounts of elements with present coincides very closely with that given by Harkin's law.

1.86×10^{-11} g/g of radium was found to be present in this mineral by NAKAI[7], which is, expressed in percent, 1.86×10^{-9}%

Chemical composition

The molecular ratios of each constituent are calculated in order to determine the chemical composition of the allanite from the results of the chemical analyses mentioned above. In this case, a value of 144.69 was tentatively used for calculation from the weight ratio of the average atomic weight of cerium oxide, which can be separated in chemical analysis by anhydrous sulphide salts.

The element Yt is omitted in this calculation because the amount present is so small that it is too difficult to deal with.

The results of the molecular ratio calculations, with the valency of each constituent-element, are as follows:

Table 3. Molecular Ratio.

Constituents	Samples		
	(1)	(2)	(3)
1) $R^{II}O$ (CaO, MgO, MnO, FeO)	0.3840	0.3786	0.3853
2) $R_2^{III}O_3$ (Fe_2O_3, Al_2O_3, $[Ce]_2O_3$)	0.2285	0.2509	0.2498
3) $R^{VI}O_2$ (ThO_2)	0.0022	0.0019	0.0023
4) (SiO_2, TiO_2)	0.5662	0.5586	0.5200
5) H_2O	0.0233	0.0389	0.0856

Calculation can be carried out assuming a value of 6 for (SiO_2, TiO_2) in the residue (SiO_2) extracted from thorite, which is tentatively contained as (Th SiO_4) in the ThO_2 constituent. The results of calculation are given in Table 4.

Table 4

Constituents	Samples		
	(1)	(2)	(3)
$R^{II}O$	4.1	4.1	4.5
$R_2^{III}O_3$	2.4	2.6	2.9
(SiO_2, TiO_2)	6	6	6
H_2O	0.3	0.4	1.0

Accordingly, chemical formulae are as follows:

(1) 4.1 $R^{II}O$, 2.4 $R_2^{III}O_3$, 6(SiO_2, TiO_2), 0.3 H_2O;
(2) 4.1 $R^{II}O$, 2.9 $R_2^{III}O_3$, 6(SiO_2, TiO_2), 0.4 H_2O;
(3) 4.5 $R^{II}O$, 2.9 $R_2^{III}O_3$, 6(SiO_2, TiO_2), 1.0 H_2O.

Many discussions on the chemical composition of allanite have been made by mineralogists such as A. MICHEL-LEVY, R. HERMANN, N. KOCHSKAROFF, etc. N. ENGSTROM[8] proposed the following two chemical formulae after detailed investigations on many chemical analyses of allanite made by many scholars; he concluded

(1) 2(2 $R^{II}O$. SiO_2), $3R_2^{III}O_3$, $4SiO_2$, H_2O;
(2) 2($R^{II}O$. SiO_2), $3R_2^{III}O_3$, $4SiO_2$, H_2O.

(1) corresponds to the chemical formula of fresh allanite, while (2) corresponds to the chemical formula of more or less decomposed allanite.

P. GROTH proposed the following for the chemical composition of allanite after he concluded that allanite should be a basic orthosilicate salt:

$$Ca_2\ (Al, O\ H)\ (Al, Ca, Fe)\ (SiO_4)_3$$

GROTH's molecular ratio for each constituent of allanite is in accord with (1) of N. ENGSTROM. However, the chemical formulae obtained from the chemical analyses of material from the above district are not strictly in agreement with any of the chemical formulae given by N. ENGSTROM on the point of too little $R_2^{III}O_3$ and H_2O in samples (1) and (2), and on the point of too much $R^{II}O$ in sample (3).

The following results on valency of all the basic elements can be obtained through calculation under the assumptions that samples (1) and (2) are hydrous crystals, and that all the H_2O is a basic constituent in sample (3):

(1) $2\times4.1+3\times2\times2.4=22.6$,
(2) $2\times4.1+3\times2\times2.7=24.4$,
(3) $2\times4.4+3\times2\times3-2=24.8$.

These results are in accord with a valency of 24 for SiO_4^{III}, the acidic ion, within certain limits when the allanite is considered an orthosilicate salt. Hence, this chemical formula of the allanite is thought to substantiate the existence of an equilibrium between positive and negative ions considering the valencies of the atoms contained in the orthosilicate.

F. MACHATSCHKI[9] stated that the structural formula of allanite can be expressed as $X_2\ Y_3\ Z_3\ (O, OH)_{13}$, from the standpoint that all lattices in the crystal alternate with each other within those that bear a close resemblance in ionic radius in each crystal. In this formula X stands for the group Ca, Mn, Th, Ce and (Ce), Y for Fe^{II}, Fe^{III}, Al, Mg, and Ti and Z for Si.

The ratios of X, Y, Z, and (O, OH) which constitute the mineral can be obtained after calculating the molecular ratios as above. The results are as follows:

Although MACHATSCHKI thought that the constituent Mn should be distributed between X and Y, and part of the Al constituent in Z, here they are calculated for all the Mn constituents attributed to X and all the Al constituents to Y.

Table 5

Sample	(Ca, Mn, Th, Ce, [Ce]) X	(Fe^{II}, Fe^{III}, Al, Mg, Ti) Y	(Si) Z	(O, OH)
(1)	1.8	2.9	3	12.4
(2)	1.9	3.0	3	12.4
(3)	2.0	3.1	3	13.1

Accordingly, chemical structural formulae obtained from the chemical analyses of these three samples cited above are as follows:

(1) $X_{1.8}\, Y_{2.9}\, Z_3\, (O, OH)_{12.1}$
(2) $X_{1.9}\, Y_{3.0}\, Z_3\, (O, OH)_{12.4}$
(3) $X_{2.0}\, Y_{3.1}\, Z_3\, (O, OH)_{13.1}$

Compared with the chemical structural formula of MACHATSCHKI mentioned above, those of samples (1) and (2) contain a little less (O, OH).

In general, it can be said that the amount of H_2O which coincides with chemical formula (1) of N. ENGSTROM agrees with the chemical structural formula of MACHATSCHKI, but samples (1) and (2), which have much less water, are a little lower in (O, OH) compared with MACHATSCHKI's formula.

2. Allanite at Talli-dong, Haksŏng-myŏn, Sŏngjin-gun, Hamgyŏng-pukto[10]

Allanite occurs along the western railroad at a point some 1.5 km south of the Ssangnyŏng R. R. station which is about 6 km South of Sŏngjin, one of the principal railway stations of the Hamgyŏng Line.

The general geology of the district is mainly comprised of the Mach'ŏl-lyŏng system, which is mostly composed of alternate mica schist, dolomite and limestone.

The general strike is NW–WNW and the dip is rather steep, 45–60°, which varies considerably in places.

One large pegmatite dike which contains allanite runs N 55° W, almost parallel to that of the main strata of the district, but its dip is not ascertainable.

This pegmatite dike crops out obliquely near the top of the range of hills which runs east to west.

Elongation of the dike cannot be traced to either side of the hill; the dike is exposed clearly only at the top.

Many pegmatite blocks are found scattered on both sides of the hill, the north of which is steeep, while the other is rather gentle. The extent of the dike can be inferred to be some 300 m long and 100 m wide, after observing the distribution of these blocks. The dike consists principally of large crystals of quartz and kali-feldspar (orthoclase) with associated zircon, sphene and hedenbergite in addition to allanite. Many of the blocks, which include much allanite, are spread over the southern slope of the hill; among these some blocks are found which consist of

two-thirds allanite. There are also found in fields on the same side many large and small pieces of allanite, which have been washed away from these blocks by weathering. This is thought to indicate the richness of the allanite crystals in the southern limb of the dike.

The allanite generally has a large platy form, and occasionally a single crystal weighs several kg, though it is not so rare. The surface of most of the allanite is covered with a limonite-like skin, produced by weathering, but the inside of the mineral, which looks fresh, is black with a resinous luster.

Physical properties

Almost no crystal face is found in the allanites occurring in dike outcrops on the southern side of the hill except for a tabular face, a(100), in a big allanite block, or in fragments from the big allanite block, or from other big blocks in the same locality. However, some crystal faces such as a(100), m(110), d(111), n($\bar{1}$11), c(001), i($\bar{2}$01), r($\bar{1}$01), l($\bar{1}$02) can be seen in small crystals of allanite which are not affected by weathering and which are usually associated paragenetically with sphene and zircon in the pegmatite blocks scattered over the southern slope of the hill (Fig. 3).

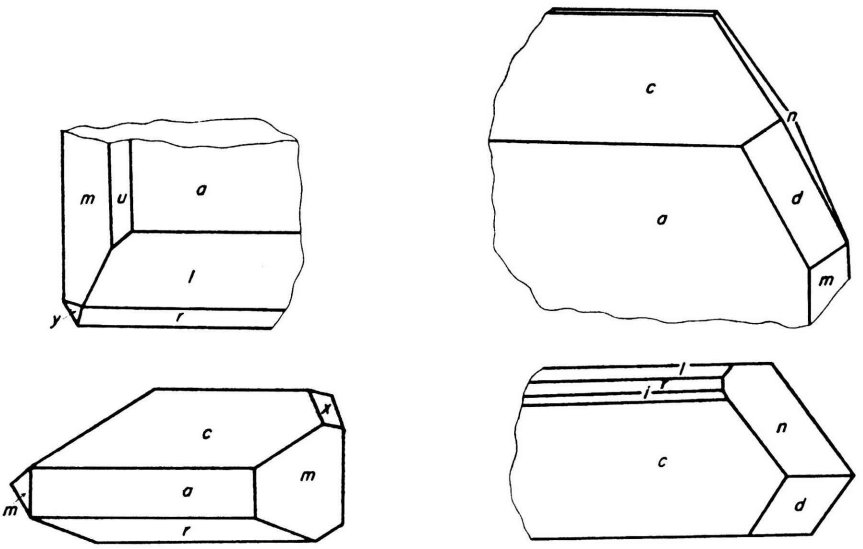

Fig. 3

KINOSAKI[11] described some additional crystal faces in these allanites, such as u(201), x(112) and y(211), besides those mentioned above.

In general, crystals are often tabular in a(100), and also are long and slender parallel to the b axis. The faces a(100), c(001) and m(110) are most common.

The microscope reveals that the structure of a crystal of allanite from this locality is rather homogeneous, and has some optical properties common to other allanite.

Chemical properties

Distillation and drying is repeated for exactly one gram of fine powdered allanite: it is heated on a sand-dish for a while, then some hydrochloric acid is added and heating is repeated; after treatment with HCI once more, and heating, the fused material is resorbed with sodium carbonate into an infusible residue of the first distillation. To the residue, which is left after extraction of SiO_2, a fixed amount of ammonia chloride and ammonia are added for alkalization, then the material which was filtered from the above residue is dissolved in nitric acid and neutralized with ammonia. The sediments of thorium and rare-earth element oxalates are obtained from solution after pouring oxalic acid into the neutralized solution; all rare-earth elements can be abstracted from the solution of nitric acid by the following processes:

Thorium by means of the hydrogen peroxide process, cerium by means of the kalium-bromic acid process, and the rare-earth elements of the cerium and yttrium groups by means of the kalium sulphuric acid process. Manganese, calcium and magnesium are separated and measured by the most common processes of chemical analyses from the solution from which the compounds of the rare-earth elements were obtained after the complete removal of oxalic acid in the oxalates from which many rare-earth elements have been filtered. Bivalent iron and water in the allanite were separated and measured from another sample. The results of the chemical analyses are as follows: (The figures in both columns (2) and (3) in the table were tabulated by SAITO[12] and MIZUMA[13], respectively.)

Table 6. Chemical Analyses of Allanite from Talli-dong, Sŏngjin-gun, Hamgyŏng-pukto.

Constituents	(1)	(2)	(3)
SiO_2	30.48	28.26	28.30
Al_2O_3	16.16	16.32	16.34
FeO	11.82	10.88	10.74
Fe_2O_3	7.05	8.81	7.55
MgO	0.34	1.24	1.12
CaO	10.83	13.49	13.60
Ce_2O_3	9.81	12.84	12.52
$[Ce]_2O_3$	11.16	5.66	6.76
$[Y]_2O_3$	0.19		
ThO_2	0.25	1.29	—
MnO	0.31	0.81	1.46
TiO_2	0.40	—	—
$H_2O^{+)}$	1.59	1.05	1.60
$H_2O^{-)}$	0.11	0.89	—
Total	100.50	99.74	99.99

The results of Nos. (2) and (3) almost completely coincide with each other, but No. (1) is somewhat different, that is, the value of SiO_2, $[Ce]_2O_3$,·$[Y]_2O_3$ of No. (1) is somewhat higher than those of Nos. (2) and (3); on the contrary, the value for CaO, Ce_2O_3 and ThO_2 in the same sample is somewhat smaller than the others. These differences may be caused not only by differences in the materials tested, but also in the dissimilarity in the methods and processes of chemical analyses. The amount of Fe_2O_3 in the results of all three tests is, in general, larger than that of most of the other results.

The rare-earth elements were extracted from a 10-gram sample by precipitation. The precipitated hydroxides were dissolved in dilute HCl and dried, then

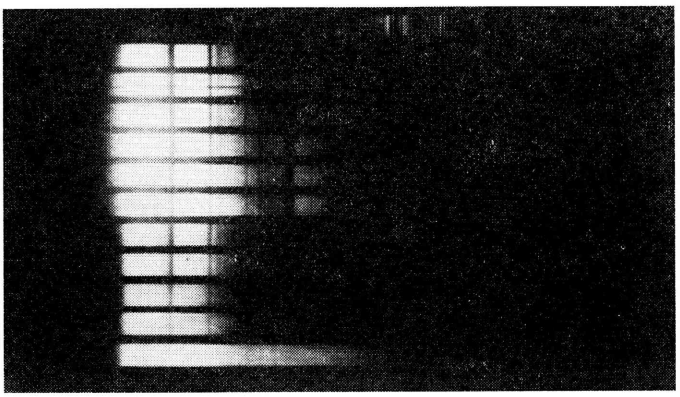

Fig. 4. Absorption Spectrum of Rare-Earth Elements.

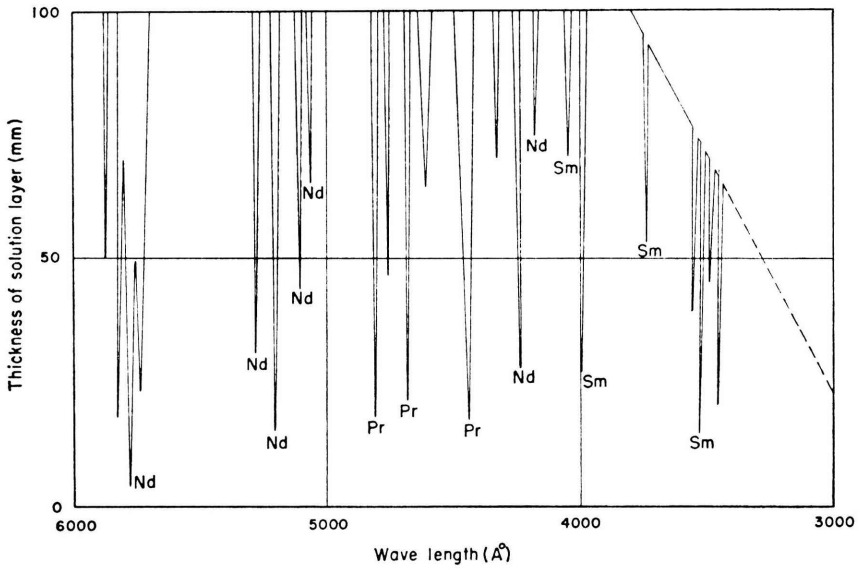

Fig. 5. Spectrum.

dissolved in 100 cc of water, placed in a Baley absorption pipe and examined through absorption spectrometry. The absorbed bands of Pr, Nd and Sm are clearly recognizable in the absorp-tionspectra photographs and absorption curves (Fig. 4 and 5).

Chemical composition

The molecular ratio of each constituent was calculated, determining chemical compositions from the above chemical analyses. The value of 144 for the average atomic weight of the cerium group of rare-earth elements in the An'ak allanite is also used here, because nothing else was tested for this group in this locality. The atomic weights of the yttrium group and ThO_2 are omitted from this calculation, because they occur in too small amounts.

The molecular ratios which were classified according to the atomic weights of each element are as follows:

Table 7

Constituents	Samples		
	(1)	(2)	(3)
1) $R^{II}O$ (CaO, MgO, MnO, FeO)	0.3706	0.4341	0.4404
2) $R_2^{III}O_3$ (Fe_2O_3, Al_2O_3, Ce_2O_3, $[Ce]_2O_3$)	0.2658	0.2661	0.2657
3) (SiO_2, TiO_2)	0.5125	0.4705	0.4712
4) H_2O	0.0883	0.0583	0.0889

All molecular ratios in the constituents $R^{II}O$, $B_2^{III}O_3$, (SiO_2, TiO_2) and H_2O, with a tentative value of 6 for (SiO_2, TiO_2) are as follows:

Table 8. Molecular Ratio.

Constituents	(1)	(2)	(3)
$R^{II}O$	4.3	5.5	5.6
$R_2^{III}O_3$	3.3	3.4	3.4
(SiO_2, TiO_2)	6	6	6
H_2O	1.0	0.7	1.1

Accordingly, the chemical composition for each sample is expressed as follows:

1) $4.3R^{II}O.\ 3.3R_2^{III}O_3.\ 6\ (SiO_2,\ TiO_2).\ H_2O$
2) $5.5R^{II}O.\ 3.4R_2^{III}O_3.\ 6\ (SiO_2,\ TiO_2).\ 0.7\ H_2O$
3) $5.6R^{II}O.\ 3.4R_2^{III}O_3.\ 6\ (SiO_2,\ TiO_2).\ 1.1\ H_2O$

These chemical formulae are a little different from those given by N. ENGSTROM: the ratios of $R^{II}O$ and $R_2^{III}O_3$ are larger and the SiO_2 constitutent is less; the

values for CaO and Fe_2O_3 are larger, on the other hand, than those in the other allanites previously analyzed.

The values for the chemical structural formula X, Y, Z and (O, OH) which correspond to X_2, Y_3, Z_3 and (O, OH), as given by MACHTSCHKI, are as follows:

Table 9

Sample	X (Ca, Mn, Th, Ce) [Ce]	Y (Fe^{II}, $Fe,^{III}$ Al, Mg, Ti)	Z Si	(O, OH)
(1)	1.9	3.5	3	13.5
(2)	2.4	3.8	3	14.3
(3)	2.4	3.8	3	14.5

Accordingly, chemical structural formulae obtained from chemical analyses are as follows:

(1) X 1.9 Y 3.5 Z_3 (O, OH) 13.5,
(2) X 2.4 Y 3.8 Z_3 (O, OH) 14.3,
(3) X 2.4 Y 3.8 Z_3 (O, OH) 14.5

No. (1) approaches the formula given by MACHATSCHKI, but the values of X, Y and (O, OH) are large compared to that of Z in Nos. (2) and (3). This fact depends mostly upon the presence of a smaller amount of SiO_2, in this case, than in the other allanites already mentioned.

3. Allanite at Sanhyŏl-li, Kŭnbung-myŏn, Kŭmhwa-gun, Kangwŏn-do[14]

Allanite occurs on the weathered surfaces of nepheline-syenite with paragenetic lepidomelane. All are massive blocks smaller in size than a man's fist. None of them show any crystal form, and are covered on their surfaces with a skin of brown earthy material which is produced by weathering. However, their fractured surface has a glassy luster and is black in color.

General physical properties of this mineral are as follows:

Hardness=6, specific gravity=4.1, optically negative, 2V is not large; index of refraction is approximately 1.78; pleochroism is Z dark brown, Y light brown.

The results of chemical analysis are given in Table X.

The figures in columns (1) and (2) of this table are results obtained by SAITO and MIZUMA, respectively.

Formulae, in accordance with the chemical formula proposed by N. ENGSTROM and the chemical structural formula introduced by MACHATSCHKI after chemical analysis of No. (1), are as follows:

4.2 $R^{II}O$. 3.4 $R_2^{III}O_3$. 6 SiO_2. 1.1 H_2O,
X 2.0 Y 3.1 Z 2.9 (O, OH) 13.5.

Both formulae approximate those of either ENGSTROM or MACHATSCHKI.

Table 10

Constituents	(1)	(2)	Constituents	(1)	(2)
SiO_3	28.12	27.80	$[R_2]O_3$	12.84	11.91
Al_2O_3	14.01	14.84	ThO_2	1.02	—
Fe_2O_3	7.98	5.29	MnO	3.10	3.15
FeO	7.65	9.82	H_2O^+	1.03	1.35
MgO	0.39	2.10	H_2O^-	0.57	—
CaO	9.16	9.35			
CeO_2	14.21	13.79	Total	100.08	99.43

4. Allanite at Chuksal-li, Ijumg-myŏn Ansŏng-gun, Kyŏnggi-do; Kaegong-ni, Oedong-myŏn, Kyŏngju-gun, Kyŏngsang-pkuto; and P'altam, Puryŏng-myŏn, Puryŏng-gun, Hamgyŏng-pukto[15]

The first collection and investigation of allanite from these localities in Korea was made by IIMORI, YOSHIMURA, and HARA in April, 1941. Allanite from all these localities occur as an accessory mineral in pegmatite.

Table 11

Sample	Chuksal-li	Kaegong-ni	P'altam
Length of crystal	5.0 mm	8.0 mm	15.0 mm
Specific gravity	3.4	3.87	3.34
Hardness	5.5 – 6.0	5.5	5.5–6.0
Weight used for chemical analysis	0.0380	0.0308	0.030
Chemical analyses:			
SiO_2	34.7	29.5	30
FeO	17.0	13.1	18
Al_2O_3	11.0	15.4	5
$(R)_2O_3 + Th\ O_2$	21.0	21.3	21
MnO	3.4	0.5	2
CaO	12.4	12.9	17
TiO_2	—	3.3	1
MgO	—	1.0	3
Total	99.5	97.0	97

Allanite at Chuksal-li is found with fine-grained garnet and magnetite, while that at Kaegong-ni is embedded in aggregates of microcrystalline epidote with magnetite.

Allanite at P'altam occurs paragenetically with rutile and yellowish-colored quartz.

All allanites of these localities have a glassy luster with greenish-brown streaks, and are weakly radioactive. Other general physical properties such as specific gravity, hardness, crystalsize and the results of chemical analysis are given in Table 11.

5. Allanites at Kanji-dong, Haksŏl-li, Puktuil-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo[16]; Samno, Sech'ŏn-dong, Haksŏ-myŏn, Sŏngjin-gun, Hamgyŏng-pukto[17]; T'apko-ri, Kŭmsŏng-myŏn, Kŭmhwa-gun, Kangwŏn-do[18]; Poksap'yŏng, Ilgŏm-dong, Musan-myŏn, Hamgyŏng-pukto[19]

Allanite occurs not only as an accessory mineral in pegmatite at the localities listed above, but also is sometimes found as an accessory mineral in contact metamorphosed limestone, or in acidic and basic igneous rocks.

Allanite crystals are so large and abundant that they may be profitably worked in the former case (pegmatite), but not in the latter case, in contact metamorphism, because they are generally very small and few in number.

Some allanite is found in the limestone paragenetically with other minerals such as actinolite, epidote, hornblende, graphite, etc., at Kanji-dong and Samno, but also occurs in basic nickel-bearing dikes and in gneiss at T'apko-ri and Ch'angyŏl-tong, respectively.

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Monazite Deposits in Korea

Hideo TSUDA

Locality: Sin'am-dong and Posan-dong, Paengnang-myŏn, Ch'ŏlsan-gun, P'yŏngan-pukto.

Location: About 23 km west of Ch'aryŏn'gwan Station on the Kyŏngsŏng-Sinŭiju Line, facing the Yellow Sea.

Introduction:

Placer deposits of monazite have been known on the east coast of Korea, and in river beds in other parts of Korea. Monazite occurring in veins, however, was not known before 1943, when a pegmatite with large crystals of monazite was discovered in the above locality. When I visited there in March 1943, only a small part of the deposit was exposed. But since it seemed promising, the Nicchitsu Mining Co. Ltd. obtained mining rights and engaged in the exploitation of the vein deposit and monazite sand in the vicinity. It was known as the Sŏnam Mine.

Geology:

The district is generally composed of gray granite-gneiss, intruded by porphyritic biotite granite, lamprophyre, pegmatite and quartz veins. The porphyritic biotite granite on the branch road from Changnae to Kibong-dong has xenoliths of gray granite-gneiss and pegmatite. At Posan-dong a granite-containing garnet and two kinds of mica were exposed; their chronological relation to the gray granitegneiss is not clear.

The pegmatite dykes and quartz veins are not large, but are exposed here and there, and contain quartz characterized by its gray or faint pink color. The quartz is similar to that in pre-Cambrian granite-gneiss found in other parts of Korea. The pegmatite dykes may also be of pre-Cambrian age. Some of these are drusy and are accompanied by monazite, forming monazite deposits. Alluvial deposits are found in narrow areas in the valleys and those near pegmatite deposits contain monazite, forming placer deposits of monazite.

The Pegmatite Deposits:

The pegmatites forming monazite deposits in this district are found at Posan-

dong and Sin'am-dong, and the monazite placers, originating from the pegmatite deposits are found on the river bed of the Posan-ch'ŏn river, the beach of Sin'am-dong and the coastal sand dunes of Kibong-dong.

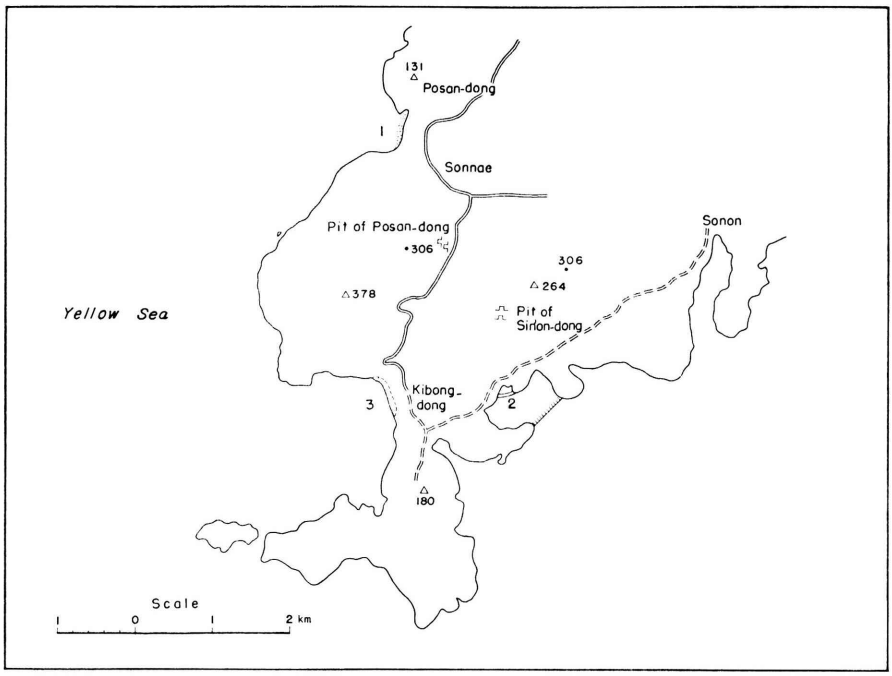

Fig. 1. Monazite Deposits of Korea.
1. Placer deposit of Posan-dong; 2. Placer deposit of Sin'am-dong;
3. Placer deposit of Kibong-dong

Deposits at Posan-dong:

The deposits are typified by xeonoliths of drusy pegmatite with monazite, in a medium-grained garnet granite. The pegmatite is composed chiefly of biotite, faint grayish or pinkish quartz, and a small amount of gray feldspar. The mica is brittle, iron black in color and is found in large block-shaped crystals, some being over 30 cm in diameter and 20 cm in thickness, although commonly less than 5 cm in diameter. Perhaps it is a biotite rich in iron.

Monazite is generally found in portions of pegmatite rich in mica. It is brown in color and does not have a good crystal form. It occurs in various sizes and some crystals are as large as a man's fist; the largest individual crystals are more than 1,300 grams, but in general they are smaller than Indian bean. Accessory minerals include only a small amount of apatite and ilmenite.

The Deposit at Sin'am-dong:

Pegmatite containing monazite is exposed on a mountain slope, about 1,200 m north of Sin'am-dong and is of drusy type. The strike of the deposit is N 40° W or so, gently dipping in a north-easterly direction; its thickness is 2.5 m at the en-

Fig. 2. Monazite. Loc. Posan-dong.

trance of the gallery and gradually pinches out along dip. The pegmatite is drusy and a zonal structure, due to the parallel arrangement of fine scale of biotite, is seen around the druses. Small crystals of monazite are contained in the parts with zonal structure. The druses themselves consist of a zonal arrangement of microcline in the lower zone, and biotite and quartz in the upper zone; monazite, ilmenite and garnet are found in the upper zone.

Placer Deposits:

Placer deposite include more important monazite deposits than the pegmatites mentioned above. Placer monazite may be formed by the weathering of pegmatite deposits.

1. *The river placer deposit of Posan-ch'ŏn*: Contains 0.04–0.05% monazite less than 30 mesh in grain-size, and is accompanied by ilmenite and garnet.

2. *The beach placer deposit of Sin'am-dong*: The monazite is concentrated by the action of sea waves and forms high-grade placers. It originates from the deposit of a coastal terrace that is more promising than the former.

3. *The beach placer of Kibong-dong*: This placer is found in the lower part of the coastal terrace of Kibong-dong and is one meter in thickness. It has a higher grade of monazite than that of the river placer at Posan-ch'ŏn.

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Mica

Chuzō KONDŌ

1. General Remarks

There are four types of mica in Korea, muscovite, phlogopite, lepidolite and zinnwaldite. Among these four, lepidolite and zinnwaldite are not utilized as mica but as lithium ore, which is discussed in another paper.* Therefore, these two types of mica will not be discussed in this report.

Mica, "tolpinul" in Korean, is an important mineral resource in Korea. It has been used in medicines or as windows since olden times. However, Korean mica was brought to public attention after the discovery of large crystals of phlogopite at Yŏn'gol, Puktuil-myŏn, Tanch'ŏn-gun, South Hamgyŏng-do toward the end of 1906. This led to the discoveries of muscovite in Yanghwa-myŏn and Noji-myŏn, P'yŏngwŏn-gun, South P'yŏngan-do, and phlogopite in Changbaek-myŏn, Kilchu-gun, North Hamgyŏng-do. Mining of these two types of mica began for the first time in 1909, by the Japanese, prior to the exploitation of phlogopite in Tanch'ŏn-gun. This marked the beginning of the history of modern mica mining in Korea.

In 1910, the next year, the Nikkan Mica Co. Ltd. was established to exploit the phlogopite in Tanch'ŏn-gun. Active mining began, and about 2 tons of mica were immediately shipped to Europe in order to enhance its reputation. At that time, however, there was no demand for mica in Japan, and knowledge on the treatment of mica was lacking. Exploitation did not continue for long, and all mica mines in Korea were closed by 1911.

In 1914 the Tōyō Mica Co. Ltd., in Toyohashi city, Japan, began manufacturing mica paper from the phlogopite of Tanch'ŏn-gun, but the operation was stopped after only 3 months. Exploitation of mica in Korea was then interrupted for a long time, until 1919.

In the meantime (1916), KAWASAKI[4] published his study of mica in Korea. This paper promoted the exploitation of mica in Korea, and the Hōshu mine in Puktuil-

* SHIBATA, Hidetaka, 1951, Lepidolite, *in* Geology and Mineral Resources of the Far East, Vol. I (Korea) Comp. Comm. Geology and Mineral Res. Far East, Tōkyō Geog. Soc.

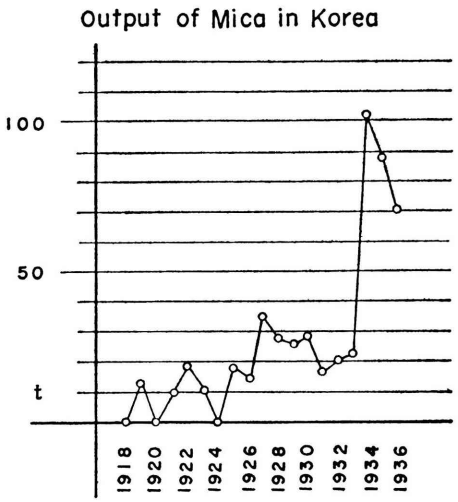

Fig. 1

myŏn, Tanch'ŏn-gun, South Hamgyŏng-do was opened by Shimakichi Seki in 1919. However, no one followed him, and the Hōshu mine produced only 20 tons annually up to 1926.

Thereafter, the manufacture of micanite by companies such as the Nippon Rika Kōgyō sho (Japan Physicochemical Industry Co.) and the Nippon Mica Seisaku-sho (Japan Mica Manufacturing Co.) began in Japan. Demand for mica increased gradually as the manufacture of electric machinery advanced in Japan. The Imdong (Rindō) mine in Kilchu-gun, North Hamgyŏng-do, started operation in 1927 and the Tōyō mica mine (later the P'yŏngbuk mine) in Ch'ŏngyong-myŏn, Pakch'ŏn-gun, North P'yŏngan-do began in 1932. However, there were still less than four mining claims, and the maximum annual production was 35 metric tons (in 1927), the average being less than 30 metric tons.

However, in 1934, the demand for mica suddenly increased in Japan, and the total number of mines jumped to 9, and the output of mica rose to 103 metric tons. The number of mines increased to 14 in 1936, and to 20 in 1938. Thus the mica-mining industry gradually became prosperous.

The Korean Mica Exploitation and Sales Co. Ltd. was established jointly by 12 major electric machine manufacturers in Japan in September 1939. Upon promulgation of the Korean mica distribution control law in December 1939, the company was officially designated as a control agency, and specifications for different grades of mica were set.[16] On the other hand, the Tōyō-Takushoku (Oriental Colonization) Co. Ltd. embarked on the exploitation of mica in Korea. Thus, for the first time, great sums were invested for the exploitation of mica in Korea, and public interest rose remarkably. As a result, new mica deposits were discovered in succession since 1943, and the output of mica recorded was 146 metric tons in 1943 and 422 metric tons in 1944.

2. Properties of Mica

There are two kinds of mica produced in Korea, i.e., muscovite and phlogopite. Muscovite is colorless and transparent, in the form of thin cleavage sheets, but it is commonly gray or light-gray, semi-transparent, in thick sheets. It is often tinged with rose, brown or green, and has a silky or pearly luster. The crystals rarely appear perfect, and the side planes are often uneven and bear horizontal striations. The crystals are usually bent and crushed. A No. 1 mica sheet, namely a sheet 20 cm × 7.5 cm or 12 cm × 12 cm in size, is rarely found in the Kŭmgang mica mine, P'yŏngwŏn-gun, South P'yŏngan-do, the most common sizes being 2 or 3 cm in diameter, namely 6B or 6C grade. Muscovite is generally superior to phlogopite in electrical insulation properties, and muscovite from the Kŭmgang mica mine rivals the muscovite from India, and is superior to the muscovite from Brazil in insulation strength. It is brittle, having little flexibility, and is not very resistant to heat. Safe use is limited to temperatures below 450°C.

Phlogopite from Korea varies in color, transparency and luster. It is sometimes colorless and transparent, but mostly semi-transparent or sub-transparent and silver-gray, silver-green, reddish-green, brownish-green, brown, reddish-brown or blackish-brown. There are various degrees of depth of color, and dark-colored mica appears black. However, even black and opaque mica becomes almost colorless and transparent or light colored if split into thin sheets. Generally, light-colored mica has a silky luster, while dark-colored mica is either pearly or glassy.

The crystals seldom appear as perfect as those of muscovite, and streaks or cracks, which correspond to the sliding plane, run in all directions on the cleavage plane. Crystals split easily and regularly along the streaks or cracks and form so-called pseudocrystals, which sometimes appear as ribbon mica or triangular mica. Cleavage sheets free from cracks which are sold are generally smaller than No. 5 grade (4 cm × 4 cm or 2 cm × 7 cm).

Phologopite is characterized chemically by magnesia, but generally contains some iron. The color is inclined to become darker with iron content, and iron-rich mica appears dark-brown or black. Optical properties are related to the chemical composition and, consequently, to the depth of color. For example, in mica in the vicinity of the boundary between North and South Hamgyŏng-do, as the color becomes deeper the optic axial angle becomes larger, and light-colored mica shows an interference figure which appears uniaxial.[4] On the other hand, the optic axial angle of the mica from Pakch'ŏn-gun, North P'yŏngan-do, becomes smaller and the refractive index higher as the color becomes darker.[9]

Phlogopite is generally inferior to muscovite in electrical insulation properties, tensile strength, exfoliation ability and acid resistance, but is far superior to muscovite in heat resistance. A sudden decline in electrical resistance due to heating occurs at about 1,000°C, and phlogopite can generally be used up to 900°C with safety. Blackish-brown mica is especially heat resistant, and flexibility is generally excellent. Phlogopites from Korea are sorted into two, hard and soft.

Soft phlogopite is used for commutators, and varies from 2.5 to 2.7 in Mohs' hardness, and is less than 16 in Shoa hardness. Hard phlogopite, on the other hand, is more than 17 in Shoa hardness, is tinged with black and is used for punched micas.*

In summary, phlogopite from Korea varies in color, luster, hardness and other properties, among which color is related not only to the chemical properties but to various physical properties. In general, light-colored phlogopite, such as silver-gray or silver-green, is rather low in insulating quality, is flexible, soft and elastic. Creases will form if it is bent, but these creases do not decrease its insulating properties. Dark mica, such as brown or reddish-brown mica, has excellent insulating properties and high heat resistance. Black or blackish-brown mica has the highest heat resistance with a high hardness.

3. Mica localities

Korea is one of the most important mica-producing countries in the world, with mica occurring in many districts. However, mica mines in the past were almost wholly confined to phlogopite mines. It is noteworthy that most of muscovite mines have been in operation only since 1940.

a. Muscovite

Muscovite is found all over the peninsula. Most of the mica is spoiled by many cracks and rents, so production is carried on at the following 8 regions only.

1. Pung-myŏn, Hŭich'ŏn-gun, North P'yŏngan-do (Ch'ŏnsang mica mine).
2. Yanghwa-myŏn, Noji-myŏn, Tongsong-myŏn, Chohŭng-myŏn, Tŏksan-myŏn, and Sunan-myŏn in P'yŏngwŏn-gun, and Sukch'ŏn-myŏn, Sukch'ŏn-gun in South P'yŏngan-do (Kŭmgang mica mine, Sunan mica mine, Huun mica mine, etc.).
3. Munhwa-myŏn, Yongmun-myŏn, and Kasan-myŏn in Sinc'hŏng-gun, Hwanghae-do (Munhwa mine, Paegsŏk mica mine, Sinch'ŏn mine, etc.).
4. Kosan-myŏn, Pyŏksŏng-gun, Hwanghae-do (Sŏktam mica mine).
5. Taegong-myŏn, Anak-gun, Hwanghae-do (Anak mica mine).
6. Wŏndŏng-myŏn, Samch'ŏk-kun, Kangwŏn-do (Samch'ŏk mine).
7. Pukhu-myŏn, Andong-gun, North Kyŏngsang-do (Tuwŏl mica mine).
8. Tonghyan-myŏn, Chinan-gun, and Kyebung-myŏn, Changsu-gun, North Chŏlla-do (Taeyu mica mine).

Among the above mines, the Kŭmgang mica mine, in Yanghwa-myŏn and Noji-myŏn, P'yŏngwŏn-gun, South P'yŏngan-do, is the oldest and most unique mine and was exploited in olden times. The others have been exploited only recently. The mines listed in (1), (4) and (6) were discovered in 1943 or 1944, and operation began immediately.

* E.N.: Mica is punched into small pieces and used for insulation.

b. Phlogopite

Phlogopite makes up most of the mica output in Korea, and there are many old mines which have a long history of exploitation, and also many mines now being worked. Phlogopite is concentrated in the following regions.

1. Changbaeng-myŏn, Yangsa-myŏn, and Tŏksan-myŏn in Kilchu-gun; Haktong-myŏn, Sŏngjin-gun, North Hamgyŏng-do, and Puktuil-myŏn, Tanch'ŏn-gun, South Hamgyŏng-do (Hōshu, Imdong, Taeam, Changbaek, Sangwŏl, Tansŏng, Osamp'o, etc., mines).
2. Hago-myŏn and Sanggo-myŏn, Myŏngch'ŏn-gun, North Hamgyŏng-do (Myŏngch'ŏn or Taiyō mica mine).
3. Ansu-myŏn, P'ungsan-gun, South Hamgyŏng-do (P'ungsan mica mine).
4. Huch'ang-myŏn and Sokhu-myŏn, Pukch'ŏng-gun, South Hamgyŏng-do (Pukch'ŏng mica mine).
5. Kogwan-myŏn, Ŭiju-gun, North P'yŏngan-do (Ŭiju mica mine).
6. Pura-myŏn, Yongch'ŏn-gun, North P'yŏngan-do (Kach'ado mica mine).
7. Ch'ŏngnyong-myŏn, Pakch'ŏn-gun, and Wŏn-myŏn, Changnim- myŏn, T'aech'ŏn-gun, North P'yŏngan-do (Nojŏn-dong or P'yŏng-buk, Unhŭng-dong, Changnyong, Sŏnyong, Ansimu, etc, mines).
8. P'unggi-myŏn, Yŏngju-gun, North Kyŏngsang-do (Tsuruhara-P'unggi mine).

Of the above locations, (1) the neighborhood of the boundary between North and South Hamgyŏng-do and (7) Pakch'ŏn-gun, North P'yŏngan-do are the main sources of mica in Korea. The former especially has a long history of exploitation and produces most of the mica in Korea. Two types of phlogopite are produced in Korea, hard and soft, which have different uses. Mica in the neighborhood of the boundary between North and South Hamgyŏng-do is soft, while that from Pakch'ŏn-gun, North P'yŏngan-do, is hard. The mica from (8) Yŏngju-gun, North Kyŏngsang-do, is also hard and resembles biotite. Localities (5) and (8) were discovered in 1944 and exploitation began immediately.

4. Ore Deposits

All micas of Korea are intimately related to granite-pegmatite, and occur in pegmatite veins or in a type of contact deposit related to pegmatite.

a. Muscovite Deposits

All muscovite in Korea occurs in pockets in pegmatite veins, and the surrounding rocks are almost wholly limited to granite gneiss or granite. Muscovite sometimes occurs in pegmatite, traversing mica schist, but in this case biotite is usually found. The muscovite crystals of this type are generally small and are rarely used for making sheets.

Pegmatite veins occasionally consist of quartz, feldspar and muscovite, but usually consist only of quartz and muscovite. Beryl is often found in Korea, and

it occurs mostly in pegmatite associated with muscovite. However, large muscovite crystals are rarely found in association with beryl, and muscovite of this type is commonly spoiled by creases or rents.

The ore deposit of the Kŭmgang mine, the oldest mine, in Yanghwa-myŏn and Noji-myŏn, P'yŏngwŏn-gun, South P'yŏngan-do, is a pegmatite vein traversing gray granite gneiss, and consists only of quartz and muscovite. There is a tendency for the quantity of mica in the center of the vein to be small, but large on either side. The crystals are generally large and sometimes No. 1, according to the specifications, which is 20 cm $\times$ 7.5 cm or 12 cm $\times$ 12 cm. The mica appears greenish-gray to white, and the optical properties are 2 E $\fallingdotseq 66°$ and $\gamma \fallingdotseq 1.596$. Its electrical insulation properties rival that of Indian ruby and are superior to muscovite from Brazil.

b. Phlogopite Deposits

Phlogopite in Korea occurs in pegmatites or thermal metamorphic rocks at the contact region between limestone or dolomite and pegmatite. The shapes of the ore deposits are commonly irregular, and phlogopite occurs in the form of streaks, nests, pockets, veins or impregnations in ore deposits.

Typical phlogopite ore deposits are found in the Mach'ŏllyong system or the gray granite gneiss. The former is extensively developed in the neighborhood of the boundary between North and South Hamgyŏng-do, and forms the most important mica-producing area in Korea, where prominent mica mines, such as Hōshu, Imdong and others, are located. Phlogopite from this region accounts for most of the mica produced in Korea. Various kinds of mica are produced, but are generally used in commutators. The latter is found in Packch'ŏn-gun, North P'yŏngan-do, and always appears dark, such as black or blackish-brown, and is hard and highly resistant to heat.

Both are intimately related to limestone or dolomite, and even though phlogopite is found in pegmatite veins, it occurs only in veins which penetrate limestone or dolomite, and even though it occurs in gray granite gneiss, it is found only in that portion of dolomite captured by gneiss. The deposits of phlogopite in Korea include diopside, amphibole, calcite, etc., and are especially related to diopside. Accordingly, Mg in the phlogopite might not have been included in magma from the beginning, but some components might have derived from calcareous rocks as the result of a pneumatolytic process.

The thermal metamorphic rocks consist of crystalline limestone, dolomite, wollastonite rock, diopside rock, diopside-orthoclasite, etc. Phlogopites have different colors, hardness, optical properties and chemical composition, and are associated with different colored diopside, according to the mode of occurrence. Generally speaking, phlogopite found in pegmatite or strongly-altered rocks, such as wollastonite rock, diopside rock or diopside-orthoclasite appears dark colored, dark black, dark-brown or brown, is rich in Fe and is hard. On the contrary,

phlogopite found in weakly-altered rocks, such as crystalline limestone, appears light-colored, white or green, and tends to have little iron content.

In comparison with ore deposits near the border of North and South Hamgyŏng-do, phlogopite deposits in Pakch'ŏn-gun, North P'yŏngan-do, are metamorphosed to a large extent. Comparing the two kinds of phlogopite, that from Pakch'ŏn-gun is darker, has a higher refractive index, is harder and is more highly resistant to heat than that of North and South Hamgyŏng-do.

1. Ore Deposits near the Boundary of North and South Hamgyŏng-do

The neighborhood of the boundary between North and South Hamgyŏng-do consists of metamorphic rocks of the Mach'ŏllyŏng system, involving thick layers of dolomite; and phlogopite occurs in pegmatite traversing dolomite, or in skarns along the margin of granite or pegmatite veins. This region forms the most important metallogenic area with regard to mica.

Phlogopite in this province appears colorless, or variously colored, such as silver-gray, light grayish-green, silver-green, dark-green, reddish-brown, brown, black, etc. It is soft and is highly regarded for use in commutators. In chemical composition, the magnesia content is commonly greater than 20 percent and never below 4.5 percent, and the iron content is commonly less than 3 percent, and sometimes mounts to 5.3 percent. In general, as the iron content increases, the color tends to deepen. Li_2O is often contained; phlogopite from Kilchu-gun is rich in Li_2O, containing 0.22 percent.[1] Fluorine is always present and sometimes amounts to 1 percent.[1]

Phlogopite found in pegmatite or strongly-altered rocks, such as wollastonite rock, diopside rock or diopside-orthoclasite, is generally dark-colored, such as dark-brown or brown, is rich in iron and has a comparatively large optic axial angle. On the contrary, phlogopite found in such weakly-altered rocks as crystalline limestone, appears light colored, white or green, contains little iron, has a small optic axial angle and shows an uniaxial interference figure.[4]

Ore deposits of the Hōshu (P'osyu) mine

Ore deposits are scattered around Mt. P'osyu, which stands on the boundary between Taesil-li, Puktuil-myŏn, Tanch'ŏn-gun and Imdong, Changbaeng-myŏn, Kilchu-gun, and occur near the contact zone between pegmatite and dolomitic rocks or limestone. The metamorphic rocks gradually grade in the order, limestone to coarse-grained limestone, phlogopite-calcite rock, phlogopite-diopside-calcite rock, phlogopite-diopside rock, diopside-orthoclasite and pegmatite. This clearly suggests that granitic residual magma, rich in mineralizer, intruded dolomitic limestone and formed phlogopite and diopside by the replacement of mineralizer. The optical properties of the mica are as follows: $Np=1.546$, $Ng=1.584$, $2E=0°$.

Ore deposit of Yon-gol, Puktuil-myŏn, Tanch'ŏn-gun

This mica deposit marked the beginning of the exploitation of mica in Korea, and its discovery goes back to 1906. Yon-gol is located on the western side of the Mach'ŏllyŏng mountain range, and is 44 km north of Sŏngjin-ŭp and 48 km

north of Tanch'ŏn-ŭp. This district is composed of phlogopite-bearing crystalline limestone, phlogopite- and diopside-bearing crystalline limestone, phlogopite-diopside rock, phlogopite-diopside-gneiss, diopside-hornblende-gneiss and mica schist, and the rock series strikes N 20°–30°E, dipping northwest from 30° to 50°. This complex is traversed by numerous younger dikes of pegmatite and porphyrite. The ore deposit is found in limestone, containing abundant diopside. It occurs close to or along pegmatite veins, traverses limestone, and makes up a zone about 200 m in breadth. There are various shapes and they appear as veins, pockets, masses or nests. The mica is colorless, white, light-green or light-brown. The chemical compositions are given in the table.

Ore deposits of Changmunnae, Imdong, Changbaeng-myŏn, Kilchu-gun

In the vicinity of Changmunnae, Imdong, there are many mica deposits in pegmatite veins traversing dolomite or in diopside skarns which were formed in the contact zone between pegmatite and dolomite. The ore deposits within pegmatite veins occur as veins and consist of diopside and phlogopite. The ore deposits in a diopside skarn, on the other hand, form either massive deposits, composed of large masses, or veins of phlogopite. In general, phlogopite is associated with diopside, forsterite and calcite, and appears dark-brown, light-brown or white.

2. Ore Deposits of Pakch'ŏn-gun, North P'yŏngan-do

Many mica deposits occur in C'hŏngnyong-myŏn, Pakch'ŏn-gun, North P'yŏngan-do, forming either veins, which conspicuously vary in breadth, or pockets in gray granite gneiss. No calcareous rock is found in the vicinity, but phlogopite occurs with diopside in phlogopite-diopside rock, as seen in North and South Hamgyŏng-do; it is thought that the calcareous rocks which formerly existed there were captured by granite gneiss and were perfectly altered.

Table 1. Chemical Compositions of Phlogopites from North and South Hamgyŏng-do.

Localities	Color	MgO	FeO	Li_2O
Yon-gol, Tanch'ŏn-gun	Colorless	7.05	1.43	None
,, ,,	Colorless	6.43	1.73	Present
,, ,,	Colorless	8.71	0.48	None
,, ,,	Light grayish-green	19.36	2.74	Present
Osamp'o, Tanch'ŏn-gun	Colorless	17.44	1.64	Present
Sogyŏlsu, Tanchŏn-gun	Dark-green	7.45	2.15	None
Sangangaji, Sŏngjin-gun	Colorless	23.77	1.14	Present
So-dong, Kilchu-gun	Dark-green	14.80	5.30	Present
Tŭngch'angŏgu, Kilchu-gun	Dark-green	20.45	1.32	Present
Imdong-ni, Kilchu-gun	Dark-green	11.68	1.19	Present
Taesungbang-dong, Kilchu-gun	Black	4.52	2.69	None

(Analyzed by the Commerce and Industry Bureau, 1910)

Table 2

	Hōshu mine Tanch'ŏn-gun	Hōshu mine Kilchu-gun	Yŏn-gol	Sogyŏlsu	Sodŭngnyŏng-dong, Imdong
SiO_2	40.31	39.27	—	—	—
Al_2O_3	15.51	17.52	—	—	—
Fe_2O_3	1.08	0.68	0.16	1.68	0.39
FeO	1.48	1.52	0.76	2.07	2.05
MgO	25.58	26.37	27.48	26.48	25.43
CaO	0.06	—	—	—	—
Na_2O	1.54	0.69	1.03	0.89	1.09
K_2O	9.52	8.40	8.72	9.40	8.98
H_2O (+)	3.35	—	—	—	—
H_2O (−)	0.69	—	—	—	—
F	1.27	0.63	0.64	1.00	0.74
TiO_2	0.50	—	—	—	—
P_2O_5	0.02	—	—	—	—
MnO	0.03	—	—	—	—
Li_2O	—	—	None	None	None
Ignition loss	—	4.23	—	—	—
Total	100.95	99.31	—	—	—
Color	—	—	Light-green	Dark-green	Black
Analyzer	Tsurumi[19]	T. Mizuma[21]	Central Experimental Station, Government-general, 1915[4]		

Table 3

	Color	Optic axial angle	Refractive indices	Color of diopside	Color of spinel
Nojŏn-dong, Ch'ŏngnyong-myŏn	Brown	$2E \fallingdotseq 15°$	$\gamma \fallingdotseq 1.575$–$1.578$	White	
Wiyŏng-dong, ,,	Light-brown	$2E \fallingdotseq 7°$	$\gamma \fallingdotseq 1.580$–$1.582$	Light-brown	Bluish-green
Nojŏn-dong mine, ,,	Black	$2V \fallingdotseq 0°$	$1.587 > \gamma > 1.583$	White or Light-green	
Unhŭng-dong, ,,	Black	$2V \fallingdotseq 0°$	$1.587 > \gamma > 1.583$	Green	Black
Ŭllyong-dong, ,,	Dark brown or black	$2V \fallingdotseq 0°$	$\gamma \fallingdotseq 1.581$	Light-green	

The mica is dark colored, such as black or brown, is hard and very heat resistant; it is used in the manufacture of spark plugs. Generally speaking, dark-colored mica has small optic axial angles and high refractive indices. There is a

tendency for dark-colored mica to be associated with green diopside, while light-colored mica is associated with white diopside.

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Supplement to "Minerals of Korea"

Hideo TSUDA

Introduction

In the second edition of *Minerals of Korea,** the writer intended to summarize all the data on the minerals which had been discovered in Korea up to 1940. When it was published in 1941, however, the writer found some omissions. Subsequently, as new localities of minerals together with minerals new to Korea were discovered, he tried to summarize knowledge of these additional data every five years, to compile finally a conclusive supplement to the former work.

At the end of World War II, as it had been about five years since the publication of the second edition of *Minerals of Korea,* the writer collected all the additional data obtained during the past five years on localities and minerals new to Korea, although he had lost some notes and some were carried back to Japan and have already been partly published in the journal "Kōbutsu to Chishitsu" (Minerals and Geology).

In this paper all additional data, published and unpublished, have been revised in part and summarized. Some papers still need revision, but are unfortunately inaccessible to the writer at present. The writer would be most happy if readers of this paper would bring any points to his attention.

1. Natural bismuth

Locality: Ilgwang Mine, Wŏl-li, Ilgwang-myŏn, Tongnae-gun Kyŏngsang-namdo

Natural bismuth[18] from the Ilgwang Mine, Tongnae-gun is usually associated with galena, tetrahedrite, zinc blende, bournonite or gudmundite and is 0.01–0.2mm in size. Under the microscope, it is granular, showing fine reticulated polysynthetic twins.

* Rep. Geological Survey of Korea, v. 15, 1941.

2. Natural silver

Locality: Kŏmdŏk Mine, Sindŏng-ni, Puktuil-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo

Natural silver[54] from the Kŏmdŏk Mine, Tanch'ŏn-gun is found replacing margins of zinc blende or as very small grains scattered in ores which consist chiefly of hemimorphite and smithsonite.

3. Molybdenite

Locality: Tanje Mine, Koegong-ni, Susan-myŏn, Chech'ŏn-gun, Ch'ung-ch'ŏngpukto
Sodŏk Mine, Myŏngdŏng-ni, Kyenae-myŏn, Changsu-gun, Chŏllapukto.
Onjŏng-ni, Oegŭmgang-myŏn, Kosŏng-gun, Kangwŏn-do
Chungjŏng Mine, Imnam-myŏn, T'ongch'ŏn-gun, Kangwŏn-do.
Pusŏng Mine, Fusŏng-ni, Changjin-gun, Hamgyŏng-namdo

Molybdenite from the Tanje Mine, Chech'ŏng-gun forms hexagonal tabular crystals, 10cm in diameter, showing short pyramidal crystals(?), with well developed basal planes.

The basal planes have striae vertical to prismatic planes and are dented in the center. The pyramidal planes show striation nearly parallel to the basal planes and are uneven and rough. There is a deformed zonal structure.

Molybdenite from the Sodŏk Mine, Changsu-gun occurs in pegmatite in two-mica granite. Crystals, hexagonal tabular, showing crystal planes c(0001) and l(10$\bar{1}$3), 4 cm in diameter of table. The basal plane, with striae perpendicular to the prismatic planes, is depressed toward the center.

Molybdenite[18] from Chjŏng-ni, Kosŏng-gun occurs in quartz veins in granite. Crystals, hexagonal tabular, tabular diameter 1 cm, thickness slightly over 1 mm, and with crystal planes: c (0001), m (10$\bar{1}$0) and l(10$\bar{1}$3), c-plane issmooth. Striae due to repeating of m- and l-planes are seen on l-plane, m-plane is small.

Molybdenite[31] from the Chungjŏng Mine, T'ongch'ŏn-gun occurs in pegmatitic quartz vein in injection-gneiss and biotite granite, and is associated with pyrite, chalcopyrite, beryl, fluorite, amazonstone and biotite. Crystals rare, usually occur as irregular scales, some 2–3 cm in diameter.

Molybdenite from the Pusŏng Mine, Changjin-gun occurs in quartz veins in biotite granite intruding gneiss. The crystals are hexagonal and tabular, the diameter being less than 1 cm and often showing characteristic plum-flower-like aggregations.

4. Zinc blende

Locality: Yonghwa-dong, Ilwŏl-myŏn, Yŏngyang-gun, Kyŏngsang-pukto

Zinc blende[10] from Yonghwa-dong, Yŏngyang-gun is grayish white in color, has a metallic luster and brown streak. It consists mainly of an o-plane, together

with a small a-plane. On the a-plane are seen many striations parallel to the edge formed by the a-and o-planes. The crystals are more or less curved, 2–5 mm in diameter, and are associated with a little pyrite and thuringite.

5. Pentlandite

Locality: Kosansang-ni, Wangjing-myŏn, Yŏnch'ŏn-gun, Kyŏnggi-do
Tŏktong-ni, Sannae-myŏn, Namwŏn-gun, Chŏlla-pukto
Sindae-ri, Sudong-myŏn, Kosŏng-gun, Kangwŏn-do
Kongch'i-dong, Yongdang-ni, P'an'gyo-myŏn, Ich'ŏn-gun, Kangwŏn-do

Pentlandite[9] from Kosansang-ni, Yŏnch'ŏn-gun is found in an amphibole schist of the Rensen (Yŏch'ŏn) system. It is granular, about 0.1 mm in diameter, disseminated and associated with pyrrhotite and chalcopyrite.

Pentlandite[9] from Tŏktong-ni, Namwŏn-gun is embedded in biotite amphybolite in porphyritic granite-gneiss and associated with pyrrhotite and chalcopyrite.

Pentlandite[9] from Sindae-ri, Kosŏng-gun occurs in amphybolite in metagneiss and is associated with pyrrhotite and violarite.

Pentlandite[40] from Kongch'i-dong ("Okura" Mine), Ich'ŏn-gun occurs in chlorite-schist in granite-gneiss, filling up interstices of pyrrhotite and pyrite. In parts, it is altered to violarite.

6. Greenockite

Locality: Hwangjŏl-li, Segong-myŏn, P'yŏngsan-gun, Hwanghae-do

Greenockite[29] from Hwangjŏl-li, P'yŏngsan-gun is a secondary mineral of zinc blende, formed in the contact zone of limestone and granite, and occurs as incrustations of thin film or powder of zinc blende, the color being yellow.

7. Niccolite

Locality: Sunch'ŏn Mine, Unp'yŏng-ni, Sŏ-myŏn, Sunch'ŏn-gun, Chŏlla-namdo

Niccolite[39),43] from the Sunch'ŏn Mine, Sunch'ŏn-gun occurs in galena-pyrite-zinc blende veins in granite-gneiss and is associated with pentlandite or native silver. It is 1 mm or so in diameter and light crimson-brown.

8. Pyrrhotite

Locality: Sujung Mine, Chŏkkong-ni, Susan-myŏn, Chech'ŏn-gun, Ch'ungchŏng-pukto

Pyrrhotite[28] from the Sujung Mine, Chech'ŏn-gun occurs in hübnerite-bearing quartz veins, associated with chalcopyrite and pyrite. It shows hexagonal short prisms, 3.5 cm in length, and 4 cm in diameter. Crystal planes u(40$\bar{1}$1), c(0001); the prismatic planes seem to show transverse striations due to repetition of u-planes.

9. Violarite

Locality: Tŏkha-ri, Yangas-myŏn, Kanghwa-gun, Kyŏnggi-do
Nabu-dong, Nodong-ni, Wangjing-myŏn, Yonch'ŏn-gun, Kyŏnggi-do
Kongch'i-dong, Yongdang-ni, P'angyo-myŏn, Ich'ŏn-gun, Kangwŏn-do
Sindae-ri, Sudong-ryŏn, Kosŏng-gun, Kangwŏn-do

Violarite[9] from Tŏkha-ri, Kanghwa-gun occurs in gabbro in meta-gneiss and is associated with magnetite, ilmenite, pyrrhotite and chalcopyrite. Under the microscope, it is faintly reddish in color, imbedded in the central portion of pyrrhotite, showing cleavages intersecting at right angles with each other, more soft than pyrrhotite and turns to dark gray with foaming in HNO_3 solution.

Violarite[11] from Nabu-dong, Yonch'ŏn-gun occurs in hornblende peridotite in mica schist of the Rensen (Yonch'ŏn) system and is associated with pyrrhotite and chalcopyrite.

Violarite[11] from Yongdang-ni, Ich'ŏn-gun occurs in a green rock in granite-gneiss and associated with pyrrhotite and copper-pyrite.

Violarite[11] from Sindae-ni, Kosŏng-gun occurs in hornblendite dyke in gneiss and associated with pyrrhotite, chalcopyrite and pentlandite.

10. Co-bearing pyrite

Locality: Okp'o-myŏn, Talsŏng-gun, Kyŏngsang-pukto

Pyrite[39] from Okp'o-myŏn, Talsŏng-gun is massive or shows crystal forms with a(100), o(111) and e(211), and is associated with limonite and micaceous iron ore (hematite). The chemical composition is as follows:

Table 1

	S	Fe	Co	As	Ni
1	51.30	44.90	0.55	very small	none
2	51.94	45.50	0.56	,,	,,

11. Chloanthite

Locality: Sunch'ŏn Mine, Ungyo-ri, Sŏ-myŏn, Sunch'ŏn-gun, Chŏlla-namdo

Chloanthite[39] from the Sunch'ŏn Mine, Sunch'ŏn-gun is found in association with smaltite, niccolite, galena, and zinc blende, is grayish in color and includes cobalt.

12. Chloanthite-smaltite

Locality: Sunch'ŏn Mine, Ungyo-ri, Sŏ-myŏn, Sunch'ŏn-gun, Chŏlla-namdo

Chloanthite-smaltite[39),43] from the Sunch'ŏn Mine, Sunch'ŏn-gun is found with chloanthite, galena, pyrite, zinc blende, and is hardly discernable from gersdorffite. It shows a fine zonal structure due to the arrangement of Ni-rich and Co-rich portions.

13. Cobaltite

Locality: Semjŏng Mine, Kalchŏl-li, Pung-myŏn, Taedŏk-kun, Ch'ungch'ŏng-namdo
Haman Mine, Yŏhang-myŏn, Haman-gun, Kyŏngsang-namdo
Talchŏlli Mine, Hada-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo

Cobaltite[39] from the Samjŏng Mine, Taedŏk-kun is found in quartz veins in the Yokusen (Okchŏn) system is reddish silver white, 3–9 mm, sometimes 1 cm in diameter, and shows crystal planes, a(100), o(111) and e(211), the e-plane being especially well developed.

Cobaltite[39] from the Haman Mine, Haman-gun is irregularly massive or occurs in hexahedron crystals, commonly 0.03–0.06 mm or rarely 0.7–1 mm in diameter. Under the microscope, it is silver white with a reddish tinge, with a strong metallic luster, and is found in paragenesis with Cu ore.

Cobaltite[39] from Talchŏl-li, Tanch'ŏn-gun is embedded in cobalt deposits in mica-schist of the Matenrei (Mach'ŏl-lyŏng) system and is in paragenic relation with Co-bearing pyrite and arsenopyrite. Commonly it shows no crystal forms but in some cases shows cubic crystals. The mineral is accompanied by a little chalcopyrite, pyrite, pyrrhotite and molybdenite.

14. Gersdorffite

Locality: Sunch'ŏn Mine, Unp'yŏng-ni, Sŏ-myŏn, Sunch'ŏn-gun, Chŏlla-namdo

Gersdorffite[43] from the Sunch'ŏn Mine, Sunch'ŏn-gun is grayish white and occurs in galena-pyrite-zinc blende veins, associated with niccolite.

15. Arsenopyrite

Locality: Sach'ŏl-li, Pung-myŏn; Hanim-ni, Chungnam-myŏn; Haman-myŏn and Yohan-myŏn, Haman-gun, Kyŏngsang-namdo
Yŏmisan Mine, Chodong-ni, Sindong-myŏn, Chŏngsŏn-gun, Kwangwŏn-do

Arsenopyrite[8] from Haman-gun occurs in auriferous quartz veins in slate of the Keishō (Kyŏngsang) formation and is associated with chalcopyrite, arsenopyrite, pyrrhotite and quartz. It shows short prismatic crystals, 7 mm or so in length, the crystal planes being as follows: c(001), m(110), u(104), q(011).

In size, the m-plane is the largest and the u-plane is next, while the q-plane is very small. On the u-plane are striations due to repetition of u and q-planes or of c-and u-planes. It contains cobalt.

Arsenopyrite[8] from Hanim-ni, Haman-gun occurs in cavities of auriferous quartz veins in granite. Its crystals consist of c(001) and m(110), the c-plane being provided with striations due to repetition of c and u-planes. It contains 1% or so of cobalt.

Arsenopyrite[39] from the Yŏmisan Mine, Ch'ŏngsŏn-gun is associated with iron-zinc blende, is silver-white, massive or shows granular crystals of 10 mm or so in diameter. The crystals consist of m(110) and u(104) planes, and are striated on the u-plane, often showing penetration-twins. It contains 0.2–1.0% of cobalt.

16. Gudmundite

Locality: Ilgwang Mine, Wŏl-li, Ilgwang-myŏn, Tongnae-gun, Kyŏngsang-namdo

Gudmundite[18] from the Ilgwang Mine, Tongnae-gun is found in pyrrhotite, with native bismuth, galena and chalcopyrite. It shows a pseudo-eutectic structure and contains small grains of pyrrhotite.

17. Klaprotholite

Locality: Holgol Mine, Suan-gun, Hwanghae-do

Klaprotholite[42] from the Holgol Mine, Suan-gun occurs in paragenesis with bornite, chalcopyrite and native bismuth, and is microgranular.

18. Cosalite-teallite

Locality: "Yamaguchi", "Furukawa" and Yŏnsu Mines, Chŏnch'ang-myŏn, Ch'angsŏng-gun, P'yŏngan-pukto

Cosalite-teallite[45] from Chŏnch'ang-myŏn, Ch'angsŏng-gun occurs in tungsten-bearing quartz veins.

19. Bournonite

Locality: Kŏmdŏk Mine, Sindŏng-ni, Puktuil-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo

Ilgwang Mine, Wŏl-li, Ilgwang-myŏn, Tongnae-gun, Kyŏngsang-namdo

Bournonite[42] from the Kŏmdŏk Mine, Tanch'ŏn-gun is found as inclusions of galena and is 1–5 μ across. Under the reflecting microscope, its color is similar to that of galena, but it is slightly harder.

Bournonite[18] from the Ilgwang Mine, Tongnae-gun is accompanied by galena, native bismuth, tetrahedrite and zinc blende, and is 0.01–0.1 mm across. Under the reflecting microscope, it is granular and shows polysynthetic twins and in some cases, two sets of twins intersecting at an angle of 98° with each other.

20. Wittichenite

Locality: Holgol Mine, Suan-gun, Hwanghae-do

Wittichenite[42] from the Holgol Mine, Suan-gun is found in small quantity, and is associated with bornite, chalcopyrite and native bismuth.

21. Boulangerite

Locality: Kŏmdŏk Mine, Sindong-ni, Puktuil-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo

Ilgwang Mine, Wŏl-li, Ilgwang-myŏn, Tongnae-gun, Kyŏngsang-namdo

Boulangerite[42] from the Kŏmdŏk Mine, Tanch'ŏn-gun is found as needle-shaped long prismatic crystals in galena. In reflecting light it resembles galena but shows a bluish green color and strong pleochroism; in the direction parallel to the elongation of needle-shaped or fibrous crystals, it is light in color, while in the other direction, at right angles to the former, it is slightly dark and dark bluish

green. In crossed-nicols, it is markedly anisotropic, showing straight extinction and grayish yellow—grayish blue at 45° position.

Boulangerite[16] from the Ilgwang Mine, Tongnae-gun is associated with galena, native bismuth and bournonite, is 0.1–0.2 mm across, and is needle-shaped or long prismatic.

22. Meneghinite

Locality: Tŏngnae Mine, Wŏl-li, Ilgwang-myŏn, Tongnae-gun, Kyŏngsang-namdo

Meneghinite[18] from the Ilgwang Mine, Tongnae-gun occurs as microscopic grains on the margin of arsenopyrite or as fine veins in the latter and is associated with chalcopyrite and pyrrhotite.

23. Stannite

Locality: "Furukawa", "Yamaguchi" and Yŏnsu Mines, Chŏnch'ang-myŏn, Ch'angsŏng-gun, P'yŏngan-pukto

Stannite[45] from Ch'onch'ang-myŏn, Ch'angsŏng-gun is found in tungsten-bearing quartz veins, brownish gray or yellowish gray, massive and brittle. It forms aggregates of granular crystals 1.0mm across, including zinc blende, chalcopyrite and cassiterite. The aggregations are, moreover, pierced by pyrite- or zinc blende-bearing quartz veins and fine veins of bismuthinite and native bismuth or of cosalite-teallite veins.

24. Opal

Locality: Hwap'yo Mine, Hwaam-ni, Tong-myŏn, Ch'ŏngsŏn-gun, Kangwŏn-do

Opal[8] from the Hwap'yo Mine, Chŏngsŏn-gun occurs as concretions in limestone. It is ellipsoidal, 10 cm in long diameter and 7 cm in short diameter, showing a grayish green color; on the surface small crystals of marcasite are seen; H.=6, G.=2.25, N=1.491.

25. Diatomite

Locality: Yulli-san, Sanmyŏng-ho and the river basin of the Taegyo-ch'ŏn, Ch'ŏlwŏn-ŭp, and Sakkok, Ojŏng-ni, Inmong-myŏn, Ch'ŏlwŏn-gun, Kangwŏn-do

Diatomite[35] from Ch'olwŏn-gun is sediment of fresh water lake origin, on plateau-basalt. It is of excellent quality and rich in supply.

26. Molybdite

Locality: Yŏngwŏl-baengnyŏn Mine, Pophŭng-ni, Suju-myŏn, Yŏngwŏl-gun, Kangwŏn-do

Molybdite[46] from the Yŏngwŏl-baengnyŏn Mine, Yŏngwŏl-gun is yellowish in color and silky in luster. The chemical composition (analyzed by T. Sudō) is as follows:

Table 2

MoO_3	Fe_2O_3	H_2O (−)	H_2O (+)	Insoluble	Total
52.5	18.9	14.3	3.0	11.1	99.0

Chemical formula: $3MoO_3 \cdot Fe_2O_3 \cdot 8H_2O$

27. Corundum

Locality: Sangok-tong, Chŏgum-ni, Sangnyŏng-myŏn, Yŏnch'ŏn-gun, Kyŏnggi-do
Chinsa-ri, Sinhŭmg-myŏn, Kangsŏ-gun, P'yŏngan-namdo
Haunsŭng-ni, Suha-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo

Corundum[41] from Sangok-tong, Yŏnch'ŏn-gun is associated with andalusite or muscovite. It occurs in blocks of 10 cm or less in diameter. The mineral is blue, translucent or opaque and irregularly spherical, the diameter being 2–5 mm. G.=3.9–4.1.

Corundum from Chinsa-ri, Kangsŏ-gun occurs in a cyanite-sillimanite-muscovite rock. Uniaxial negative; Z=1.762, X=1.753, Z−X=0.009. It shows partings, normal to X.

Corundum from Haunsŭng-ni, Tanch'ŏn-gun is found in the river bed of the Namdae-ch'ŏn, light red or purplish red in color. Some are 0.5–1.5 cm and at times 2.8 cm in long diameter.

28. Titaniferous hematite

Locality: Tomok-tong, Tŏksan-myŏn, Kilchu-gun, Hamgyŏng-pukto

Titaniferous hematite[10] from Tomok-tong, Kilchu-gun is grayish black and granular. The diameter of the grains is 2–5 mm, with little variation. It shows sections nearly hexagonal in outline, with a dark brown streak. Ti=4.76%, Fe=44.24% (analyzed by T. Mizuma).

29. Spinel

Locality: Samhwa Iron Mine, Samhwa-ri, Puksam-myŏn, Samch'ŏk-kun, Kangwŏn-do
Sŏngdŏk, Ch'unhŭng-dong, Yangsa-myŏn, Kilchu-gun, Hamgyŏng-pukto

Spinel[10] from the Samhwa Iron Mine, Samch'ŏk-kun is found sticking to magnetite. It is black and consists only of o(111), the diameter being 1 mm or so; N≒1.77.

Spinel[4] from Sŏngdŏk, Kilchu-gun occurs in metamorphosed limestone and is associated with diopside, phlogopite and calcite; N=1.73, diameter=1–2 mm.

30. Picotite

Locality: T'ongch'ŏn coal field, T'ongch'ŏn-gun, Kangwŏn-do

Picotite[2] from the T'ongch'ŏn coalfield occurs as a rock-forming mineral in olivine basalt.

31. Ilmenite

Locality: Kŭmsok Mine, Yonghwa-dong, Chip'o-ri, Kalmal-myŏn, Ch'ŏlwŏn-gun, Kangwŏn-do
Sach'ŏng-san, Haju-ri, Hyŏnnae-myŏn, P'yŏnggang-gun, Kangwŏn-do
Tomok-tong, Tŏksan-myŏn, Kilchu-gun, Hamgyŏng-pukto

Ilmenite[28] from the Kŭmsok Mine, Ch'ŏlwŏn-gun is black. G.≒4.1, H.=5.5. It is associated with columbite and garnet, and occurs as short prism, showing the following crystal planes: c(0001), a(11$\bar{2}$0), n(22$\bar{4}$3), n'($\bar{2}$4$\bar{2}$3), π($\bar{1}$2$\bar{1}$3), π(11$\bar{2}$3). The c-plane is well developed and, in consequence, the crystals are often tabular, having n-and n'- planes and a-and a'- planes always in symmetry. One to three pairs of a-planes are seen. The basal diameter is about 1 cm and the prismatic length 7 mm.

Ilmenite from Sach'ŏng-san, P'yŏnggang-gun is associated with lepidomelane and titanite, and is about 10 cm in diameter. It shows partings of three different directions.

Ilmenite[10] from Tomok-tong, Kilchu-gun occurs as fine grains in pegmatite in limestone and dolomite and is black. The grains are irregular in form and 5 mm in diamter. Ti=31.53%, Fe=36.61% (analyzed by T. Mizuma).

32. Magnetite

Locality: Samhwa Mine, Samhwa-ri, Puksam-myŏn, Samch'ŏk-kun, Kangwŏn-do

Magnetite[10] from the Samhwa Mine, Samch'ŏk-kun occurs in the contact deposits and shows crystal forms which consist of o(111) and d(110), some crystals being 5 cm in diameter. It is covered by spinel and delessite.

33. Braunite

Locality: Kŭmjik-san Mine, Nam-myŏn, Chŏngsŏn-gun, Kangwŏn-do

Braunite[28] from the Kŭmjik-san Mine, Chŏngsŏn-gun is associated with goethite, spessartite, etc., and is iron black in color and metallic in luster. It occurs as micro-crystals which are generally irregular in external form, but in cases bi-pyramidal, showing in section, tetragonal or octagonal outlines and perfect partings of three different directions. It is soluble in HCl.

34. Ilmeno-rutile

Locality: Tallok Mine, Kunt'al-li, Kalmal-myŏn, Ch'ŏlwŏn-gun, Kangwŏn-do
Samsal-li, Yangdong-myŏn, Yangp'yŏng-gun, Kyŏnggi-do

Ilmeno-rutile from the Tallok Mine, Ch'ŏlwŏn-gun occurs in pegmatitic veins, associated with columbite and beryl. It is composed of the following crystal planes: s(111), a(100), h(210), m(110).

There are three types of crystals: (1) single crystals, flattened in the a-plane,

(2) crystals which show contact-twins with (101) as the twinning plane, and terminal planes of a-and m-plane and (3) crystals which consist of a terminal-plane of h.

Ilmeno-rutile from Samsal-li, Yangp'yŏng-gun occurs in pegmatitic veins, associating with beryl, a variety of zircon, etc. TiO_2=21.77%, Ta_2O_3=21.67%, Nb_2O_5=41.31% (analyzed by K. KIMURA).

35. Pyrolusite

Locality: Kyŏngsang Mine, Kyŏn'gong-myŏn, Kyŏngju-gun, Kyŏngsang-pukto
Chisa-ri, Noksan-myŏn, Kŭmhae-gun, Kyŏngsang-namdo
Kasa-ri, Sindong-myŏn, Ch'ŏngsŏn-gun, Kangwŏn-do
"Kōshūha" Mine and Kanggyŏng Mine, Wŏnnam-myŏn, Kŭmhwa-gun, Kangwŏn-do

Pyrolusite[33] from the Kyŏngsang Mine, Kyŏngju-gun is found in the Taikyū (Taegu) formation of Shiragi (Silla) series and is associated with psilomelane and manganite.

Pyrolusite[33] from Chisa-ri, Kŭmhae gun is found deposited along joints of quartz-porphyry and is associated with psilomelane, manganite, pyrite, galena and zinc blende. Mn=23.4% (analyzed by the Geological Survey, Government-General of Korea).

Pyrolusite[33] from Kasa-ri, Ch'ŏngsŏn-gun occurs as lenses in a limestone of the Chōsen (Chosŏn) system, associated with psilomelane and manganite.

Pyrolusite[33] from Wŏnnam-myŏn, Kŭmhwa-gun occurs as veinlets or tabular masses in alternating beds of limestone, dolomite and phyllite of the Syōgen (Sangwŏn) system, associated with psilomelane, rhodonite, garnet, olivine, pyrite and quartz.

36. Manganite

Locality: Kyŏngsang-Mine, Kyŏn'gong-myŏn, Kyŏngju-gun, Kyŏngsang-pukto
Chisa-ri, Noksan-myŏn, Kŭmhae-gun, Kyŏngsang-namdo
Kasa-ri, Sindong-myŏn, Ch'ŏngsŏn-gun, Kangwŏn-do

Manganite[33] from the Kyŏngsang Mine, Kyŏngju-gun is found in the Taikyū (Taegu) formation of the Shiragi (Silla) series, associated with psilomelane and pyrolusite.

Manganite from Chisa-ri, Kŭmhae-gun occurs as lenses along joints of quartz porphyry, and is associated with psilomelane, pyrolusite, pyrite, galena and zinc blende.

Manganite from Kasa-ri, Ch'ŏngsŏn-gun occurs as lenticular masses in limestone of the Chōsen (Chosŏn) system, associated with psilomelane, Pyrolusite and calcite.

37. Psilomelane

Locality: Kyŏngsang Mine, Kyŏn'gong-myŏn, Kyŏngju-gun, Kyŏngsang-pukto

Chisa-ri, Noksan-myŏn, Kŭmhae-gun, Kyŏngsang-namdo
"Nippon Kōshūha" and Kanggyŏng Mines, Wŏnnam-myŏn, Kŭmhwa-gun, Kangwŏn-do
Kasa-ri, Sindong-myŏn, Chŏngsŏn-gun, Kangwŏn-do
Sinp'yŏng-dong, Agan-myŏn, and Hago-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto

Psilomelane[33] from the Kyŏngsang Mine, Kyŏngju-gun is associated with pyrolusite and manganite in the Taikyū (Taegu) formation of the Shiragi (Silla) series.

Psilomelane[33] from Chisa-ri, Kŭmhae-gun is found deposited along joints of quartz porphyry and is associated with pyrolusite and manganite.

Psilomelane[33] from Wŏnnam-myŏn, Kŭmhwa-gun occurs forming veinlets or tabular masses in alternating bed of limestone, dolomite and phyllite of the Shōgen (Sangwŏn) system. It is accompanied by psilomelane, rhodonite, garnet, olivine, pyrite and quartz. It contains manganese as follows (analyzed by Geological Survey, Government-General of Korea):

Table 3

	Kōshūha Mine	Kanggyŏng Mine
Mn	38.89%	40.76%

Psilomelane[33] from Kasa-ri, Ch'ŏngsŏn-gun occurs as lenses in the Great limestone series of the Chōsen (Chosŏn) system and is associated with manganite, pyrolusite and calcite. Mn=32.52% (analyzed by Geological Survey, Government-General of Korea).

Psilomelane from Myŏngch'ŏn-gun occurs in the Shichihōzan (Ch'ilbongsan) alkali trachyte. That of Sinp'yŏng-dong contains 35.86% Mn (Analyzed by Geological Survey, Government-General of Korea).

38. Wad

Locality: Kŭmch'ŏn-gun, Hwanghae-do
Chunghwa-gun, P'yŏngan-namdo
Kŏmun-dong, Majang-myŏn, Ch'ŏlwŏn-gun, Kangwŏn-do
Kŭmjik-san Mine, Sindong-myŏn, Ch'ŏngsŏn-gun, Kangwŏn-do

Wad from Kŭmch'ŏn, Chunghwa and Ch'ŏlwŏn-gun forms beds in limestone of the Shōgen (Sangwŏn) system. That of Kŏmun-dong contains 15.75% Mn (analyzed by Geological Survey, Government-General of Korea).

Wad[28] from the Kŭmjik-san Mine, Ch'ŏngsŏn-gun is found as small scales, one degree or so in hardness, more or less porous and light. It shows a brown streak and is easily decomposed by HCl. Under the microscope, it shows straight

extinction parallel to elongation of the scale. Elongation Z′, X′ ⊥ Z′, Z′=deep brownish, X′=brownish. $1.77<N_1$, $N_2 \fallingdotseq 1.8$.

The chemical composition of the mineral, accompanied by much calcite and sericite, is as follows (analyzed by T. MIZUMA):

Table 4

SiO_2	FeO	Al_2O_3	CaO	MgO	MnO	lg. loss
11.72	2.52	11.76	32.70	1.01	21.47	18.40

39. Calcite

Locality: Taeya-ri, Kŏch'ang-gun, Kyŏngsang-namdo
Ilwŏl Mine, Ilwŏl-myŏn, Subi-myŏn, Yŏngyang-gun, Kyŏngsang-pukto
Kohyŏn Mine, Ibam, Simch'ŏn-dong, Koan-myŏn, Chŏngju-gun, P'yŏngan-pukto
Somin-dong, Yongsan-myŏn, Yŏngbyŏn-gun, P'yŏngan-pukto
Ŏbok-tong, Haksŏ-myŏn, Haksŏng-gun, Hamgyŏng-pukto

Calcite[55] from Taeya-ri, Kŏch'ang-gun occurs in cavities in gold veins. It shows hexagonal prismatic crystals with c(0001) and m(10$\bar{1}$0), the basal plane a little curving. H.=3, G.=2.8. The chemical composition is as follows (analyzed by Y. TANIYAMA):

Table 5

CaO	MnO	CO_2	Insoluble	H_2O	Total
54.54	1.21	43.20	0.07	0.96	99.98

Calcite[49] from the Ilwŏl Mine, Yŏngyang-gun occurs as a gangue mineral or in druses. That in druses forms, in cases, crystal aggregates composed of large crystals with r(10$\bar{1}$1), exceeding 10 cm on an edge length. Some show f(02$\bar{2}$1) and e(01$\bar{1}$2), but these are smaller, being 2–3 mm in edge length and later in crystallization than the former.

Calcite[10] from Somin-dong, Yŏngbyŏn-gun occurs in druses in country rock of zinc deposite in limestone of the Chōsen (Chosŏn) system and is colorless, white or light brown, transparent to translucent, showing the following crystal planes: m(10$\bar{1}$0), a(11$\bar{2}$0), r(10$\bar{1}$1), σ(51$\bar{6}$4), ν(21$\bar{3}$1), ω(31$\bar{4}$5).

It shows two sorts of crystal forms, one rhombohedral and the other dog-tooth-shaped scalenohedron. The rhombohedral forms occur in two further types of crystal as follows:

(a) The crystals mainly consist of well-developed r and small ν, together with very small m, σ and ω. Crystals belonging to this type are most common and

are colorless, white or light brown, the diameter being 12 cm or more. The crystals are simple or twinned. In the twinning forms, there are two types; a symmetric form with a common axis and c-plane as boundary, and another which has c-planes in common and interpenetrates.

(b) The crystals are white to grayish white, the surface being partly stained with brown. The planes, excepting the m-plane, are more or less chemically affected and dull; the m-plane is covered with a yellowish brown incrustation and is bright.

Crystal planes are m, r, σ, ω and ν. The σ-plane is the best developed; the ω-plane is next; the r-plane is small; the m-and ν-planes are smaller and the ν-plane is barely visible. The ω-plane shows striations, which are considered to be the cause of the repetition of the r-plane, and is generally curved.

Some large crystals reach 8 cm in diameter. Simple crystals are common, but show, in some cases, twinning, with symmetrical attachment to the c-plane and the c-axis in common.

Two types are also seen in the scalenohedral forms. One consists mainly of scalenohedral planes, with r-, f-and m-planes. It is colorless or white, transluscent, and 3 cm in the length of the c-axis. The other consists mainly of the ν-plane, with m-and f-planes also present. The c-axis are 8 cm in length.

Calcite[4] from Ŏbok-tong, Haksŏng-gun occurs as calcite veins in hornblende schist, and is colorless and translucent. It shows prismatic crystals, composed of e$(01\bar{1}2)$ and m$(10\bar{1}0)$, the prismatic length being 1 cm and prismatic diameter 0.5 cm.

40. Mangano-calcite

Locality: Paegyang-ni, Namsan-myŏn, Ch'unch'ŏn-gun, Kangwŏn-do

Mangano-calcite[10] from Paegyang-ni, Ch'unch'ŏn-gun occurs as a rock-forming mineral of limestone in crystalline-schist, associated with diopside, spessartite, titanite, kali-feldspar, quartz, sericite, prehnite, pyrrhotite, apatite, tremolite, epidote and zinc blende. N=1.685.

41. Mangano-dolomite

Locality: "Suganuma" Kŭmhwa Mine, Tul-li, Wŏnnam-myŏn, Kŭmhwa-gun, Kangwŏn-do

Mangano-dolomite[8] from the "Suganuma" Kŭmhwa Mine, Kŭmhwa-gun forms manganese deposit, associated with spessartite and rhodonite. It is white or lights red. Under the microscope, it generally shows no pleochroism, but is rarely pleochroic as follows: Ng=light brownish, Np=colorless~transparent. The mineral occurs as aggregations of small crystals in a mosaic structure, each crystal having polysynthetic twinning. N_0=1.690—1.742.

42. Brugnatellite

Locality: Namch'ŏl-li, Pongsan-myŏn, P'yŏngsan-gun, Hwanghae-do

Brugnatellite[10] from Namch'ŏl-li, P'yŏngsan-gun occurs in contact deposit of magnetite and is associated with magnetite, dolomite, chondrodite (?) and vesuvianite. The crystals are thinly tabular and arranged more or less radially. In the interstitial spaces crystallized magnetite is seen. The mineral is white and flexible, the crystal plate is 0.5–1.0 mm in diameter, 0.01–0.03 mm in thickness, and shows an imperfect cleavage parallel to the basal plane and a parting perpendicular to the cleavage. Uniaxial negative. Ng=1.538, Np=1.510.

43. Breunnerite

Locality: "Hōkoku" Cobalt Mine, Amnyang-myŏn, Kyŏngsan-gun, Kyŏng-sang-pukto

Breunnerite[43] from the Hōkoku Cobalt Mine, Kyŏngsan-gun occurs as a gangue mineral in the cobalt deposits.

44. Orthoclase

Locality: Nojŏn-dong, Ch'ŏngnyong-myŏn, Pakch'ŏn-gun, P'yŏngan-pukto
Taedang Mine, P'anhang-ni, Hwach'ŏn-myŏn, Hongch'ŏn-gun, Kang-wŏn-do

Orthoclase[8] from Nojŏn-dong (Nojŏl-li), Pakch'ŏn-gun shows prismatic crystals which elongate generally along the a-axis and rarely along the c-axis, and is tabular parallel to the b-plane.

The crystals elongated to the a-axis show two habits, long and short. The long prismatic crystals are as much as 1 cm in diameter and 3.5 cm long, showing baveno twins, though terminel planes are imperfect, showing no distinct plane.

The short prismatic crystals are simple, 1.5 cm in diameter, 2 cm long and clearly show both terminal planes as follows: b(010), c(001), m(110), z(130), y($\bar{2}$01), n(021), o($\bar{1}$11).

The c- and b-planes are well developed, the m-and y-planes follow, and the z, n- and o-planes are small. Crystals, tabular parallel to b-plane, show carlsbad twins, with b-, m-, z- and o-planes (Fig. 1, Pl. 1).

Orthoclase from the Taedang Mine, Hongch'ŏn-gun is a rock-forming mineral of granite. In this case, the prismatic and terminal planes are perfectly developed (Fig. 2, Pl. 1).

There are short prismatic crystals (a-axis=2 cm, b-axis=1 cm, c-axis=1 cm) and long ones (a-axis=1.5 cm, b-axis=1 cm, c-axis=2 cm); in both cases the crystals are tabular to the b-plane. The recognized crystal planes are as follows: b(010), c(001), m(110), y($\bar{2}$01).

45. Microcline

Locality: Ka-dong, Unsan-gun, P'yŏngan-pukto

Microcline[7] from Ka-dong, Unsan-gun occurs as a phenocryst in granite-gneiss. The crystals are simple or twinned, 2–8 cm in long diameter, grayish white,

rough on the surface and include hornblende and biotite. The crystal planes are as follows: b(010), c(001), m(110), y($\bar{2}$01).

In simple crystals, the b-and c-planes are especially well developed, the crystals being elongated along the a-axis. These often show carlsbad twins and rarely trilling twins due to combination of carlsbad and baveno twins. (−) 2V=80−88°. α=1.521, β=1.524, γ=1.526, $\gamma-\alpha$=0.005±0.001.

The marginal portion of the crystals commonly shows narrow a zonal structure.

46. Microcline-perthite

Locality: "Tanryoku" (Tallok) Mine, Kunt'al-li, Kalmal-myŏn, Ch'ŏlwŏn-gun, Kangwŏn-do

Microcline-perthite[28] from the Tanryoku Mine, Ch'ŏlwŏn-gun occurs in association with beryl and columbite, in pegmatite in granite. These are 19 cm (horizontal) and 16 cm (vertical) in prismatic diamters, 20 cm in prismatic length, white and a little rough on the crystal planes. $N_2 \fallingdotseq 1.522$, $N_1 \fallingdotseq 1.515$. The crystal planes are as follows: b(010), c(001), m(110), f(1$\bar{3}$0), M(1$\bar{1}$0), z(130), x($\bar{1}$01), y($\bar{2}$01), **m**(111), p($\bar{1}$11), o($\bar{1}$11), a(100).

Of these, the b-and c-planes are best developed, to almost the same extent, and the terminal planes **m** and M are also developed to the same extent. Next come the f-, z-and x-planes, while the p- and o-planes are small (Fig. 3, Pl. 1).

47. Amazonstone

Locality: Chungjŏng Mine, lmnam-myŏn, T'ongch'ŏn-gun, Kangwŏn-do

Amazonstone[31] from the Chungjŏng Mine, T'ongch'ŏn-gun occurs as a gangue mineral in molybdenite-bearing pegmatitic quartz veins, associated with beryl, fluorite, biotite and garnet. In most cases, the mineral is irregularly massive, grass-green, and shows carlsbad twins. It encloses quartz, beryl and biotite. γ=1.525.

48. Cleavelandite

Locality: Sinnamch'ŏl-li, Namch'ŏn-ŭp, P'yŏngsan-gun, Hwanghae-do

Cleavelandite from Sinmanch'ŏl-li, P'yŏnsan-gun forms a rock-forming mineral of pegmatite which intrudes into an alternation of limestone and slate and is associated with amazonstone, quartz, albite, lepidolite and zinnwaldite.

49. Oligoclase

Locality: Samhwa Mine, Saenggŭm-ni, Segong-myŏn, P'yŏngsan-gun, Hwanghae-do

Oligoclase[10] from the Samhwa Mine, P'yŏngsan-gun is found as a rock-forming mineral of pegmatite in limestone, associated with quartz, zoisite, fluorite, epidote and bismuthinite(?). The mineral is white and shows prismatic crystals consisting of the following planes: m(110), M(1$\bar{1}$0), b(010), x($\bar{1}$01), c(001).

In general aspect, the crystals are rhombic prisms, composed largely of m-and

M-planes, with small b-and c-planes and a well developed x-plane. The prism is 4 mm in short diameter, 7 mm in long diameter and 20 mm in prismatic length. G.=2.56. N_1=1.539, N_2=1.544. CaO=3.35% (analyzed by T. MIZUMA).

50. Diopside

Locality: Holgol Mine, Suan-gun, Hwanghae-do

Diopside[48] from the Holgol Mine, Suan-gun is found accompanying tremolite, calcite, quartz, orthoclase, titanite and brucite in the contact-zone of limestone and shows prismatic or teragonal tabular crystals. The prismatic crystals consist of (100), (001) and (110)? showing a penetration-twin with c-axis as the twinning axis or a polysynthentic twin with the composition-plane of basal planes.

In the tabular crystals (100) and (001) only are developed, and a polysynthetic twin with the basal plane as the composition-plane is seen. The mineral is light brown, green or white, subglassy in luster and shows scaly or, at times, uneven fracture. G.=3.279 (D20°C). $c \wedge Z = 38°42'$. Optical plane=(110), (+) $2V \fallingdotseq 60°$, $\nu < \rho$, Np=1.6690, Nm=1.6800, Ng=1.6986.

The chemical composition (analyzed by S. MURATA) is as follows:

Table 6

SiO_2	CaO	MgO	Fe_2O_3	MnO	Ig. loss	Total
54.79	26.59	16.21	2.27	tr.	0.22	100.08

$Ca\,Mg\,Si_2O_6$ 94% (diopside mol.)
$Ca\,Fe\,Si_2O_6$ 6% (hedenbergite mol.)

51. Mangano-diopside

Locality: Paegyang-ni, Namsan-myŏn, Ch'unch'ŏn-gun, Kangwŏn-do

Mangano-diopside[10] from Paegyang-ni, Ch'unch'ŏn-gun is found in limestone and is associated with mangano-calcite, spessartite, titanite, kali-feldspar, quartz, sericite, prehnite, pyrrhotite, apatite, tremolite, epidote and zinc blende. It is light green in color. Mangano-diopside of 0.1% Mn: $c \wedge Z \fallingdotseq 33°$, $Np \fallingdotseq 1.685$, Mangano-diopside of 1.78% Mn: $c \wedge Z \fallingdotseq 43°$, $Np \fallingdotseq 1.685$.

52. Mangan-hedenbergite

Locality: Kalgŭm-ni, Yŏnp'ung-myŏn, Koesan-gun, Ch'ungch'ŏng-pukto

Mangan-hedenbergite[10] from Kalgŭm-ni, Koesan-gun occurs in the contact-zone between limestone and granite, and is associated with stilpnomelane(?) and

Table 7

SiO_2	Fe_2O_3	FeO	MnO	CaO	Total
46.70	7.73	13.11	7.67	19.65	94.86

goethite. It is brownish and shows prismatic cleavage, but no distinct crystal form. (+) 2V large, $c \wedge Z = 54°$, $N_2 \fallingdotseq 1.742$, $N_1 \fallingdotseq 1.723$. The chemical composition is as Table 7 (analyzed by T. MIZUMA).

53. Wollastonite

Locality: Hwach'ŏn Mine, Hwach'ŏl-li, Sangmu-myŏn, Koesan-gun, Ch'ungch'ŏng-pukto

Wollastonite from the Hwach'ŏn Mine, Koesan-gun is associated with calcite and prehnite. It is white and has a silky luster. The fiber is 2 cm. $Z \fallingdotseq 1.631$, $Y \fallingdotseq 1.629$, $X \fallingdotseq 1.614$.

54. Cummingtonite

Locality: Paegun-san, Kwangyang-gun, Chŏlla-namdo

Cummingtonite[8] from Paegun-san, Kwangyang-gun accompanies zircon, actinolite, hornblende, apatite and magnetite.

It is hypidiomorphic and shows no distinct crystal forms, but its prism plane is considered to be constructed of m(110); perfect cleavage parallel to m-plane and marked polysynthetic twins having a contact plane of (100) are observed. Diameters of the prisms are 0.07–0.15 mm and the lengths are 0.2 mm or less. It is colorless, transparent or faintly yellowish brown. X=colorless, Y=Z=light yellowish brown ($\fallingdotseq$ colorless), $X < Y < Z$, Y//b, Optical plane // (010), $c \wedge Z = 15°$. (−) 2V large. $N_2 = 1.720$, $N_1 = 1.684$.

55. Rhodonite

Locality: "Suganuma" Kŭmhwa Mine, Tul-li, Wŏnnam-myŏn, Kŭmhwa-gun Kangwŏn-do

Rhodonite from the "Suganuma" Kŭmhwa Mine, Kŭmhwa-gun is associated with mangano-dolomite and spessartite, and is light red in color. Under the microscope it is colorless, transparent and granular. (+) 2V large, $Nm \fallingdotseq 1.725$. The margins of the crystals are altered into mangano-dolomite.

56. Beryl

Locality: Samsal-li, Yangdong-myŏn, Yangp'yŏng-gun, Kyŏnggi-do
Taehwa Mine, Nŭngam-ni, Angsŏng-myŏn, Ch'ungju-gun, Ch'ungch'ŏng-pukto
Munŭi-myŏn, Ch'ŏngju-gun, Ch'ungch'ŏng-pukto
Kumi-ri, Chungoebang-ni, Tanyang-myŏn, Tanyang-gun, Ch'ungch'ŏng-pukto
Sujung Mine, Chŏkkong-ni, Susan-myŏn, Chech'ŏn-gun, Ch'ungch'ŏng-pukto
"Nakamura-machi", Taejŏn-bu, Ch'ungch'ŏng-namdo
Chindong-myŏn, Pung-myŏn, Taedŏk-kun, Ch'ungch'ŏn-namdo
Ch'angnak Mine, Ch'angnak-tong, P'unggi-myŏn, Yŏngju-gun, Kyŏngsang-pukto

Taedang Mine, P'anhang-ni, Hwachŏn-myŏn, Hongch'ŏn-gun, Kangwŏn-do
Kunt'al-li, Kalmal-myŏn, Ch'ŏlwŏn-gun, Kangwŏn-do
Turyu-san, Yongdam-ni, Sanae-myŏn, Ch'unch'ŏn-gun, Kangwŏn-do
Hach'owŏl-li, Konggŭn-myŏn, Hoengsŏng-gun, Kangwŏn-do
"Oku-banbutsusō", Kŭmgang-san, Chugŏm-ni, Oegŭmgang-myŏn, Kosŏng-gun, Kangwŏn-do
Chungjŏng Mine, Oegŭmgang-myŏn, Imnam-myŏn, T'ongch'ŏn-gun, Kangwŏn-do

Beryl from Samsal-li, Yangp'yŏng-gun is found in pegmatite, associated-with a special variety of zircon, ilmeno-rutile, etc. It is 6 cm in diameter and 13 cm in length. The mineral is generally weathered, accompanying mica on the crystal surface. Rarely, it is green and transparent.

Beryl from Kumi-ri, Tanyang-gun occurs in pegmatite with lepidolite and shows a zonal structure of red, green or light blue, and light-red. Ng=1.569, Np=1.564.

Beryl[28] from the Sujung Mine, Chech'ŏn-gun occurs in wolframite-bearing quartz veins as a gangue mineral. It is light green, long and prismatic, consisting of m$(10\bar{1}0)$, the terminal planes not being clear. Ng=1.569, Np=1.564.

Beryl from the Ch'angnak Mine, Yŏngju-gun occurs as a gangue mineral in wolframite-bearing quartz veins in gray granite-gneiss and is associated with molybdenite, bismuthinite, siderite, calcite and fluorite. The crystals are hexagonal prismatic, large crystals exceeding 3 cm in length, light blue. Ne$\fallingdotseq$1.567, No=1.572, No−Ne=0.005.

Beryl[32] from the Taehwa Mine, Ch'ungju-gun occurs as small prismatic crystals in wolframite-bearing quartz veins as a gangue mineral and is light green and transparent. The crystals consist of c(0001), s$(11\bar{2}1)$ and m$(10\bar{1}0)$, and are longitudinally striated on the m-plane (Fig. 4, Pl. 1).

Beryl from the Taedang Mine, Hongch'ŏn-gun occurs in tungsten-bearing quartz veins or pegmatite veins in granite, associated with molybdenite, chalcopyrite, dolomite and fluorite. The mineral is light blue and shows hexagonal prismatic crystals, consisting of a prismatic plane m$(10\bar{1}0)$; the terminal planes are lacking. Prismatic diameter 1–2mm. Prismatic length 5 mm. Uniaxial negative. Z=1.574, X=1.570, Z−X=0.004.

Beryl[28] from Kunt'al-li, Ch'ŏlwŏn-gun occurs in pegmatite veins and is light yellow. The crystals are hexagonal prismatic, showing no terminal planes. Prismatic diameter 2 cm or so. Vertically striated on the prismatic plane. Sometimes small scales of muscovite are seen on the crystal surface. H.=7.5. Uniaxial negative. Z=1.574, X=1.570, Z−X=0.004.

Beryl[28] from Turyu-san, Ch'unch'ŏn-gun (Fig. 5, Pl. 1) is light yellow and translucent showing hexagonal prismatic crystals with the basal plane as the terminal plane. Prismatic diameter 2.5 cm. Prismatic length 1.5 cm. Cleavages

parallel to the basal plane are more or less distinct. The crystals also show cracks running parallel to the basal plane. Ng=1.573, 1.569>Np>1.564.

Beryl[28] from Hach'owŏl-li, Hoengsŏng-gun (Fig. 6, Pl. 1) is found is pegmatite veins in granite, and is light yellow to light yellowish green and prismatic or tabular in habit. Prismatic length 7 cm. Prismatic diameter 7 cm. The observed crystal planes are m(10$\bar{1}$0), c(0001), s(11$\bar{2}$1), δ(5.5.$\bar{1}$0.7) and ν(51$\bar{6}$1). No=1.572, Ne=1.568.

Beryl[3] from Chungŏm-ni, Kosŏng-gun occurs in pegmatite veins, about 30 cm wide, and is associated with cassiterite and topaz.

Beryl[3] from the Chungjŏng Mine, T'ongch'ŏn-gun occurs in pegmatitic quartz veins with molybdenite, in injection gneiss or in biotite granite, as a gangue mineral of the molybdenite deposits, and is associated with amazonstone, fluorite, biotite, garnet, pyrite and chalcopyrite. In this locality, two types of beryl are observed. One is light green, translucent, idiomorphic and is enclosed in amazonstone, while the other is light blue, translucent, prismatic and forms veins which consist almost entirely of beryl. In the latter, prismatic planes are well developed, and many enclosures of biotite are seen. No$\fallingdotseq$1.568. Ne=1.565.

57. Nepheline

Locality: Sangp'al-tong, Changbaeng-myŏn, Kilchu-gun, Hamgyŏng-pukto

Nepheline[27] from Sangp'al-tong, Kilchu-gun has the following chemical composition (analyzed by E. IWASE and Y. KANEMURA):

Table 8

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Total	D $^{12°C}_{4°C}$
1*	41.99	34.35	1.21	1.21	0.37	16.45	4.38	99.96	2.62
2**	41.63	36.11	1.14	1.06	0.37	16.04	4.35	100.70	2.63

Notes: *Nepheline from Chikchŏn-dong: brownish black, translucent.
**Nepheline from Yongso-dong: grayish white, translucent.

Chemical formula: (1) $(Na, K \ldots)_{0.96}\ Al_{0.97}\ Si_{1.01}\ O_{4.00}$
(2) $(Na, K \ldots)_{0.93}\ Al_{1.01}\ Si_{0.99}\ O_{4.00}$

58. Cancrinite

Locality: Maengyang-dong, Changbaeng-myŏn, Kilchu-gun, Hamgyŏng-pukto

Cancrinite[27] from Maengyang-dong, Kilchu-gun occurs as fine veins, 4 mm across, in feldspar and is honey yellow or light red, transparent or translucent and has the following chemical composition (analyzed by E. IWASE and Y. KANEMURA):

l/m=5.6~4.5, l/n=4.2~3.6, Na is replaced by K, Al by Fe^{III}, Ca by Mg, NaH and KH.

Table 9

	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	CO_2	H_2O (+)	H_2O (−)	Total	$D^{13°C}_{4°C}$
1*	37.55	27.72	0.43	0.61	2.71	18.63	1.82	5.58	1.73	1.61	98.39	2.51
2**	35.38	29.91	0.35	0.81	5.69	18.57	0.73	5.66	2.12	0.63	99.85	2.45

Note: *Honey-yellow (No ≒ 1.523, Ne ≒ 1.499)
**Light red

Chemical formula: $lNaAlSiO_4 . m\,CaCO_3 . nH_2O$

59. Grossularite

Locality: Simgi-ri, Yŏnp'ung-myŏn, Koesan-gun, Ch'ungch'ŏng-pukto
Samul-li, Sangmo-myŏn, Koesan-gun, Ch'ungch'ŏng-pukto
Kumi-ri, Oejungbang-ni, Tanyang-myŏn, Tanyang-gun, Ch'ungch'ŏng-pukto
Pusung-dong, Kungno-dong, P'an-myŏn, Ch'osan-gun, P'yŏngan-pukto

Grossularite[8] from Simgi-ri, Koesan-gun occurs in contact zones of granite and limestone and is light yellow. Its crystals consist of d(110), some being 2 cm in diameter. Under the microscope, the mineral shows a striking optical anomaly. N > 1.78.

Grossularite from Samul-li, Koesan-gun occurs as a contact mineral in limestone and is grayish green; its crystals consist of d(110) and are 2–5 mm in diameter; it shows optical anomaly. N ≒ 1.750.

Grossularite[8] from Kumi-ri, Tanyang-gun is light brownish and consists of d(110) and n(211).

Grossularite[8] from Pusung-dong and Kungno-dong, Ch'osan-gun is found as a contact mineral in limestone caught as xenoliths in granite-gneiss and is associated with scapolite, sphene and diopside.

Grossularite from Pusung-dong is light red. N = 1.741. In that of Kungno-dong, the measurements are as follows: N = 1.741. G. = 3.605.

60. Spessartite

Locality: "Suganuma" Kŭmhwa Mine, Tul-li, Wŏnnam-myŏn, Kŭmhwa-gun, Kangwŏn-do

Spessartite from the "Suganuma" Kŭmhwa Mine, Kŭmhwa-gun, together with mangano-dolomite and rhodonite, forms a banded structure and is brownish yellow. Under the microscope, it is olivine yellow and granular. N > 1.78. Often it encloses abundant black minerals and shows a crystal plane of d(110).

61. Scapolite

Locality: Sach'i-ri, Sugu-myŏn, Suan-gun, Hwanghae-do

Scapolite[29] from Sach'i-ri, Suan-gun belongs to dipyre. $\omega = 1.5542$, $\varepsilon = 1.5400$. Ma 70, Me 30 (by KITAMURA).

62. Vesuvianite

Locality: Changhyŏl-li, Kŭmsan-myŏn, Yŏnbaek-kun, Hwanghae-do

Vesuvianite[8] from Changhyŏl-li, Yŏnbaek-kun is found as brownish prismatic crystals, consisting of c(001), a(100), m(110) and p(111).

The prismatic plane (Fig. 7, Pl. 1) consists mainly of the m-plane which is uneven and shows striations due to the repeating of the m-and a-planes, the a-plane being very small. The basal plane consists mainly of a small p-plane; prismatic diameter 1 cm; prismatic length 2.5 cm; uniaxial negative. X and $Y<1.720$.

63. Zircon

Locality: Paegun-san, Kwangyang-gun, Chŏlla-namdo
Poksin-san, Sŏ-myŏn, P'yŏnggang-gun, Kangwŏn-do
Iha-ri, Namduil-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo
Talli-dong, Hangnam-myŏn, Haksŏng-gun, Hamgyŏng-namdo

Zircon[8] from Paegun-san, Kwangyang-gun occurs in association with cummingtonite, magnetite, hornblende and actinolite. It shows tetragonal prisms, 0.5–1.00 mm in length and 0.2–0.5 mm in diameter. It is light brownish in color, vitreous in luster, transparent and consists of m(110), p.(111) and u(331), the u-plane being small; uniaxial positive (Fig. 8, Pl. 1). $X>1.77$, $Z-X\fallingdotseq 0.03-0.05$. Under the microscope, a perfect cleavage of (110) is seen.

The chemical compositionof zircon[36] from Poksin-san P'yŏnggang-gun is as follows (analyzed by J. Takubo):

Table 10

	SiO_2	rare earth	Fe_2O_3	MnO	Al_2O_3	MgO	CaO	$(ZrHf)O_2$	TiO_2	$(NaK)_2O$	Total
1	32.18	0.08	2.39	0.08	0.67	0.05	0.29	63.85	0.00	—	99.59
2	33.83	0.05	3.46	0.10	0.99	0.09	0.33	60.8	0.00	0.06	99.76

Zircon[8] from Iha-ri, Tanch'ŏn-gun occurs in pegmatite, associated with feldspar, magnetite and quartz. It is brown and shows tetragonal prisms in its crystal habit, some being 1 cm in diameter and 3 cm in length. $H.\fallingdotseq 7.5$.

The crystal planes observed are as follows (Fig. 9, Pl. 1): a(100), m(110), p(111), x(311), u(331).

The prismatic planes are represented by m, the a-plane being rare and small, and the terminal planes by p- and x-, the u-plane being small.

Zircon[8] from Talli-dong, Haksŏng-gun occurs as long and short prisms in pegmatite, and shows the following crystal planes (Fig. 10, Pl. 3): a(100), m(110), p(111), u(331), x(311).

Of these, the m-, p- and u-planes are common, and the a- and z-planes are very small. The chemical composition is as follows (analyzed by T. Mizuma):

Table 11

ZrO_2	SiO_2	Fe_2O_3	Total
65.93	32.30	0.78	99.01

According to Nobufusa SAITO[30] the specific gravity and radium content of the mineral from Talli-dong are as follows: G.=4.58—4.60. Ra= 72.39—94.48 × 10^{-12} g.

64. Uranothorite

Locality: Talli-dong, Hangnam-myŏn, Haksŏng-gun, Hamgyŏng-pukto

Uranothorite[56] from Talli-dong, Haksŏng-gun is found in association with allanite, zircon, etc. It is orange yellow, translucent or opaque and has a resinous luster. G.=4.56 (11° C). The chemical composition is as follows (analyzed by S. IIMORI):

Table 12

SiO_2	PbO	Fe_2O_3	Al_2O_3	MgO	ThO_2	ΣCe_2O_3	ΣY_2O_3	UO_3
15.12	0.80	0.77	0.56	0.13	58.75	5.53	0.12	7.56

$H_2O(+)$	$H_2O(-)$	Total
7.70	2.44	99.48

Chemical formula: $(ThU)O_2 . SiO_2 . 2H_2O$. Pb/U=0.03 (about 230×10^6 years).

65. Topaz

Locality: Yongyŏl-li, Mun'gyŏng-myŏn, Mun'gyŏng-gun, Kyŏngsang-pukto

Topaz[57] from Yongyŏl-li, Mun'gyŏng-gun occurs in druses of pegmatite, associated with kali-feldspar, albite and quartz. It is light brownish, transparent to translucent and shows short prismatic crystals. It shows the following planes (Fig. 11, Pl. 2): m(110), l(120), Q(540), b(010), f(021), u(111).

In general terminal planes are not seen, the m-plane is largest, l-plane large or small and Q-plane rare and narrow. The size of the crystals varies from 1.8 × 2 cm to 3 × 2.3 cm. Sometimes etched figures are seen on the well developed basal plane.

66. Andalusite

Locality: Munŭi-ri, Munŭi-myŏn, Ch'ŏngju-gun, Ch'ungch'ŏng-pukto

Andalusite[41] from Munŭi-ri, Ch'ŏngju-gun occurs in mica-schist in siliceous schists or granulite and is associated with cyanite and muscovite.

67. Cyanite

Locality: Yangsal-li (Tŏngmong-ni), Pŏlgong-myŏn, Nonsan-gun, Ch'ung-ch'ŏng-namdo
Hugong-ni (Sansŏ-ri), Yonghŭmg-myŏn and Munŭi-ri, Munŭi-myŏn, Ch'ŏngju-gun, Ch'ungch'ŏng-pukto
Sinp'ung-ni, Mi-myŏn, Okku-gun, Chŏlla-pukto
Tahak-tong, Chinsa-ri, Sinhŭng-myŏn, Kangsŏ-gun, P'yŏngsan-namdo

Cyanite from Sansŏ-ri, Ch'ŏngju-gun, and Tŏngmong-ni, Nonsan-gun occurs in a coarse chiastolite-schist in mica-schist and graphite-schist of the Yokusen (Okch'ŏn) system and commonly shows large crystals of 20–50 cm in length.

Cyanite from Munŭi-ri, Ch'ŏngju-gun[26] occurs in a mica-schist in siliceous-schist or granulite and is associated with andalusite and muscovite.

Cyanite[26] from Sinp'ung-ni, Okku-gun occurs in chlorite-phyllite of the crystalline schist system and is associated with magnetite. The crystals are small and difficult to see with the naked eye.

Cyanite[26] from Tahak-tong, Kangsŏ-gun is found in blocks on the grounds accompanying muscovite, sillimanite and corundum. It is light blue and shows prismatic crystals but no distinct forms. It shows, however, cleavages parallel to (100), (001) and (101). In size, it is 1–1.5 cm along the c-axis, and 0.5–1 cm normal to the c-axis. (−) 2V=large. Nm$\fallingdotseq$1.723.

68. Beta-zoisite

Locality: Samhwa Mine, Saenggŭm-ni, Segong-myŏn, P'yŏngsan-gun, Hwanghae-do

Beta-zoisite[10] from the Samhwa Mine, P'yŏngsan-gun is pink and shows no distinct crystal forms. It is associated with labradorite. Under the microscope, it is colorless and transparent; (+) 2V=middle; dispersion of optical angles distinct; $\rho>\nu$; Nm=1.705; and cleavage of (010) is perfect and shows straight extinction.

69. Epidote

Locality: Panghyŏn Mine, Imgi-ri, Soch'ŏn-myŏn, Ponghwa-gun, Kyŏngsang-pukto
Kŭmgang "Tokushu" Mine, Sinp'ung-ni, Naegŭmgang-myŏn, Hoeyang-gun, Kangwŏn-do
Murŭng-ni, Sŏsang-myŏn, Puryŏng-gun, Hamgyŏng-pukto

The chemical composition of epidote[8] from the Panghyŏn Mine, Ponghwa-gun is as table 13 (analyzed by T. Mizuma).

Epidote[4] from the Kŭmgang "Tokushu" Mine, Hoeyang-gun occurs in cavities or fissures of quartz veins and shows three types as follows:

(1) More or less weathered epidote which is brownish and earthy.
(2) Yellowish green epidote showing fibrous or radiated crystals.

(3) Lustrous epidote which is yellowish-green or black-green and sometimes partially translucent.

Table 13

	SiO_2	Al_2O_3	Fe_2O_3	CaO	Ig. loss	Total	S. G.
1	37.70	29.10	7.1	23.61	2.15	99.66	3.39
2	62.83	28.53	4.44	42.16	11.94		
3	10.44	9.51	1.48	10.54	11.94		

Notes: 1—Chemical composition; 2—molecule percentage; 3—values derived from the molecule percentages of 2, by dividing respectively by 6, 3, 3 and 4.

Chemical formula: $H_2O.\ 4CaO.\ 3Al_2O_3.\ Fe_2O_3.\ 6\ SiO_2$.

The crystals are generally 1–2 mm in both thickness and length, and at times 4–5 mm in length.

Epidote[4] from Murŭng-ni, Puryŏng-gun occurs as a contact mineral in association with garnet and is 1–10 mm in length. It shows good crystals with the following crystal planes: a(100), c(001), m(110), r(101), o(011), n($\bar{1}$11).

70. Allanite

Locality: P'ano-ri, Anang-myŏn, Anak-kun, Hwanghae-do
Sanhyŏl-li, Kŭmbung-myŏn, Kŭmhwa-gun, Kangwŏn-do
Talli-dong, Haksŏng-myŏn, Haksŏng-gun, Hamgyŏng-pukto

Allanite[16] from P'ano-ri, Anak-kun has the following chemical composition (analyzed by T. NAKAI):

Table 14

MgO	CaO	MnO	FeO	Fe_2O_3	Al_2O_3	Ce_2O_3	$(La,Y)_2O_3$ etc.	ThO_2
1.11	10.60	1.28	10.83	4.65	15.67	6.78	15.63	0.60

SiO_2	H_2O	Total	S. G.
31.23	1.54	99.92	$D^{17°C}_{4°C} = 3.81$

Chemical formula: $(Ca, Mn, \Sigma\ Ce, Th)_2.\ (Al, Fe''', Fe'', Mg)_3.\ Si_3(O,OH)_{13}$ $4.4R^{II}O \cdot 3R_2^{III}O_3 \cdot 6SiO_2 \cdot H_2O$ when the elements of two and three atom value are respectively grouped together. The radium content of the mineral of 1 gr: 1.86×10^{-11} g/g. Rate percent: 1.86×10^{-9}%.

Allanite[8] from Sanhyŏl-li, Kŭmhwa-gun is found with lepidomelane on the

weathering surface of nepheline syenite. It occurs as masses the size of a man's fist or less, with earthy encrustments, less than 1 mm thick and brown in color. Sometimes scales of lepidomelane are found on the surface. In a fresh section, it has a glassy luster and is black; it shows no crystal form; H.=6. G.≒4.1. (—) 2V= small; dispersion of light large, $\rho>\nu$; Nm≒1.78; pleochroism strong; Z=dark brown; Y=light brown. The chemical composition is as follows (1. analyzed by T. MIZUMA, 2. by N. SAITO[12]):

Table 15

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Ce_2O_3	Rare earth oxide (except Ce)
1	27.80	14.84	5.29	9.82	2.10	9.35	13.79	11.94
2	28.12	14.01	7.98	7.65	0.39	9.16	14.21	12.84

ThO_2	MnO	H_2O (+)	H_2O (−)	Total	S.G.
	3.15	1.35		99.43	
1.02	3.10	1.03	0.57	100.08	$3.7\left(D^{22°C}_{4°C}\right)$

According to N. SAITŌ, the presumptive amount of beryllium content is 10^{-3}—10^{-4}%, and the chemical formula is as follows:

$$(Ca, Mn, \Sigma Ce, Th)_{2.0}\ (Al, Fe^{II}, Fe^{III}, Mg)_{3.1}\ Si_{2.9}$$
$$(O{\cdot}OH)_{13.5} \text{ or } 4.2R^{II}\,O \cdot 3.4R_2^{III}\,O_3 \cdot 6SiO_2 \cdot 1.1H_2O$$

Table 16

	SiO_2	Al_2O_3	FeO	Fe_2O_3	CaO	MgO	Ce_2O_3	$(La, Y)_2O_3$ etc.
1	28.26	16.32	10.88	8.01	13.49	1.24	12.84	5.56
2	30.48	16.16	11.82	7.05	10.83	0.34	9.81	11.16
3	28.30	16.34	10.74	7.55	13.60	1.12	12.52	6.76

ThO_2	MnO	H_2O (+)	H_2O (−)	TiO_2	Total
1.29	0.81	1.05	0.89		99.74
0.25	0.31	1.59	0.11	0.40	100.50
	1.46	1.60			99.99

Allanite from Talli-dong, Haksŏng-gun is black and has strong glassy luster and radioactivity. The chemical composition is as Table 16 (1. analyzed by N. SAITO[12]; 2. by J. TAKUBO[14]; 3. by T. MIZUTA):

The chemical formula derived from the chemical composition 1 in the above table is as follows: $(Ca, Mn, \Sigma Ce, Th)_{2.1}$, $(Al, Fe^{II}, Fe^{III}, Mg)_{3.4}$, $Si_{2.6}$, $(O \cdot OH)_{12.8}$

71. Prehnite

Locality: Hwach'ŏn Mine, Hwach'ŏl-li, Sangmo-myŏn, Koesan-gun, Ch'ung-ch'ŏng-pukto

Paegyang-ni, Namsan-myŏn, Ch'unch'ŏn-gun, Kangwŏn-do

Prehnite[9] from the Hwach'ŏn Mine, Koesan-gun forms veins together with calcite in limestone, and is associated with quartz and wollastonite. It is light green to green, translucent, massive, showing no distinct crystal form. Some crystals, however, exceed 5 cm in diameter. (+) $2V \fallingdotseq 60°$. $X \fallingdotseq 1.616$, $Y \fallingdotseq 1.622$, $Z \fallingdotseq 1.645$.

Prehnite[9] from Paegyang-ni, Ch'unch'ŏn-gun occurs in manganese deposits in granite-gneiss, associated with diopside, garnet, orthoclase and quartz. It is colorless, transparent and has perfect cleavage parallel to 100. In cases, the mineral aggregates into tabular bundles of 0.1–1 mm in diameter. (+) 2V and Z are normal to cleavage piece. X//a. Y//b. Z//c. $Ng = 1.644$, $Nm = 1.623$, $Np = 1.616$.

72. Chondrodite

Locality: Namch'ŏn Mine, Namch'ŏn-li, Pongsan-myŏn, P'yŏngsan-gun, Hwanghae-do

Chondrodite[10] from the Namch'ŏn Mine, P'yŏngsan-gun occurs in contact deposits of magnetite, associated with brugnatellite and dolomite. The mineral is white to light brown and shows crystals of 1 mm across or so. (+) 2V not large. $Ng = 1.635$, $Nm = 1.617$, $Np = 1.604$.

73. Clinohumite

Locality: Chung-bong, Chil-li, Yŏnp'ung-myŏn, Koesan-gun, Ch'ung-ch'ŏng-pukto

Clinohumite[9] from Chŭng-bong, Koesan-gun is found as a contact mineral of iron deposits, associated with magnetite and clinochlorite. It occurs as small grayish crystal aggregates. Under the microscope, the crystals show polysynthetic twinning and distinct cleavages parallel to the composition plane (001) or nearly normal to the same plane. If the plane (001) is taken as the composition plane, X inclines to (001) at an angle of 10°. (+) 2V large. $Ng = 1.650$, $Np = 1.625$.

74. Lessingite

Locality: Yangjang Mine, Songna-san, Ch'ŏnma-ri, Nam-myŏn, Pyŏng gang-gun, Kangwŏn-do

Lessingite[15] from Songna-san, Pyŏnggang-gun is found in syenite, associated with fluorite, alkali-hornblende, molybdenite and allanite. It is dark red, and the chemical composition is as follows (analyzed by J. TAKUBO):

Table 17

SiO_2	FeO	Fe_2O_3	MnO	Al_2O_3	ThO_2	Ce_2O_3	Σ La_2O_3	Σ Y_2O_3	CaO
19.02	1.86	—	1.79	0.36	0.00	30.71	27.76	2.80	12.47

MgO	K_2O	Na_2O	CO_2	P_2O_5	H_2O (+)	H_2O (−)	F		$F_2=O$	Total
0.15	—	—	—	0.87	0.57	0.04	2.51	100.91	−1.06	99.85

Chemical formula: $(Ca, Fe, Mn)_2 [(Ce, Na....)O]_2 (Ce, Na...)_2 (SiO_4)_3$

75. Tourmaline

Locality: Chuch'ŏl-li, Unbong-myŏn, Namwŏn-gun, Chŏlla-namdo
Myŏngbong-dong, Chinsa-ri, Tongno-myŏn, Mungyŏng-gun, Kyŏngsang-pukto

Tourmaline[28] from Chunch'ol-li, Namwŏn-gun is lacquer black, short prismatic, showing both terminal planes, 2.3 cm in length and 2 cm in diameter. Its crystals consist of the following planes: m(10$\bar{1}$0), a(11$\bar{2}$0), r(10$\bar{1}\bar{1}$), e(01$\bar{2}$1). No$\fallingdotseq$1.650, Ne$\fallingdotseq$1.628. Z=dark brown, X=colorless to light brown.

Tourmaline[51] from Myŏngbong-dong, Mungyŏng-gun occurs with almandite, in pegmatite in gneiss. It is black opaque, and shows prismatic crystals with the following crystal planes: m(10$\bar{1}$0), a(11$\bar{2}$0), r(10$\bar{1}$1), e(01$\bar{1}$2), o(0$\bar{2}$1$\bar{2}$), c(0001).

In the crystal forms, there are three types, as follows:

(1) Nearly hexagonal prisms with well-developed terminal planes r and o, and prismatic plane a, the m-plane being small.
(2) Nearly hexagonal prisms with well-developed terminal plane e and prismatic plane a, the planes r and c being small.
(3) Nearly trigonal prisms, with well-developed terminal plane r, with narrow plane of e on the edge.

In size, these crystals are 4 cm in diameter, 4–5 cm in length and sometimes 2 cm in diameter and 7–8 cm in length. N_{OD}=1.652, N_{ED}=1.627, $N_{OD}-N_{ED}$=0.025.

76. Stellerite

Locality: Chewŏn Mine, Tonggong-ni, Chewŏn-myŏn, Kŭmsan-gun, Chŏlla-pukto

Stellerite[8] from the Chewŏn Mine, Kŭmsan-gun is found forming veins in granite, white and massive, showing no distinct crystal forms. It shows cleavages, however,

one of which is perfect along (101)?, while the others are distinct respectively along (100), (001), and (111). The cleavage planes have a glassy to pearly luster. H=3. G=2.1—2.2.

Sometimes the crystal is tabular and shows crystal planes of a(100), b(010), c(001) and p(111). In general, it shows parallel growth that has the b-plane as its composition plane and is 5 mm on the a-axis, 2 mm on the b-axis and 7 mm on the c-axis. X // C, Z // a, Y // b. Z=1.497, X=1.488.

77. Hydromica

Locality: Kumi-ri, Oejungbang-ni, Tanyang-myŏn, Tanyang-gun, Ch'ungch'ŏng-pukto

Hydromica[28] from Kumi-ri, Tanyang-gun occurs in pegmatite with lepidolite. It is yellow, massive or micro-crystalline and more or less resinous in luster. (—) 2V small. Ng=Nm=1.578, Np=1.547.

78. Lepidolite

Locality: Songgye-ri, Hansu-myŏn, Chech'ŏn-gun, Ch'ungch'ŏng-pukto
Kumi-ri, Oejungbang-ni, Tanyang-myŏn, Tanyang-gun, Ch'ungch'ŏng-pukto
Onjŏng-ni, Chŏgam-myŏn, P'yŏngsan-gun, Hwanghae-do

Lepidolite[9),19)] from Songgye-ri, Chech'ŏn-gun is found in pegmatite in limestone, associated with quartz, amazonstone and red tourmaline. In some cases it is light violet or light russet. The light violet crystals are scaly, some large ones being 1 cm in diameter. (—) 2E=0°—60°. 2V≒38°; Ng=1.554 and Np=1.551 in the case of 2E≒60°, and Ng≒1.548 in the case of 2E≒0°; both cases being at times observed in the same section.

The light russet crystals are smaller than the preceding one, being about 5 mm or less in diameter. (—)2E≒60°. (—)2V≒38°. Ng=1.554.

Lepidolite from Kumi-ri, Tanyang-gun shows the following chemical composition (analyzed by M .ISHIBASHI and T. ISHIHARA):

Table 18

SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	SrO	Na_2O	K_2O	LiO_2
50.65	23.75	0.73	3.42	0.58	0.24	0.01	1.12	6.80	3.97

Rb_2O	Cs_2O	F	H_2O		$F_2=0$	Total
2.96	0.10	6.23	1.96	102.52	—2.63	99.89

$\frac{1}{2}O=F-2.63$ Total 99.89

The age of lepidolite calculated from the amount of Pb and Sr in the above table is about $1{,}060\times10^6$ years.

Lepidolite[5] from Onjŏng-ni, P'yŏngsan-gun occurs in pegmatite in biotite granite associated with zinnwaldite, amazonstone, muscovite, orthoclase, albite and quartz, some large crystals being 6 cm in diameter.

79. Phlogopite

Locality: I-ri and Pudong-ni, Huch'ang-myŏn, Pukch'ŏng-gun, Hamgyŏng-pukto
Yŏnju-ri, Sokhu-myŏn, Pukch'ŏng-gun, Hamgyŏng-pukto
Homal-li, Yanghwa-myŏn, Pukch'ŏng-gun, Hamgyŏng-pukto

Phologopite[10] from Pukch'ŏng-gun forms beds or lenses rich in the mineral in gneiss and is associated with diopside or actinolite. When it is associated with diopside, its crystals are generally large, up to 20 cm in diameter. The central portion of these crystals is grayish white, while the marginal portion is brownish. $(-)2V \fallingdotseq 0$ in both parts. Ng=1.572 (grayish white*), Ng=1.574 (brownish).

The grayish white portion encloses microcrystals of rutile and is therefore difficult to strip off and is brittle.

80. Lepidomelane

Locality: Yŏngyu Mine, Wŏnnyu-ri, P'yŏngwŏn-myŏn, P'yŏngwŏn-gun, P'yŏngan-namdo

Lepidomelane[43] from the Yŏngyu Mine, P'yŏngwŏn-gun occurs in apatite deposits, associated with apatite, quartz and calcite. The mineral is dark green and tabular or scaly. Nm=1.606, Ng=1.661. $(-)2E=22°$.

81. Clinochlore

Locality: Chŭng-bong, Chil-li, Yŏnp'ung-myŏn, Koesan-gun, Ch'ungch'ŏng-pukto

Clinochlore[9] from Chŭng-bong, Koesan-gun occurs in iron deposits in limestone and is associated with magnetite and clinohumite. The crystals are grass green, tabular, often hexagonal, some having a basal plane 5 mm in diameter. Cleavages along the basal plane are perfect. (+) 2V variable. $2E \fallingdotseq 10°-35°$. Weak clino-dispersion is seen. Optical plane parallel to $(10\bar{1}0)$. Z is nearly vertical to the basal plane. $Ng \fallingdotseq Nm \fallingdotseq 1.575$.

82. Delessite?

Locality: Samhwa Iron Mine, Samhwa-ri, Puksam-myŏn, Samch'ŏk-kun, Kangwŏn-do

Delessite[10]? from the Samhwa Iron Mine, Samch'ŏk-kun is found adhering to magnetite and is represented by whitish aggregations of crystals which are about 1 mm in diameter and easily stripped off, the cleavage pieces having a pearly luster. $H. \fallingdotseq 2$, $(-)\ 2V \fallingdotseq 0°$. X is nearly normal to cleavage plane. Ng=Nm=1.656, Ng−Np=0.005.

* Phlogopite from I-ri contains 0.59% TiO_2 (analyzed by T. Mizuma).

83. Stilpnomelane

Locality: Kalgŭm-ni, (Ibsŏng-ni), Yŏnp'ung-myŏn, Koeasan-gun, Ch'ung-ch'ŏng pukto
Sinhŭng Mine, Yŏnch'ŏn-myŏn, Puryŏng-gun, Hamgyŏng-pukto

Stilpnomelane[10] from Kalgŭm-ni, Koesan-gun fills up interstices of crystals of mangan-hedenbergite in a contact zone. X is nearly normal to the cleavage which seems to be parallel to its basal plane. $(-)2V \fallingdotseq 0°$; dispersion of optic axes is large. Z=Y=deep green, X=yellow, Z=Y>X, 1.74> Z=Y>1.72, Z−X=0.05.

Stilpnonelane[47] from the Sinhŭng Mine, Puryŏng-gun occurs as a constituent of magnetite-mangan-grunerite-stilpnomelane-apatite-quartz schist. $\beta \fallingdotseq \gamma =$ 1.694, $\alpha = 1.611$. $(-)2V = 0-5°$. X=yellow, in cases gold yellow, Y=Z= reddish brown−dark brown.

84. Thuringite

Locality: Yonghwa-dong, Ilwŏl-myŏn, Yŏngyang-gun, Kyŏngsang-pukto

Thuringite[10] from Yonghwa-dong, Yŏngyang-gun is accompanied by zinc blende, chalcopyrite and quartz. It is dark green or olive in color. The dark green crystals are tabular, hexagonal in outline, 0.1 mm across, and have strong pleochroim. X=pale yellow (almost colorless), Y=Z=deep green. $(-)\ 2V \fallingdotseq 0°$. Dispersion of the optic axes is large. The axis is nearly normal to basal cleavage. Z=1.680, Z−X=0.01.

85. Montmorillonite

Locality: Kumi-ri, Oejungbang-ni, Tanyang-myŏn, Tanyang-gun, Ch'ung-ch'ŏng-pukto
Sanae Fluorite Mine, Sach'ang-ni, Sanae-myŏn, Ch'unch'ŏn-gun, Kangwŏn-do

Montmorillonite[28] from Kumi-ri, Tanyang-gun is found partly replacing feldspar in pegmatite. It is red, translucent, and more or less massive (several millimeters to 1 cm). $N \fallingdotseq 1.540$.

Montmorillonite from the Sanae Fluorite Mine, Ch'unch'ŏn-gun occurs in fluorite-bearing quartz veins cutting granite, and is pink.

86. Gageite

Locality: Kŭmjik-san Mine, Nam-myŏn, Ch'ŏngsŏn-gun, Kangwŏn-do

Gageite[28] from the Kŭmjik-san Mine, Ch'ŏngsŏn-gun is brown, fibrous, about 2 mm long, about 0.1 mm wide and is associated with braunite and spessaritite. Two prismatic cleavages almost at right angle to each other are well developed. Z=c, Y=b, X=a. X, Y plane is normal to the cleavages, and in the section normal to Z, the X−Y plane bisects the angle between the cleavages. $(-)2E \fallingdotseq 90°$. $Z' \fallingdotseq 1.72$, $X' \fallingdotseq 1.71$, $Y' \fallingdotseq Z'$. H.≒3. G.=3.5±. The chemical composition is as follows:

Table 19

SiO_2	FeO	Al_2O_3	CaO	MgO	MnO	ZnO	Ig. loss	Total
38.05	10.13	4.45	11.50	1.23	20.81	10.37	5.45	101.99

(Analyst: T. MIZUMA. The sample is relatively impure.)

87. Bourlingite

Locality: Nabu-dong, Nodong-ni, Wangjing-myŏn, Yŏnch'ŏn-gun, Kyŏnggi-do

Bourlingite[9] from Nabu-dong, Yŏnch'ŏn-gun is contained in violarite-bearing hornblende periodotie, as an alteration product of olivine. It varies from deep green to deep brown in thin section; the cleavage, which is nearly normal to X and seems to be parallel to the basal plane is perfect and shows strong pleochroism. $X=Z$=yellowish-green, Y=deep brownish-yellow. (−)2V small. Nm=1.6±.

88. Titanite

Locality: Talli-dong, Haksŏng-myŏn, Haksŏng-gun, Hamgyŏng-pukto
Pultanggol, Ŏbok-tong, Haksŏ-myŏn, Haksŏng-gun, Hamgyŏng-pukto
Tomok-tong, Tŏksan-myŏn, Kilchu-gun, Hamgyŏng-pukto

The chemical composition of the titanite from Talli-dong[8], Haksŏng-gun is as follows (analyzed by T. MIZUMA):

Table 20

TiO_2	SiO_2	CaO	Rare earths	Total
37.60	30.60	25.30	0.00	93.50

According to N. SAITŌ, the specific gravity of the mineral is 3.50—3.52 and Ra content $16.47-28.15\times10^{-12}$ g/g.

Titanite from Pultanggol, Haksŏng-gun is found in the pegmatite in limestone, is macroscopically pale brown and is lamellar on η (221) with rhombic cross section, the terminal plane being indistinct. The parting parallel to the (221) plane is well developed. Some crystals are 2 cm in length and 1 cm in width.

Titanite[10] from Tomok-tong, Kilchu-gun occurs in pegmatite in limestone. It is macroscopically brown and shows the rhombohedron crystal form, consisting only of η(221) and wanting in terminal planes. In some crystals, it is 9 cm in long diameter and 4 cm in short diameter. The partings parallel to the η-plane are common, and quartz and feldspar are seen crystallized out along the parting.

89. Fergusonite

Locality: Chunggye-ri and Pongjil-li, Hongbung-myŏn, Hongsŏng-gun, Ch'ungch'ŏng-namdo

Kukkun Mine*, Songgye-ri, Kŭmsal-li, Unsal-li, Haewŏl-myŏn, Yŏnbaek-kun, Hwanghae-do

Fergusonite[38] from Hongbong-myŏn, Hongsŏng-gun is found in gold placer, black with light streaks, conchoidal fracture, and resinous luster. G.=6.04. The chemical composition is as follows (analysed by S. HATA and T. IIMORI):

Table 21

BeO	MgO	CaO	MnO	FeO*	PbO	Al_2O_3	Ce_2O_3	$(La, Nd)_2O_3$
0.03	0.10	1.21	0.21	0.28	0.20	0.18	0.0	0.0

Y_2O_3	TiO_2	ZrO_2	ThO_2	UO_2*	SnO_2	SiO_2	Nb_2O_5	Ta_2O_5	Total
40.68	1.11	0.07	0.91	7.49	0.01	0.07	35.16	12.38	100.09

Chemical Formula: $Y(Nb, Ta)O_4$. The age of the mineral determined by the Pb/U ratio is 260×10^6 years.

Fergusonite[37] from the Kukkun Mine, Yŏnbaek-kun is contained in gold placer. It is black, submetallic luster, subconchoidal in fracture, and light in streak (Fig. 12, Pl. 2). G.=5.82. H.=6.0–6.5.

The chemical composition is as follows (analyzed by S. HATA and K. SHIMMI):

Table 22

MgO	CaO	MnO	FeO	Al_2O_3	Ce_2O_3	Y_2O_3	TiO_2	ZrO_2	ThO_2
0.3	2.6	0.1	0.6	0.1	1.5	33.5	0.6	0.6	3.4

UO_2	SiO_2	SnO_2	Nb_2O_5	Ta_2O_5	Total
8.4	0.1	0.2	31.1	17.4	100.5

Chemical Formula: $6Y(Nb, Ta)O_4 + (Ca, UO)_2(Nb, Ta)_2O_7$.

90. Columbite

Locality: Sujung Mine, Chŏkkong-ni, Susan-myŏn, Chech'ŏn-gun, Ch'ungch'ŏng-pukto

Chaeil Mine, Ch'ach'ang-myŏn, Hŭich'ŏn-gun, P'yŏngan-pukto

Columbite[28] from the Sujung Mine is contained in wolframite veins, intruding granite and is associated with galena, zinc blende, cassitarite and fluorite. It is

* Iron and uranium were assumed to be present as FeO and UO_2.

macroscopically iron black, incomplete in its crystal forms, and 2 mm across. H.=5.5. G.≒5.5. In thin section it is brown with intense pleochroism. $Z'>X'$. (−) $2V\fallingdotseq 90°$. $N>1.8$.

Columbite from the Chaeil Mine, Hŭich'ŏn-gun is found in small quantity in pegmatite, and shows no crystal form. It is dark brown and intimately associated with green mica.

91. Yttro-tantalite

Locality: Pongjil-li and Chunggye-ri, Hongbung-myŏn, Hongsŏng-gun Ch'ung-ch'ŏng-namdo

Yttro-tantalite[38] from Hongbung-myŏn, Hongsŏng-gun is found in placer gold. It is black and shows subconchoidal fracture and a resinous luster. The chemical composition (analyzed by S. HATA and T. IIMORI) is as follows:

Table 23

CaO	MnO	FeO*	PbO	$Ce_2O_3+(La,Nd)_2O_3$	Y_2O_3	TiO_2	ThO
0.02	1.89	5.58	1.50	tr.	19.71	0.89	2.59

UO_2*	SnO_2	SiO_2	Nb_2O_5	Ta_2O_5	Total
4.60	1.10	0.89	20.27	37.48	96.52

* Iron and uranium were assumed to be present as FeO and UO_2.

92. Tantal-euxenite

Locality: Ditto.

Tantal-euxenite[38] from Hongbung-myŏn, Hongsŏng-gun is contained in gold placer and is black, has pale brown streaks, a submetallic luster and uneven fracture. G.=5.15.

The chemical composition is as follow (analyzed by S. HATA and T. IIMORI):

Table 24

BeO	MgO	CaO	MnO	FeO*	PbO	Al_2O_3	Ce_2O_3	$(La,Nd)_2O_3$
0.00	0.03	0.00	2.66	5.13	0.18	0.10	1.27	6.46

Y_2O_3	TiO_2	ZrO_2	ThO_2	UO_2*	SnO_2	SiO_2	Nb_2O_5	Ta_2O_5	Total
7.46	19.80	0.30	2.30	4.18	0.02	0.04	26.92	23.46	100.31

* Iron and uranium were assumed to be present as FeO and UO_2.

Chemical Formula: $Y_2Ti_4O_{11}+2.5$ (Fe, Mn) $(Nb,Ta)_2O_6$

The age of the mineral determined by the Pb/U ratio is 260×10^6 years.

93. Monazite

Locality: Kŭmsal-li, Haewŏl-myŏn, Yŏnbaek-kun, Hwanghae-do
Changp'yŏng-ni and Kŏjil-li, Odae-myŏn and Taejil-li Changnae-myŏn Kosŏng-gun, Kangwŏn-do
Inhuung-myŏn, Yŏnghŭng-gun, Hamgyŏng-namdo

Monazite[4] from Kŭmsal-li, Yŏnbaek-kun is contained in gold placer and has the following crystal planes: a(100), m(110), n(120), w(101), x($\bar{1}$01) e(011) and υ($\bar{1}$11) (Fig. 13, Pl. 2).

The a-plane is well developed, followed by the m-plane. It is 1 cm in length and about 3 mm in thickness. (+)2V small. The optic plane is normal to (010). X//b. N>1.77.

Monazite[4] from Odae-myŏn and Changnae-myŏn, Kosŏng-gun occurs in coastal heavy sands, containing 1–15% monazite. The crystals are tabular and 0.10–0.16 mm across. There are two types of monazite, the yellowish brown and transparent type with glassy luster, and the reddish brown or dark brown type which is greasy to dull in luster. G.≒5.0.

Monazite[6] from Inhŭng-myŏn, Yŏnghŭng-gun is found in gold placers, is macroscopically black with a greenish tinge, opaque and has intense radioactivity. G.≒5.14–5.16.

The chemical composition of monazite with a specific gravity of 5.16 is as follows (analyzed by T. Iimori):

Table 25

SiO_2	P_2O_5	Ce_2O_3	$(La,Nd)_2O_3$ etc.	Y_2O_3 etc.	ThO_2	UO_3	Fe_2O_3	Al_2O_3
0.93	27.55	25.10	37.14	1.26	5.81	0.66	0.42	0.45

CaO	MgO	BeO	Total
1.58	0.00	0.00	100.90

94. Apatite

Locality: Sangp'al-tong, Changbaeng-myŏn, Kilchu-gun Hamgyŏng-pukto

Apatite[9] from Sangp'al-tong, Kilchu-gun occurs in phologopite deposits in limestone. It is pale green, translucent, and has perfect basal cleavage. It shows long prismatic crystals consisting mainly of m(10$\bar{1}$0), with well-developed terminal planes at both ends.

The terminal plane x(10$\bar{1}$1) is more or less rounded. No=1.639. In some cases, the crystals have a length of 55 mm and a diameter of 12 mm.

95. Pyromorphite

Locality: Taeryong-dong, Kunbung-myŏn, Tongnae-gun, Kyŏngsang-namdo

Pyromorphite[8] from Taeryong-dong, Tongnae-gun shows a crystal form of hexagonal prism with c(0001) and m(10$\bar{1}$0), 1 mm in diameter and commonly 1–3 mm in length. It is yellowish green, or greenish black (Fig. 19, Pl. 3)

96. Triplite

Locality: "Furukawa-Yamaguchi" Yŏnsu Mine, Chŏnch'ang-myŏn, Ch'ang-Sŏng-gun, P'yŏngan-pukto

Triplite[45] from Chŏnch'ang-myŏn, Ch'angsŏng-gun occurs in tungsten-bearing quartz veins and is associated with wolframite, zinc blende, cosalite and teallite. It is light brownish pink in color and is found as locally crowded aggregations of irregular grain in the quartz vein. Rarely, the aggregations are pierced by quartz veins and show a brecciated structure. Np=1.660, Nm=1.670, Ng=1.683, Ng−Np=0.023. (+) 2V=85°, Y=b, Z∧a=40°.

97. Pseudoheterosite

Locality: Kŭmgong-ni, Kyenae-myŏn, Ch'angsu-gun, Chŏlla-pukto

Pseudoheterosite[4] from Kŭmgong-ni, Ch'angsu-gun is found as small grains in heterosite. X=deep brown, Y=light brown, Z=deep brown, Z>X>Y. (+) 2V middle. $\rho > \nu$.

98. Strengite?

Locality: Kŭmgong-ni, Kyenae-myŏn, Ch'angsu-gun, Chŏlla-pukto

Strengite[4] (?) from Kŭmgong-ni, Ch'angsu-gun is a dark green to black mineral, associated with heterosite. It shows a streak of olive color. H.=5−5.5. Biaxially positive or negative; 2V large. $\rho > \nu$. Straight extinction on the cleavage direction. Z green, Y green, X light brown, Z>Y>X, Z>1.779, X≒1.760. Z−X>0.03. soluble in HCl.

99. Suanite*

Locality: Holgol Mine, Suan-gun, Hwanghae-do

Suanite from the Holgol Mine, Suan-gun is found in association with ludwigite and kotoite in contact-metamorphosed limestone. The mineral is white and occurs as aggregates of fibrous crystals with a silky luster, the fibers attaining 3 cm in length. The chemical composition of the mineral more or less accompanying calcite and forsterite is as Table 26 (analyzed by K. Isono).

G.=2.91. Np=1.596, Nm=1.639, Ng=1.670. (−)2V=70°. X′ direction coincides with the crystal axis.

* Named by Takeo Watanabe.

Table 26

MgO	CaO	Fe_2O_3	Al_2O_3	B_2O_3	SiO_2	Na_2O	K_2O	CO_2	H_2O	Total
46.48	3.70	0.33	0.97	38.20	0.70	0.90	0.00	5.70	3.50	100.48

Chemical formula: $2\,MgO\,B_2O_3 = Mg_2\,B_2O_7$

100. Jōhachidolite*

Locality: Sangp'al-tong, Ch'angbaeng-myŏn, Kilchu-gun, Hamgyŏng-pukto

Jōhachidolite[52] from Sangp'l-tong, Kilchu-gun is enclosed in nepheline, colorless, transparent and occurs usually as a laminated form, 1 mm in thickness and 1 cm in length. H.=6.5—7. G.≒3.4. 2V=72°. $\rho > \nu$. $\alpha_D = 1.715$; $\beta_D = 1.720$, $\gamma_D = 1.729$. It shows bluish fluorescence.

The chemical composition is as follows (analyzed by E. Iwase and N. Saitō):

Table 27

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	Na_2O	P_2O_5	B_2O_5	Cl
0.34	28.34	0.09	—	0.23	24.77	8.27	0.03	24.21	—

F	H_2O (+)	H_2O (−)	SO_3			Total
12.21	6.52	0.07	—	105.08	$-O=F_2$	99.94

Chemical formula: $H_6\,Na_2\,Ca_3\,Al_4\,F_5\,B_6\,C_{20}$

101. Barite

Locality: Kŏnsang-dong and Inam-dong, Oegwi-myŏn, Kanggye-gun, P'yŏngan-pukto

Barite[53] from Inam-dong, Kanggye-gun occurs as irregular veins in limestone and shows in druses, good crystals exceeding 10 cm in diameter, which consists of c(001), m(110), d(102), o(011), a(100), etc.

102. Gypsum

Locality: Sangwŏl-tong, Haun-myŏn, Myŏngch'ŏn-gun, Hamgyŏng-pukto

Gypsum[33] from Sangwŏl-tong, Myŏngch'ŏn-gun is found as thinly tabular bodies 1 cm thick along the bedding plane of Tertiary shale. The length of the crystals is commonly less than 0.5 mm but at times reaches 1 cm.

103. Chalcanthite

Locality: Koraesu Mine, Koraesu-ri (Kyŏngsu-ri), Sobaeng-myŏn, Yŏngwŏn-gun, P'yŏngan-namdo

* Named by Eiichi Iwase.

Chalcanthite[9] from the Koraesu Mine, Yŏngwŏn-gun is found where mine water drops in the mining pits of the tungsten-bearing quartz veins. It is a beautiful colloid of deep greenish blue but becomes earthy from dehydration.

104. Wolframite

Locality: Taehwa Mine, Nŭngam-ni, Ch'ungju-gun, Ch'ungch'ŏng-pukto
Yangdŏk Mine, Yangdŏk-kun, P'yŏngan-namdo

Good crystals of wolframite from the Taehwa Mine, Ch'ungju-gun were reported in the second edition of the "Minerals of Korea" to be constructed of a(100), b(010), l(210), m(110), t(102), y($\bar{1}$02), f(011), o($\bar{1}$11) and σ(121).

In addition, Ryuji SUGIYAMA and Tomoshige MAKINO[32] have also observed the following crystal planes of this mineral from the same mine: h($\bar{3}$10), ($\bar{3}$1$\bar{0}$), x(101), c(001), w(111), s($\bar{1}$21), ($\bar{1}\bar{2}$1) Δ(112), z(113), (1$\bar{1}$3), m'($\bar{1}$10) a'($\bar{1}$00) b'(0$\bar{1}$0), h'($\bar{3}$10), h''($\bar{3}\bar{1}$0), m'''(1$\bar{1}$0), (122), (1$\bar{2}$2), ($\bar{5}$10), (230), (232), (1$\bar{2}$2), (2$\bar{1}$1), (520), ($\bar{7}$20), (5$\bar{2}$0), (3$\bar{1}$0), ($\bar{1}$05).

In a good crystal* collected by the author, moreover, Yoshio KINOSAKI[28] reported the presence of the following planes: a(100), c(001), m(110), t(102), f(011), s($\bar{1}$21), σ(121) (Fig. 14, Pl. 2).

The chemical composition of wolframite from the Yangdŏk Mine is as follows (analyzed by T. MIZUMA):

Table 28

SiO_2	FeO	CaO	MnO	WO_3	Total
1.90	5.48	0.90	15.88	75.70	99.86

105. Scheelite

Locality: Taehwa Mine, Nŭngam-ni, Angsŏng-myŏn, Ch'ungju-gun, Ch'ungch'ŏng-pukto
Ilgwang Mine, Wŏl-li, Ilgwang-myŏn, Tongnae-gun, Kyŏngsang-namdo
P'ungsu Mine, Ch'angnak Mine, Ch'angnak-tong and Such'ŏl-tong, P'unggi-myŏn, Yŏngju-gun, Kyŏngsang-pukto
Panggye Mine, Kyech'ol-li, Pangnim-myŏn, P'yŏngch'ang-gun, Kangwŏn-do

Scheelite[23),50] from the Taehwa Mine, Ch'ungju-gun shows good crystals and is apt to be abundant in a comparatively shallow zone of the wolframite veins. The mineral is white, light yellowish brown, grass green, grayish black, translucent or opaque and consists of the following planes (Fig. 15, Pl. 3): c(001), p(111), h(313), s(131), e(101). On the e-plane, etchingfigures and numerous striae parallel to (121) are seen.

* 3 cm in c-axis, 2 cm in b-axis, 0.8 cm in a-axis.

Scheelite[9),18)] from the Ilgwang Mine, Tongnae-gun occurs in a greisenized rock and is associated with tourmaline, chalcopyrite and magnetite. It is white, but shows a light flesh color on the surface. The crystals are pyramidal and up to 1.5 cm in breadth. The observed crystal planes are as follows (Fig. 16, Pl. 3): o(102), e(101), β(113), p(111). In some cases these crystals are partly replaced by wolframite.

Scheelite[28)] from the P'ungsu Mine, Yŏngju-gun occurs as simple crystals or as parallel growths of the mineral in wolframite-bearing quartz veins in granite gneiss. It is brownish, translucent, 2–2.5 cm in length on the c-axis and shows the following planes (Fig. 17, Pl. 3): e(101), p(111), k(515).

Scheelite[28)] from the Ch'angnak Mine, Yŏngju-gun occurs in quartz-veins in granite-gneiss, and is associated with siderite, beryl, bismuthinite, molybdenite and wolframite. It is yellowish brown and translucent, rarely light brown to white and translucent, 5–20 mm in length on the c-axis, and shows crystal planes of e(101) and p(111).

Scheelite[28)] from the Panggye Mine, P'yongch'ang-gun occurs in contact deposits, composed mainly of pyrrhotite, which are formed between limestone and granite. The mineral here is green and translucent or at times brown or white, showing crystal planes of e(101) and p(111), the length of the c-axis being 5–15 mm (Fig. 18, Pl. 3).

106. Wulfenite

Locality: Namyang Mine, Pugyang-ni, Ŭmdŏng-myŏn, Suwŏn-gun, Kyŏnggi-do

Wulfenite from the Namyang Mine, Suwŏn-gun occurs in wolframite-bearing molybdenite quartz veins and is associated with chalcopyrite, pyrite, galena, siderite, fluorite, zinc blende and secondary minerals such as cerussite, pyromorphite, limonite, azurite, etc.

It is yellowish and shows tabular crystals, and chiefly consists of c(001) together with insignificant planes of n(111) and ν? Under the microscope, it is yellow and shows strong pleochroism. $Z > X$. Uniaxial, negative; index and double refraction are large.

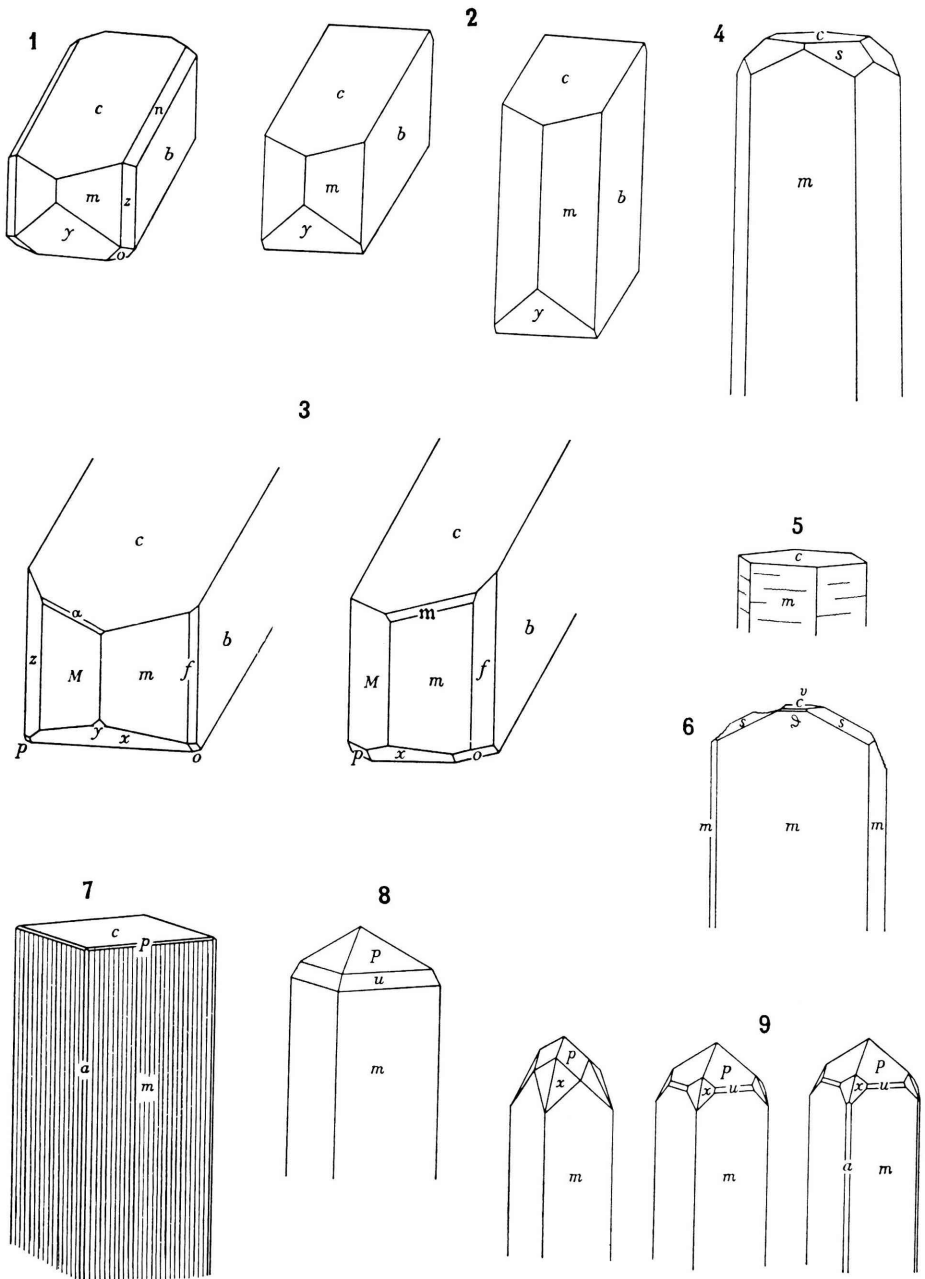

Plate 1

Fig. 1. Orthoclase. Nojŏn-dong (after Y. KINOSAKI)
2. Orthoclase. Taedang Mine (after Y. KINOSAKI)
3. Microcline-perthite. Tanryoku Mine (after Y. KINOSAKI)
4. Beryl. Taehwa Mine, Ch'ungju-gun (after R. SUGIYAMA)
5. Beryl. Turyu-san (after Y. KINOSAKI)
6. Beryl. Hach'owŏl-li (after Y. KINOSAKI)
7. Vesuvianite. Changhyŏl-li (after Y. KINOSAKI)
8. Zircon. Paegun-san (after Y. KINOSAKI)
9. Zircon. Iha-ri (after Y. KINOSAKI)

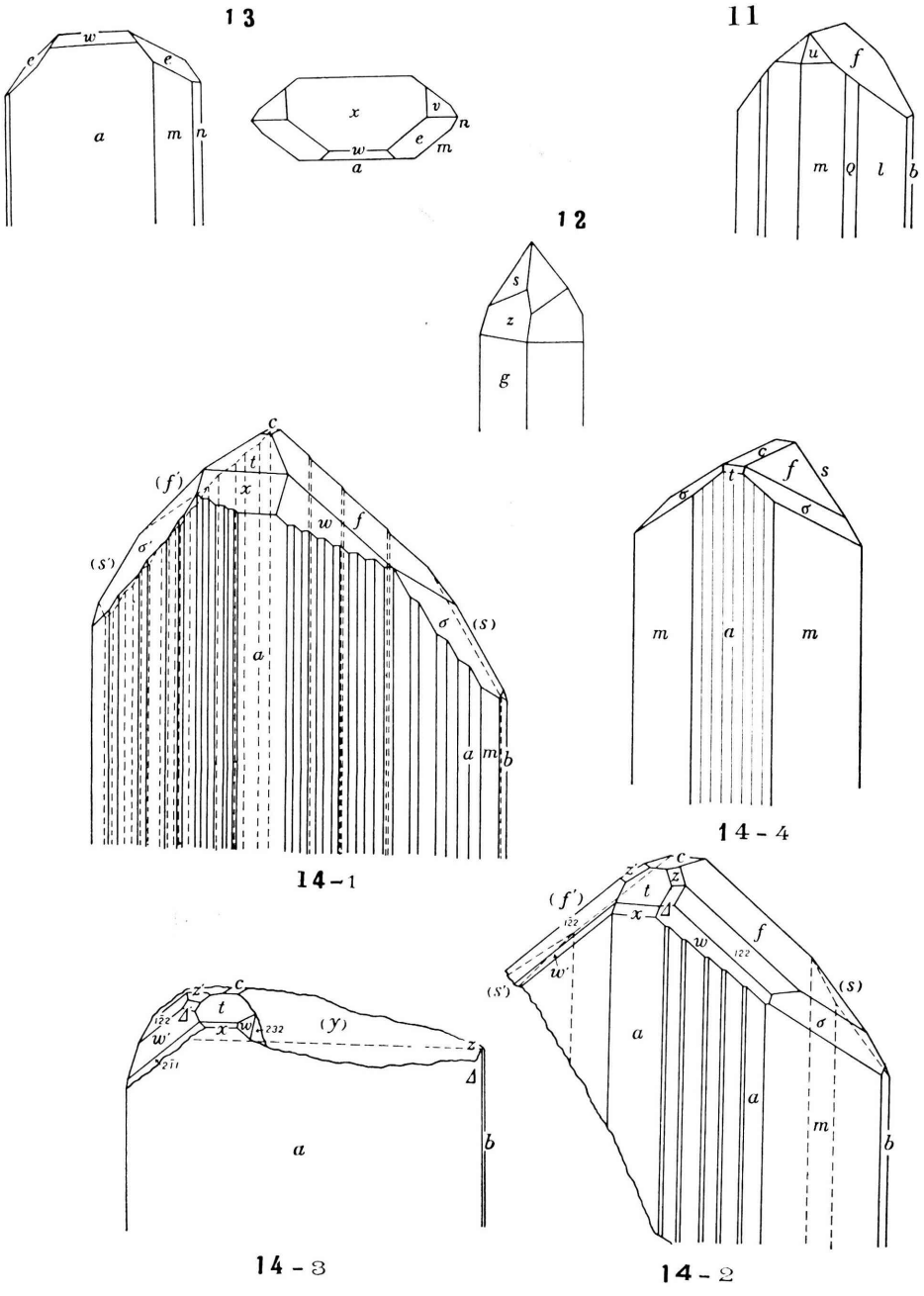

Plate 2

Fig. 11. Topaz. Yong'yŏl-li (after K. SAKURAI)
12. Fergusonite. Kukkun Mine (after Y. KINOSAKI)
13. Monazite. Kŭmsal-li (after Y. KINOSAKI)
14. Wolframite. Taehwa Mine (1–3; after R. SUGIYAMA; 4; after Y. KINOSAKI)

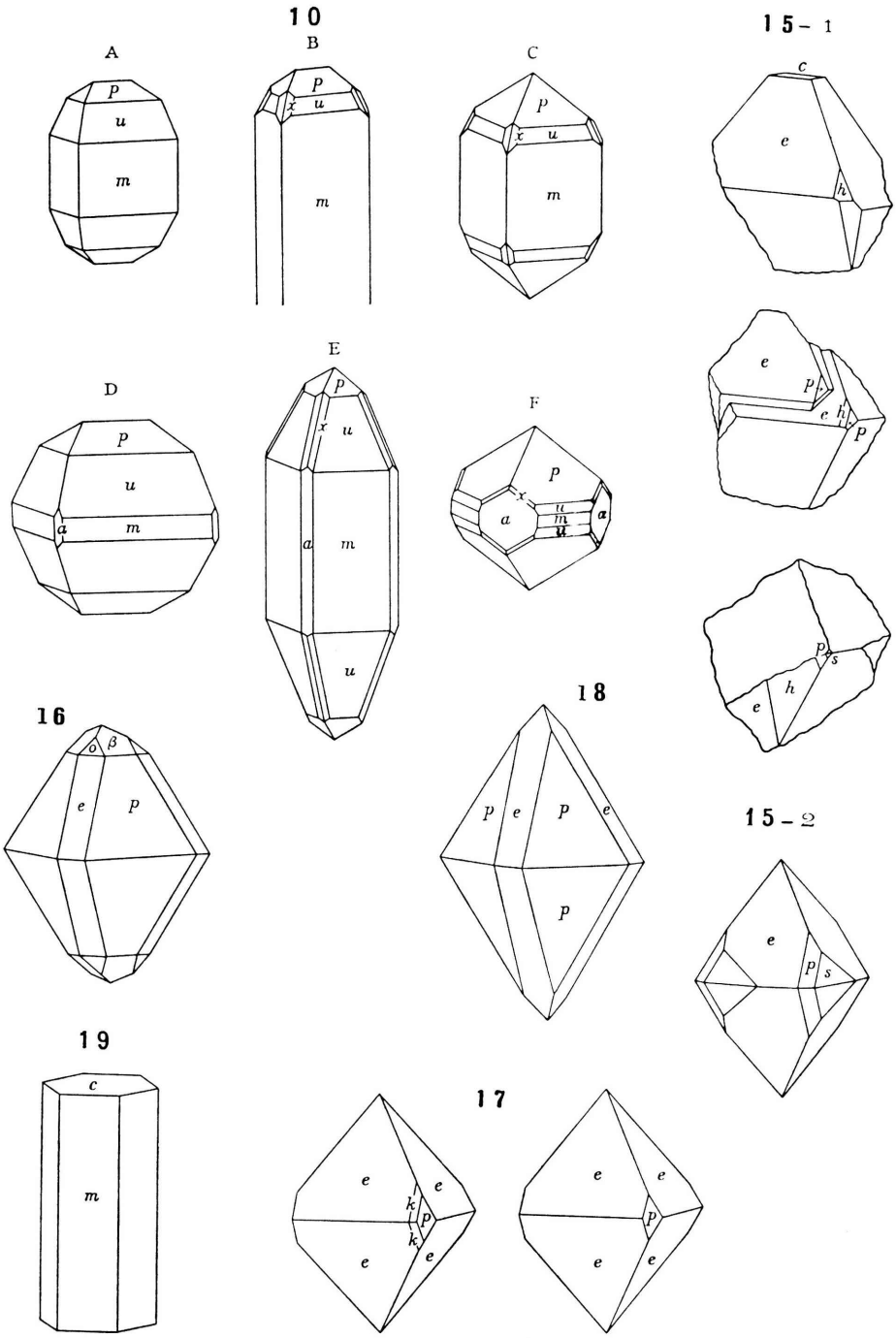

Plate 3

Fig. 10. Zircon. Talli-dong (after Y. KINOSAKI)
15. Scheelite. Taehwa Mine (1: after Z. HARADA; 2: after T. MAKINO)
16. Scheelite. Ilgwang Mine (after Y. KINOSAKI)
17. Scheelite. P'ungsu Mine (after Y. KINOSAKI)
18. Scheelite. Panggye Mine (after Y. KINOSAKI)
19. Pyromorphite. Taeryong-dong (after Y. KINOSAKI)

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Thermal Springs and Cold Mineral Springs in Korea

CHUZO KONDO

1. Introduction

A mineral spring is one whose water contains mineralized matter, gases, radioactive substances, etc. A thermal spring is not always a mineral spring. The name "mineral spring" is given to a spring in which 1 kg of water contains more than 1 g of solid matter; others are called a simple spring. According to this definition, almost none of the thermal springs in Korea may be referred to as mineral springs, but are simple springs.

As to the classification of thermal and cold springs, KOMADA[8] treated springs less than 20°C in maximum temperature as cold springs, and springs 20°C or higher in maximum temperature as thermal springs. He divided thermal springs into three groups, tepid springs (from 20°C to less than 40°C), warm springs (from 40°C to less than 70°C) and hot springs (over 70°C). According to Tokyo Hygienic Laboratory classification, however, which is widely adopted in Japan, thermal springs are separated from cold springs at 25°C. The author has adopted this classification.

We do not like to bathe in water below human body temperature, however, so from this viewpoint, tepid springs are separated from hot springs. A comfortable temperature for bathing is 40°C–45°C for Japanese. Thus, thermal springs of less than 40°C were dealt with as tepid springs, and those 40°C or higher as hot springs.

In addition, there are many springs, called "Yangsu" (medicine water), "Yŏngch'ŏn" (holy spring), "Naengch'ŏn" (cold spring), "Kamch'ŏn" (sweet spring), "Hamch'ŏn" (salty spring), "Samch'ŏn" (acid spring), "Ch'usu" (spicy water), etc., all over the peninsula. All are used mainly for drinking purpose. Some of those called "Yangsu", "Naengch'ŏn" or "Kamch'ŏn" are not special in quality, and some are mineralized so little that they are sometimes more pure than common groundwater. "Hamch'ŏn" are commonly found near the seashore, so some may contain water intruding from the sea. Some "Yangsu", which are appreciated for their iron oxide content, have their source in pyrite-bearing quartz veins, exposed in abandoned adits. Hence, the total number of cold mineral springs may be reduced if strictly examined. However, all those described as

mineral springs or "Yangsu" in the literature will be treated as cold mineral springs in this paper.

In addition, KOMADA explored the important hot springs in Korea geologically, and even carried out boring at the Tongnae and Haeundae spas. His work contributed very much to the research, enterprise, and management of hot springs in Korea, and the present author owes very much to his work also.

2. Geographical Distribution

There are 46 hot springs, with maximum temperatures above 40°C, 13 tepid springs with maximum temperatures above 25°C and below 40°C, and 30 cold mineral springs with maximum temperatures below 25°C. These are not distributed equally over the peninsula.

Hot springs are most numerous in Hwanghae-do, P'yŏngan-namdo and Hamgyŏng-pukto, while no hot springs are known in Kyŏnggi-do, Kyŏngsang-pukto, Cholla-pukto and Cholla-namdo.

Some tepid springs will be included as hot springs if they might be developed, but tepid springs known at present are most numerous in Kangwŏn-do, followed by Hamgyŏng-pukto. Also, no tepid springs are known in P'yŏngan-namdo, Ch'ungch'ŏng-pukto, Kyŏngsang-namdo, Kyŏngsang-pukto, Chŏlla-namdo and Chŏlla-pukto.

There are many cold mineral springs, named "Yangsu", all over Korea. However, as far as the literature is concerned, no cold mineral springs are known in Kyŏnggi-do, Chŏlla-namdo and Chŏlla-pukto, but many cold mineral springs are found in Hamgyŏng-pukto, P'yŏngan-namdo, Kwangwŏn-do and Kyŏngsang-pukto.

In summary, there are many hot springs and cold mineral springs in Hwanghae-do, P'yŏngan-namdo, Kangwŏn-do and Hamgyŏng-pukto. There is an abundance of hot springs in the western part of Hwanghae-do, among which many are higher than 70°C in maximum temperature. It is noteworthy that all the above provinces are also active in the mining industry.

On the contrary, there are no hot springs, tepid springs or cold mineral springs in Chŏlla-pukto and Chŏlla-namdo. These two provinces rank lowest throughout the peninsula in total number of mines also, and these two provinces are least blessed with underground resources in all of Korea. They are followed by Kyŏnggi-do and Kyŏngsang-pukto, but cold mineral springs are not so few in Kyŏngsang-pukto.

Besides, according to Shigetaro KAWASAKI,[2] there might be more hot springs than are known at present. It may be that some springs were abandoned due to the decay of post-volcanic action itself, some were choked up at their openings and some became cold due to mixing with cold water.

However, it may be interesting to note, from Korean history, that the sources of some springs were blocked artificially. There are many old tales and records

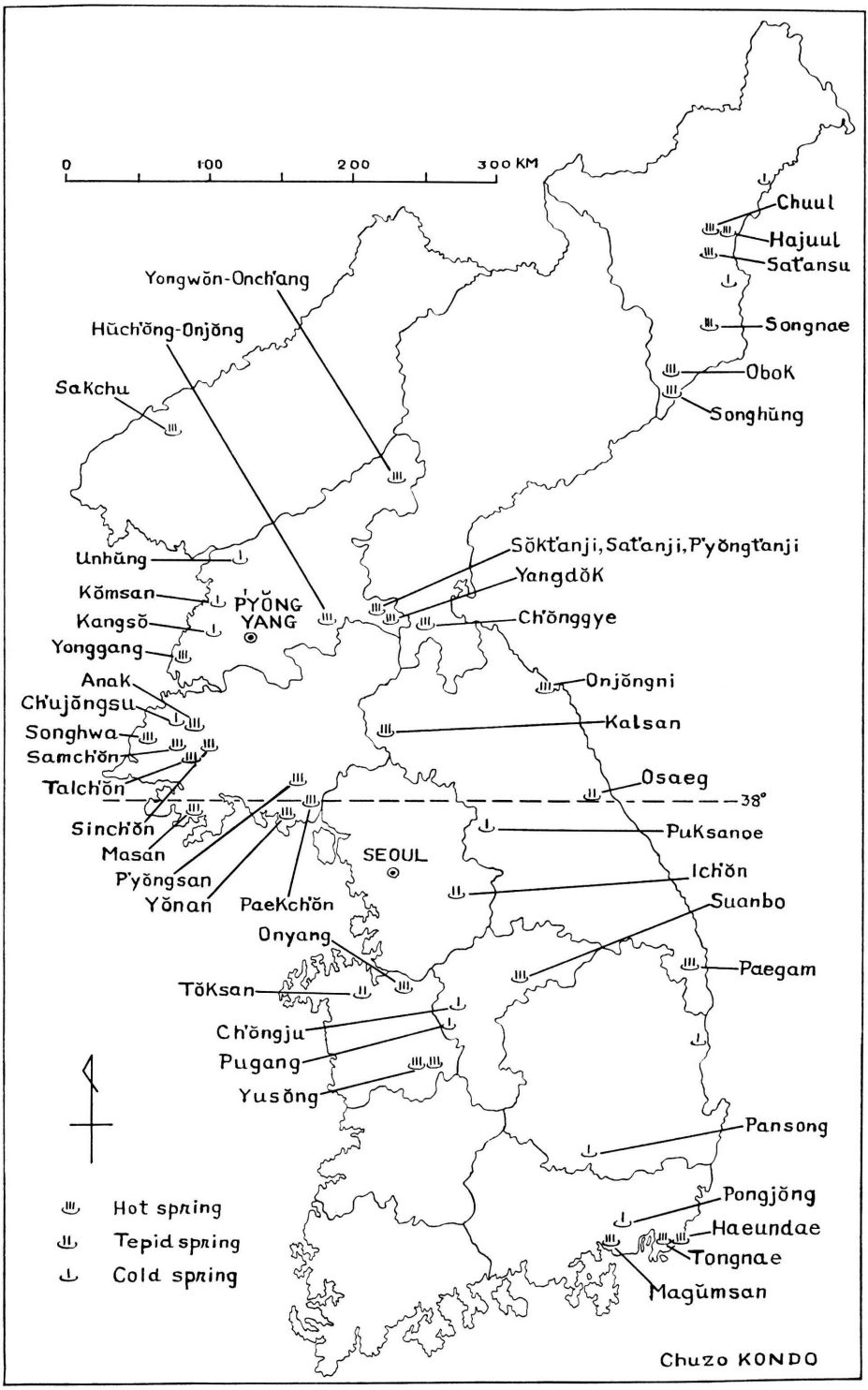

Fig. 1. Distribution of Thermal Springs and Cold Mineral Springs in Korea.

telling of *Yanban,* government officials, who came to the spas too frequently, stole drink and food from inhabitants and pressed young girls into service, so that the complaining inhabitants clogged the sources of the spring. Some records suggest that there might be a hot spring in Pup'yŏng, near Sŏul, which seems to have been clogged by inhabitants because of their complaints against officials.[17] It is also said that the exploitation of the Haeundae hot springs had been prevented for a long time for similar reasons.

3. History of Utilization

It is certain, from old records, that cold mineral springs and thermal springs were used for drinking and bathing. Hot springs of the type called "Onyang" (warm positive), "Onjŏng" (warm well), "Pich'ŏn" (boiling spring), "Tanjŏng" (hot water well), etc., seem to have been used since primitive times, especially for the treatment of pox.[2]

It is said that king of the "Shiragi" (Silla) dynasty (A.D. 500–935) often bathed in the Tongnae hot spring of Kyŏngsang-namdo, so the utilization of hot springs in Korea might have begun about 1,000 years ago. There might have been some accomodation about 400 years ago, and a pleasure resort was established about 200 years ago in Tongnae.[6]

The Onyang spa was already known in the age of "Kudara" (Paekche) (百済) (A.D. 313–663), and the Korean style bath, preserved until today, is said to have been constructed by order of "T'aejo" (太祖), the founder of the I dynasty (李朝), repaired by Prince Taewŏngun (大院君) and was used occasionally by ITaewang (李大王).[7]

All famous spas, such as Yusŏng, Sinch'ŏn, Anak, Yonggang, Onjŏngni and Chuul, seem to have begun 400 or 500 years ago. It is said that "T'aechong" (太宗) of the I dynasty (1401–1419) once bathed in the Yusŏng hot spring,[7] and also tha "Sejo" (世祖), King Hyechang (恵荘) nce ostayed where the Manryukaku hotel is at the t present time.

As already stated, Koreans have a long history of using hot springs, but they do not appreciate bathing itself. Also the people could not enjoy the natural gift of hot springs due to misgovernment.

Most famous spas of today did not have good accomodations before the annexation of Korea (1910). NAKAMURA once stated that the Paegam spa in Kangwŏn-do was installed with a comfortable bathroom and has the best accomodation among Korean style spas.[7] However, Koreans had the custom of drinking the water of thermal springs and cold mineral springs since long ago. For example, the mineral water, "Ch'usu", of Ch'ŏngju in Ch'ungch'ŏng-pukto, the most famous mineral spring in Korea, is drunk and bathed in by many persons, who come a long way, and girls enjoy washing their hair in it. Also, it is said that kings of the I dynasty, such as "Se-jong (世宗)" and "Sejo", visited there.[11]

Immediately after annexation, the Police Affairs Department of the Govern-

ment-General of Chosen began an investigation of mineral springs all over Korea and published the results twice, in 1914 and 1918.[1] Many Japanese went to Korea to advance the development of spas to bring the prosperity of today. Therefore, the majority of important spas were exploited by Japanese from the end of Meiji to the middle of the Taisho period. For instance, the Tongnae spa became such as it is today only since 1916.

4. Present State of Utilization

(1) Hot springs

Almost all hot springs are being used for bathing, but some are used only by the local inhabitants and do not even have a bath installed. Some are used only for laundry. There are 46 known hot springs in total, but only 30 of these springs are equipped with both bath and lodging houses. However, hot spas such as Tongnae, Haeuudae, Yusŏng, Onyang, Sinch'ŏn, Paekch'ŏn, Yonggang, Onjŏng-ni, Chuul and Hajuul have good accomodations as hot spring resorts and are always crowded with visitors. The Tongnae spa has best accomodations and the Onyang spa follows. Spas, such as those at Onp'ung (Sakchu), Yangdŏk, Anak, Samch'ŏn, Talch'ŏn, Songhwa, P'yŏngsan, Yŏnan, Masan, Ŏbok (Sech'ŏn), Songhŭng, Suanbo and Magŭmsan also have good accomodations and are always crowded with visitors (see Fig. 1).

In Korea, hot springs are used for bathing and drinking almost exclusively, but hot spring waters at Haeundae, Chuul, Sinch'ŏn and Paekch'ŏn are also used for heating purposes and for hot house cultivation and swimming pool facilities at Paekch'ŏn.

For bathing, tubs are usually set in seepage or winze, and framed with well-cribbing, or seepage water is led to bath tubs which are set apart. Usually no artificial means is applied to obtain water, however water is being pumped from drilled wells at Tongnae, Haeundae, Yusŏng, Sinch'ŏn, Onyang and Yonggang.

The first drilling in Korea was attempted by IWANAGA at Haeundae in 1911, and hot water (52°C or so) was found by drilling to a depth of 10 m or so. The first bore in Tongnae was made at about the same time, and at the new Yusŏng spa in 1912, and at Sinch'ŏn in 1921.

Most wells, including drilled wells, vary from 6 to 15 m in depth, and the deepest well in Korea, found at Onyang, is 93.3 m deep. However, most wells in Onyang are only several meters deep. Large scale pumping equipment is found only at Tongnae, Haeundae and Paekch'ŏn.

(2) Tepid springs

All tepid springs are used as sources of drinking water, but tepid spring water, except in the hot season, usually requires heating for bathing purposes. Hence, very few tepid springs are used for bathing, they being found only at Ichŏn in Kyŏnggi-do, Tŏksan in Ch'ungch'ŏng-namdo and Osaek in Kangwŏn-do, and

accomodations are poor except at Ichŏn. Of course, no artificial means are being used to obtain water.

(3) Cold mineral springs

Almost all cold mineral springs are utilised exclusively for drinking purposes, and some are crowded all day with people of all ages, coming great distances to drink the water in summer. The Ch'ŏngju-Ch'usu cold mineral spring in Ch'ungch'ŏng-pukto especially has been exploited by a company since 1919, and bottled water for sale under the commercial name "Crystal" has been gaining public favor since 1921.

Some cold mineral springs are used for bathing. For instance, water from the Pongjŏng mineral spring in Kyŏngsang-namdo is used for bathing after being heated. Water from the Pansong-Yangsu spring in Kyŏngsang-pukto is not only drunk as a cure for diseases of the stomach, but is bathed in as a treatment of skin diseases. Such mineral springs as the "Ch'ujŏngsu" in Sŏha-myŏn, Anak-kun, Hwanghae-do, the Kŏmsan-Yangsu in P'yŏngan-namdo, the new Kangsŏ-Yangsu in P'yŏngan-namdo, "Yangsu" in Hwangim-myŏn, Yonggang-gun, P'yŏngan-namdo and "Yangsu" in Puksanoe-myŏn, Ch'unch'ŏn-gun, Kangwŏn-do are all used for bathing. None of these, however, have good accomodations and the baths resemble a vapour bath.

In addition, water from the Unhŭng-Yangsu spring in Anju-gun, P'yŏngan-namdo is used for treating of eye diseases and worms.

5. Geology

Hot springs of Korea differ strikingly from those of Japan in geologic features, the majority occurring in alluvial plains, and gushing out from alluvial deposits of sand, gravel and mud. Only springs at Masan, Suanbo, Yangdŏk and Chuul form exceptions.

There are many springs where the bedrock is unknown. But bedrocks which yield springs are, in general, composed of acidic intrusive rocks such as granite-gneiss, granite, granite-porphyry, quartz-porphyry, felsophyre, etc.; granite is especially common. For example, the bedrock at the Tongnae spa consists of a batholith of granite crossed by biotite-felsophyre. The Onyang spa is composed of porphyritic biotite-hornblende granite, older than deposits of the Lower Jurassic system. The environs of the new Yusŏng spa is composed of gray two-mica granite, intruded in the Okch'ŏn system and traversed by both quartz-porphyry and biotite granite. The hot spring at Yangdŏk flows out of granite. Most hot springs in the western part of Hwanghae-do gush out from granite or injection-gneiss. Many of the hot springs in Hamgyŏng-pukto are in a granite-gneiss region. In the vicinity of the Haeundae spa, both pyroxene porphyrite of the Silla series and hornblende-biotite granite of the Pulgukksa series (which traverses the former) occurs, but thermal water is obtained only from the dike or neck of granite.

As stated above, the majority of hot springs in Korea occur in granitic rocks, but the bedrock is usually traversed by other acidic rocks, as seen at Tongnae and Yusŏng. In the Tongnae spa, the area of high water temperature appears as an ellipse elongated from north to south, and the portion having an especially high temperature is found near the west boundary between granite and felsophyre, intruded in the former, and the shape roughly follows that of the felsophyre core.[6] The granite in the Onyang spa is traversed by pegmatites, and thermal water gushes out from fissures of both granite and pegmatite. Judging from the underground temperature distribution, the thermal water of the Paekch'ŏn spa is thought to have some relation to pegmatite.[12, 13]

NAKAMURA once pointed out the close connection between hot springs and the presence of tungsten and molybdenum ore.[16] Indeed, there are many tungsten and molybdenum mines in Mt. Kŭmgang near the Onjŏng-ni hot spring. The Santoku (Samdŏk) molybdenum mine was located near the Suanbo spa. Tungsten ore deposits are found north of the Ch'ŏnggye hot spring in Hamgyŏng-namdo, and the Pugang cold mineral spring is in a tungsten ore-producing area.

As already stated, the two provinces, Chŏlla-pukto and Chŏlla-namdo, which are least blessed with mineral resources in all Korea, also lack any hot, tepid or cold mineral springs.

Hot springs in Korea are not related to volcanoes, except for one or two in the vicinity of Mt. Paektu. In Hamgyŏng-pukto, younger volcanicr ocks such as basalt and trachyte predominate, nevertheless hot springs are rather more numerous in granite regions than in volcanic rock regions. Hence, most hot springs in Korea are related to magmatic intrusions, and are intimately connected with acidic intrusive rocks. The age of formation is thought to be the pre-Tertiary period. As the surface of the earth becomes more deeply eroded, the possibility of discovering new hot springs will increase.

In most hot springs which flow out on alluvial plains, however, both temperatures and yields usually increase with rainfall. Accordingly, it is certain that rain water feeds the alluvial deposits of thermal water.

The majority of cold mineral springs have not yet been investigated geologically, but the mineral spring of Ch'ŏngju in Ch'ungch'ŏng-pukto gushes out from fissures in both biotite granite and quartz-porphyry. The Pugang mineral spring in Ch'ungch'ŏng-pukto flows from a dike of biotite granite traversing gneiss. The geology of cold mineral springs seems similar to that of hot springs. Therefore, most cold mineral springs may be cooled hot springs.

Sometimes, however, no igneous rock is found in the vicinity of hot springs. For example, the Masan hot spring district is composed of garnet-bearing altered rocks, mica schists and breccia, and thermal water gushes out from the breccia. The Suanbo spa consists of calcareous clayslate and grayish-white limestone in alternation, dark-brown sandstone and dark-brown sandyslate, all belonging to the Okch'ŏn system; thermal water flows out from fissures in the sandstone.

6. Geologic Structure and Horizontal Distribution of Water Temperature

Hot springs are usually related to geologic structures such as faults, fissures, etc., in the district concerned, and hot springs in Korea are generally distributed in the directions, east to west, north to south, or close to these two directions, suggesting their intimate relation to geologic structures. Two predominant tectonic lines are known in the peninsula; one is the Sinian direction, running from ENE to WSW, and the other is the Korean direction, going from NNW to SSE.

First, looking over those in the east-west direction or in a direction close to it, one finds the Yusŏng hot springs and the new Yusŏng hot springs, which run east to west. The isothermal lines of ground water temperature in the new Yusŏng spa extend from east to west, and major fissures predominate in the same direction; the thermal water is thought to gush out from these fissures, or from a dike running east to west. In the Sinch'ŏn spa, thermal water can be obtained by drilling less than 100 m below the surface only within an elliptical area, elongated from ESE to WNW, 360 m in major axis and 75 m in minor axis. The sources of the Chuul spa are located within an area 285 m long from ENE to WSW, and 52 m long from NNW to SSE, and concentrated in the WSW portion. Those of the Suanbo spa are distributed over an area 60 m long from east to west, and 40 m long from north to south.

The other direction, from north to south, on the other hand, is also important. The Tongnae spa is located in a fault valley, running close to the north-south direction, and the isothermal lines of underground temperature at a depth of from 6 to 9 m below the surface form an elliptical shape, elongated from north to south; the area, enclosed by isothermal line of 45°C 118 m in major axis and 94 m in minor axis, is 9,311 m^2. The Masan hot springs occur in an area 20 m east to west and 60 m north to south. In Hamgyŏng-pukto, there is a big fault running from Kyŏngsŏng-gun to Songjin through Myŏngch'ŏn-gun, north to south, and many springs occur in a zone along this fault.

The Onyang hot springs are distributed over an area 100 m long from east to west and 80 m north to south, but two major zones are found within this area. One runs nearly north to south and yields thermal water of 43°C, while the other extends from ESE to WNW and yields thermal water of from 42°C to 50°C. These two zones are probably related to either fault lines or dikes. The Onjŏngni hot springs occur at the junction of two valleys, and are thought to gush out at the intersection of two geotectonic lines; springs are distributed linearly NW to SE for 42 m.

Furthermore, looking over the distribution of thermal springs (see Fig. 1), a major zone, extending NNW-SSE from the western portion of Hwanghae-do to the eastern portion of Kyŏngsang-namdo through the eastern part of Ch'ungch'ŏng-namdo, is thought to exist. The zone involves the very hot springs of Hwanghae-do, hot and tepid springs of Ch'ungch'ŏng-namdo, mineral springs

of Ch'ungch'ŏng-pukto and hot springs of Kyŏngsang-namdo. The existence of such a zone is supported by a depression in the sea east of Kyŏnggi-do

Moreover, two thermal springs zones are thought to exist in a ENE-WSW direction from the southern extremity of Hamgyŏng-namdo to the south-western corner of P'yŏngan-namdo, and from the southern extremity of Kangwŏn-do to the northern part of Ch'ungch'ŏng-namdo.

7. Supply

Almost all hot springs in Korea, which gush out from Quaternary deposits, have a constant supply, which is not active usually. The pressure head of thermal water at the Chuul hot spring is 2 m above the surface, and the thermal water at Sinch'ŏn, Yonggang, etc., flows out above the surface, but most hot springs in Korea are under too low pressure to flow out above ground, so where no pumps are available, baths are usually set 2 to 3 m below the surface.

Supply, therefore, is usually small and the maximum supply is 10,000 koku per day (330 gallons per min) or so at the Chuul hot springs or the Sinch'ŏn hot spring, where supply is greatest throughout Korea. At the Tongnae hot springs, the maximum yield of one well is only 160 koku per day (5.29 gpm), so the total supply is estimated at 2,500 koku per day (82.7 gpm) or so. At the Onyang spa, some well yields 4,900 koku per day (162 gpm), but the main well yields only 200 koku per day (6.6 gpm). At the Haeundae spa, the supply rarely exceeds 100 koku per day (3.3 gpm) or so, and is usually less than 50 koku per day (1.65 gpm) per well and 320 koku per day (10.6 gpm) in total.

In general, when rainfall is high, yield increases and temperature rises also, and when the atmospheric pressure is low, supply increases. Supply is generally greater in July and August than at other time thoughout the year. According to KOMADA, the pressure head changes about 3 cm or so per 10 mm of atmospheric pressure, and the supply increases as the head rises in the Tongnae spa.

8. Temperatures of Spring Waters

The temperatures of hot springs and cold mineral springs in Korea range from 5°C (cold springs) to 94°C (hot springs).

The hot springs, with maximum temperatures over 40°C, number 46, among which very hot springs, 70°C ormore, number only 10 (Masan (94°C), Paekch'ŏn (89.5°C), Talch'ŏn (80°C), Sat'ansu (80°C), Sŏkt'anji and Sat'anji (80°C), P'yŏngt'anji (76°C), Anak (75°C) P'yŏngsan (75°C), Yŏnan (74°C), and Songnae (70°C)). It is noteworthy that most very hot springs are concentrated in the western half of Hwanghae-do. Those 60°–70°C in temperature number only 10 also, and the majority of hot springs run from 40°C to 60°C. The temperatures of hot springs in Korea are generally not too high then, and most springs belong to the warm spring group of KOMADA.

Most tepid springs run from 35°C to 39°C and 8 out of a total of 13 springs are included in this range.

As for cold mineral springs commonly called "Yangsu", there are many whose temperatures are unknown. However, the temperatures of cold mineral springs generally vary from 10°C to 13°C, although some change with the season. According to observations made at Ch'ongju-Ch'usu from 1912 to 1917, the water temperature varies from 10°C to 16°C, and is controlled by rainfall to some degree, but is hardly affected by the season, and commonly varies from 14°C to 15°C and is always higher than the average air temperature in the district.[10]

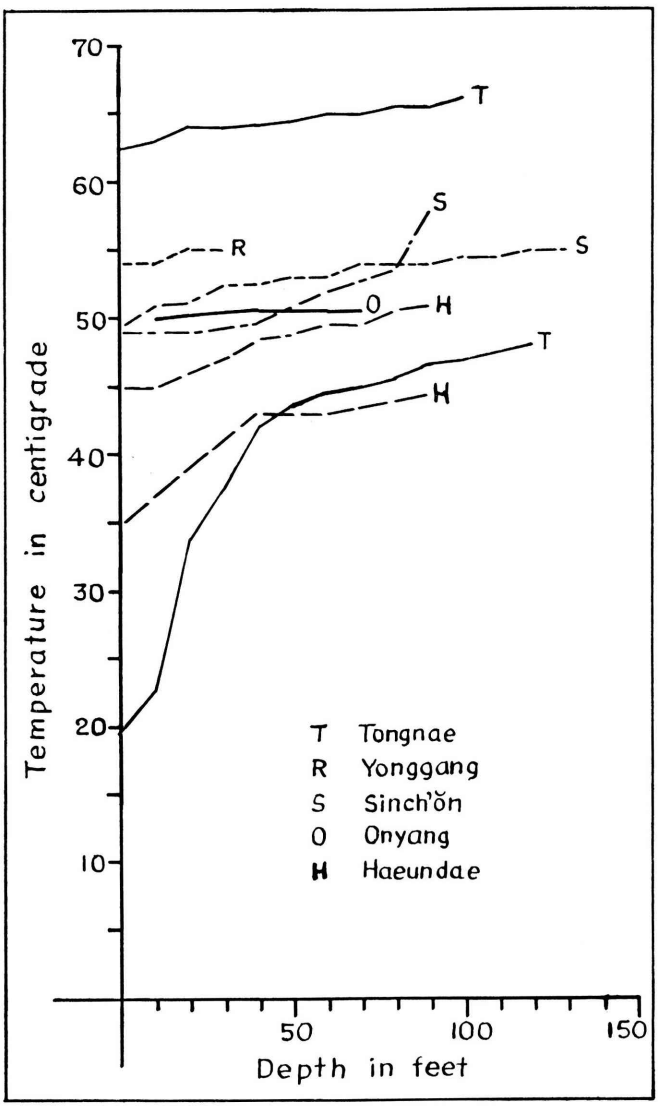

Fig. 2. Geothermal Gradients.

Geothermal gradients in general show no remarkable changes in hot spas in Korea (see Fig. 2). At the Tongnae spa, the underground temperature usually increases from 0.2°C or 0.3°C to several degrees, rarely more than 10°C, at a depth of 3–6 m and rarely 9 m or so below the surface. These depths are equal to the thickness of the Quaternary formation there, which may indicate that the underground temperature is affected by aquifers in the Quaternary formation at these depth. If one bores into the bedrock, the underground temperature increases with depth, but the geothermal gradient is rather small, and even if a bore is sunk very deeply, a remarkable rise in temperature is not expected. This may be due to the fact that the heat source is intrusive material, which are situated far below the surface. Some wells at the Tongnae spa, however, show a decrease in temperature at a depth of from 12 m to 18 m below the surface, and then temperatures decrease with depth. This is due to the fact that the thermal water comes from fissures in the bedrock. There are two groups of hot springs at the Tongnae spa.

The horizontal distribution of underground temperature is as transitive as the vertical distribution is and the change in temperature is generally greater horizontally. In short, hot springs in Korea have the horizontal distribution of temperatures, elliptical or elongated elliptical. However, hot springs sometimes occur in a linear distribution.

At the Tongnae spa, the supply increases and temperature rises with rainfall. At the Onjŏngni spa, on the other hand, the temperature decreases with rainfall. Variation in temperature is generally greatest in July and August. This may indicate meteoric water to be one source of thermal water. At the Onyang spa, however, the temperature of thermal water seems to be independent of rainfall.

9. Quality of Spring Water

A. Hot springs

The water of hot springs in Korea is colorless, transparent and odorless, but classified into two according to taste, i.e., salty and tasteless. The former includes the majority of hot springs in Korea, and Tongnae, Haeundae, Anak, Yonggang, Onjŏngni and Masan comprise this group; they are neutral at normal temperature but become alkaline if boiled. The latter are weakly alkaline even at normal temperatures, and the alkalinity increases with boiling. This group is comprised of the Yusŏng, Sinch'ŏn, Onjŏngni, Chuul, Hajuul and P'yŏngsan springs. The thermal water of the Onyang hot springs is slightly salty, but belongs to the latter group. Among the above, the thermal water of Sinch'ŏn is the strongest in alkalinity throughout Korea.

We know very little about the chemical composition of thermal water from Korea, but it is known that the total amount of solute contained in 1 kg of thermal water is generally very small, being more than 1 g at only 4 hot springs (Tongnae, Haeundae, Yonggang and Masan). The greatest concentration (26.3417 g) is at the Yonggang hot springs, but the other springs contain 5 g or less (at Tongnae,

only 1.077 g). Excluding the above, most hot springs contain less than 0.5 g of total solid and are not classed as mineral springs, but as simple springs. All hot mineral springs are included in earth-chloride-bearing common salt springs, and there are only 3 quality classifications for hot spring water in Korea.

(1) Earth-chloride-bearing common salt hot springs

These springs contain over 1,000 mg of solid per 1 kg of water, with Cl^- anions and Na^+ cations as the principal constituents which together form common salt. The content of common salt is greater than 5,000 mg but less than 15,000 mg. The water also contains large amounts of Ca^{++} ion which forms $CaCl_2$, $MgCl_2$ and KCl. Only Yonggang belongs to this type.

(2) Earth-chloride-bearing weak common salt hot springs

Springs of this type are similar to the preceding ones, and differ only in their content of common salt, which is less than 5,000 mg. Masan, Tongnae and Haeundae belong to this type. However, the thermal water at Masan is richer in $MgCl_2$ and poorer in $CaSO_4$ than at the Tongnae and Haeundae springs.

(3) Simple hot springs

This type includes those in which the contents of both free carbonic acid and solid are less than 1,000 mg per 1 kg of water, and all remaining springs belong to this group. Simple springs are sub-divided into the following three groups on the basis of their principal ingredients.

a. *Alkaline simple hot springs*: The principal ingredients are hydro-carbonic acid anions and Na^+ cations, which combine to form sodium bicarbonate. The Onyang, Chuul, Onjŏngni, Pyŏngsan, Yusŏng and Suanbo springs belong to this group.

b. *Common-salt-bearing alkaline simple hot springs*: A considerable amount of Cl^- ion is added to the former. Only Sinch'ŏn belongs to this group.

c. *Alkaline common-salt-bearing simple hot springs*: The principal ingredients are Cl^- anions and Na^+ cations, which combine to form common salt, and a remarkable amount of hydrocarbonic acid ion is also contained. Only Anak belongs to this group.

As stated above, highly mineralized hot springs in Korea are included in common salt springs, and dilute hot springs are mostly alkaline simple springs.

In addition the Kalsan hot spring in Kangwŏn-do is said to be a simple alkaline carbonated spring, and there are some hot springs described as sulphuric acid springs or sulphurous springs,[1)] but these are not certain.

B. Tepid springs

The most mineralized of the tepid springs is the Osaeg-Yangsu spring at Koraegok, Sŏ-myŏn, Yangyang-gun, Kangwŏn-do, but the total solid content is only 2,104.0 g per 1 kg of water. Hence, tepid springs in Korea are dilute, too. These are classified into three groups, weakly alkaline carbonated springs, common salt springs and simple springs. Among these three groups, simple springs predominate. There are additional springs, cited as sulphurous springs, but very little is known among them.

C. Cold mineral springs

Cold mineral springs have not yet been investigated thoroughly, but as already stated, many of the "Yangsu" should be included as simple springs. Some, however, are described as carbonated springs, iron springs and vitriol or sulphurous springs. Most of the water from these springs is tasteless and odorless, but the mineral water of the Pongjŏng mineral spring in Kyŏngsang-namdo is brownish yellow, like Japanese "Sake", transparent, strongly acidic and has both an acidic taste and a characteristic stimulating odor. Some are colorless and odorless, but cloudy due to light yellowish-brown colored floating matter. The famous mineral springs, represented by the Ch'ŏngju-Ch'usu spring at Ch'ungch'ŏng-pukto and the Ch'ujŏngsu spring in Sŏha-myŏn, Anak-gun, Hwanghae-do, however, are carbonated springs, and most of them contain iron, and taste bitter to some degree.

The mineralized water of Ch'ŏngju is colorless, transparent and odorless, and its taste is refreshing and stimulating. It is acidic at normal temperatures but becomes alkaline if boiled, and is a simple carbonated spring containing neither iron nor alumina. It is of rare good quality as a refreshing drink.

In addition, the Ch'ongju-Ch'usu spring has a 60 mache Radon content, the greatest throughout Korea. It is followed by the Onjŏngni hot spring, which varies from 40 to 44 mache. These are included as radioactive springs of a low grade, and are followed by the Yusŏng and Haeundae hot springs, which are 28 and 25 mache respectively. Other springs are less than 10 mache in Radon content.

Table 1. Table of Hot Springs and Cold Mineral Springs.
Hot Springs

Names	Location			Quality	Maxim. temperature (°C)	Yield (koku/day)
	Myŏn or Ŭp	Gun	Do			
1. Tongnae	Tongnae	Tongnae	Kyŏngsang-namdo	Earth-chloride-bearing weak common salt	51–69	2,500
2. Haeundae	Nam	do.	do.	do.	54–66	320
3. Magŭmsan	Puk	Ch'angwŏn	do.	Common salt-bearing simple	42.5	
4. Onyang	Onyang	Asan	Ch'ungch'ŏng-namdo	Alkaline simple	50.5–54	
5. Yusŏng	Yusŏng	Taejŏn	do.	do.	50–57	
6. Suanbo	Sangmo	Koesan	Ch'ungch'ŏng-pukto	do.	45.5–51	
7. Onjŏng-ni	Sinpuk	Kosŏng	Kangwŏn-do	do.	45	6,700
8. Sangdŏkku	Puk	Ulchin	do.		40	
9. Paegam	Onjŏng	do.	do.	Alkaline simple	46	1,000
10. Kalsan	Pangjang	Ich'ŏn	do.	Alkaline simple carbonated	46	
11. Yŏnan or Kŭmsŏng	Onjŏng	Yŏnbaek	Hwanghae-do	Earth-bearing alkaline	70–74	
12. Paekch'ŏn	Ŭnch'ŏng	do.	do.	Simple sulphurous	89.5	
13. P'yŏngsan	Chŏgam	P'yŏngsan	do.	Alkaline simple	55.0	2,300
14. Masan	Masan	Ongjin	do.	Earth-chloride-bearing weak common salt	94.0	
15. Songhwa	Yŏnjŏng	Songhwa	do.	Alkaline simple	46.0	100
16. Yongch'ŏn	Kunghŭng	Sinch'ŏn	do.	Simple	53	
17. Samch'ŏn	do.	do.	do.	Simple sulphurous	59–62	40

18. Yongch'ŏn	do.	do.	do.		53	
19. Sinch'ŏn	Onch'ŏn	do.	do.	Common salt-bearing simple	58	10,000
20. Talch'ŏn	Ch'ori	do.	do.	Simple sulphurous	53–80	100
21. Anak	Ŭnhong	Anak	do.	Simple	72–75	
22. Yonggang	Haeun	Yonggang	P'yŏngan-namdo	Earth-chloride-bearing common salt	55	1,000
23. Yongt'aek	Yŏngch'ŏn	Sŏngch'ŏn	do.	Simple	46.5	400
24. Yŏngwŏn-Onch'ang	Onhwa	Yŏngwŏn	do.	Sulphurous	60	2,592
25. Sat'anji and Sŏkt'anji	Onch'ŏn	Yangdŏk	do.	Carbonated	80	500
26. P'yŏnt'anji	do.	do.	do.	do.	76	200
27. Yangdŏk	Kuryong	do.	do.	Simple	53–55	
28. Sot'anji	do.	do.	do.	Carbonated	45	100
29. Onjŏng	Sinp'ung	Hŭich'ŏn	P'yŏngan-pukto	Sulphurous	43–50	70
30. Onjŏng or Ch'umogwŏn	Ŭiyon	Unsan	do.	Simple	44–56.5	
31. Onp'ung or Sakchu	Sakchu	Sakchu	do.	Simple	59–61	
32. Onjungdong	Kunnae	do.	do.		56	120
33. Myŏnghwa-dong or Pohye	Pohye	Kapsan	Hamgyŏng-namdo	—	38–41.5	
34. Nokkaktŏng-ni Hamsu	Puk	Changjin	do.	—	65	20
35. Ch'ŏnggye	P'ungha	Tŏgwŏn	do.	Common salt-bearing simple	60	50
36. Yangsup'o	Wiing	Anbyŏn	do.		46	72

37. Chuul	Chuulon	Kyŏngsŏng	Hamgyŏng-pukto		44–56.5	10,000
38. Hajuul or Kaneta	do.	do.	do.		53	300
39. T'angjisu	do.	do.	do.	Alkaline	50	100
40. T'ansu	Chunam	do.	do.	Alkaline saline	60	720
41. Sat'ansu	do.	do.	do.	do.	80	700
42. T'an	do.	do.	do.		60	
43. Songhŭng	Haksang	Sŏngjin	do.	Alkaline	52	1,173
44. Ŏbok or Sech'ŏn	Haksŏ	do.	do.		68	
45. Songnae	Yŏngbuk	Kilchu	do.		70	14
46. Sanggo	Sanggo	Myŏngch'ŏn	do.		Cold water to be added for bathing	150

Tepid Springs

Name of spring	Location			Quality	Temperature (°C)	Yield (koku/day)
	Myŏn	Gun	Do			
1. Ich'ŏn	Ŭmnae	Ich'ŏn	Kyŏnggi-do	Simple	31.5	
2. Tŏksan	Tŏksan	Yesan	Ch'ungch'ŏng-namdo	Common salt-bearing simple	36	
3. Unhang and Songjŏng	Pangjyang	Ich'eon	Kangwŏn-do	—	—	
4. Osaeg-Yangsu	Sŏ	Yangyang	do.	Common salt and alkaline carbonated	35	
5. Kalsan-Yangsu	do.	do.	do.	Carbonated	35	
6. Chogae-Yangsu	do.	do.	do.	do.	35	
7. Yujŏm-sa	do.	Kosŏng	do.	—	26	
8.	Sinam	P'yŏngsan	Hwanghae-do	—	28	
9. Onjŏng or Onhwa	Changdong	Hŭich'ŏn	P'yŏngan-pukto	Sulphurous	39	20
10. Majang	Inhŭng	Yŏnghŭng	Hamgyŏng-namdo	Weak common salt	38	
11.	Oha	Musan	Hamgyŏng-pukto	—	35.6	300
12.	Yongsŏng	Kyŏngsŏng	do.	Alkaline	38	50
13.	Changbaek	Kilchu	do.	—	Less than 35	

Cold Mineral Springs

Name of spring	Location			Quality	Temperature (°C)	Yield (koku/day)
	Myŏn	Gun	Do			
1. Ponjŏng	Punae	Changwŏn	Kyŏngsang-namdo	Vitriol		20
2. Pansong-Yangsu	Okp'o	Talsŏng	Kyŏngsang-pukto			17
3. Kilch'on-Hwangsu	Kilch'on	Yŏngch'ŏn	do.	Sulphurous		5
4. Wŏlha-dong Yangsu	Ch'ŏngsŏng	Ch'ŏngsŏng	do.	Alkaline	13	7.8
5. —	Puhae	Yŏngdŏk	do.	Iron		15
6. —	Ch'angsu	do.	do.	do.		5
7. Ch'ŏngju -Ch'usu	Pugil	Ch'ŏngju	Ch'ungch'ŏng -pukto	Carbonated	14–15	
8. Pugang	Puyong	do.	do.	Iron-bearing carbonated		
9. —	Togo	Asan	Ch'ungch'ŏng-namdo			
10. —	Yŏngok	Kangnŭng	Kangwŏn-do		12	0.7
11. —	Puksanoe	Ch'ungch'ŏn	do.		18	
12. —	Inje	Inje	do.			
13. —	Nae	do.	do.			
14. Kappi	Kop'yŏng	Taedong	P'yŏngan-namdo	Iron		
15. Kŏmsan-Yangsu	Kŏmsan	P'yŏngwŏn	do.	Carbonated		
16. Kangsŏ new	Tongjin	Kangsŏ	do.	do.	10	100
17. Kangsŏ old	Kangsŏ	do.	do.	do.	5	

18. —	Sŏngdae	Kangsŏ	do.	do.		
19. Yonggye-ni Yangsu	Sinanju	Anju	do.			0.2
20. Yongyon	Chunae	do.	do.			1.5
21. Unhŭng	Tong	do.	do.			100
22.	Aejŏn	Maengsan	do.	Simple	20	
23.	Hwangim	Yonggang	do.	Common salt		
24. Kungdong iron	Chiun	do.	do.	Vitriol		3
25. Sŏjŏng-ni iron	Samhwa	do.	do.	do.		12
26. Ch'ujongsu	Sŏha	Anak	Hwanghae-do			
27. Sŏgwang-sa	Munsan	Anbyŏn	Hamgyŏng-namdo	Carbonated		1
28. Okp'ok	Hamusan	Puryŏng	Hamgyŏng-pukto		24	
29.	Samchang	do.	do.		22.8	
30.	Pujŏm	do.	do.			

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MANCHURIA

Summary of Physiography of Manchuria

Riuji ENDO

1. Outline

At first sight of the general physiography of Manchuria, the mountain systems seem to trend in all directions. Careful observation reveals, however, that the mountain systems can be divided into two regular groups which trend, NE-SW and NW-SE.

The NE-SW trend was named the Sinian direction by R. PUMPELLY in 1866. The mountains along this direction include the Great Khingan Range in the west extending from Jehol Province to Khingan Province, and the Chang-pai Mountains in the east near the border between Manchuria and Korea. The northern extension of the Changpai Mountains constitutes the Wan-ta Mountains which form the axis of Mu-tan-chiang and Tung-an Provinces, and the southern extension forms the backbone range of the Liao-tung Peninsula. In addition to these two great mountain systems, there are the Sa-ha-liang and Lao-chang-kuang-sui-ling Mountains, running west of, and parallel to, the Chang-pai Mountains. They constitute the central mountain region found in Feng-tien and Kirin Provinces. On their west, and also parallel, runs the Ta-hei-shan Mountains along the Chang-chun～Ta-lien Railway. Other mountain systems of the Sinian direction are the Sung-ling, Ta-ching-shan and Ling-yuan Mountains stretching roughly parallel to, and west of, the Feng-shan Railway.

The other trend, NW-SE, was named the Korean direction by Bunjiro KOTO in 1930. This trend is represented by the Small Khingan Range that runs along the Hei-lung-chiang River in the northern part of East Khingan Province and along the border between Hei-ho and Pei-an Provinces. Other mountains of the Korean direction are the Chi-lao-tu and Yen-shan Mountains, running roughly parallel to the Great Wall of China in the southern part of Jehol Province, and the so-called Hei-laio Divide, which is undulating hilly land dividing the Laio-ho and Hei-lung-chiang Rivers.

In the structural geology of Manchuria, there is one notable fact. The Sinian direction roughly coincides with the strikes of formations that constitute the mountains, but the Korean direction is not followed by these mountain ridges. Although

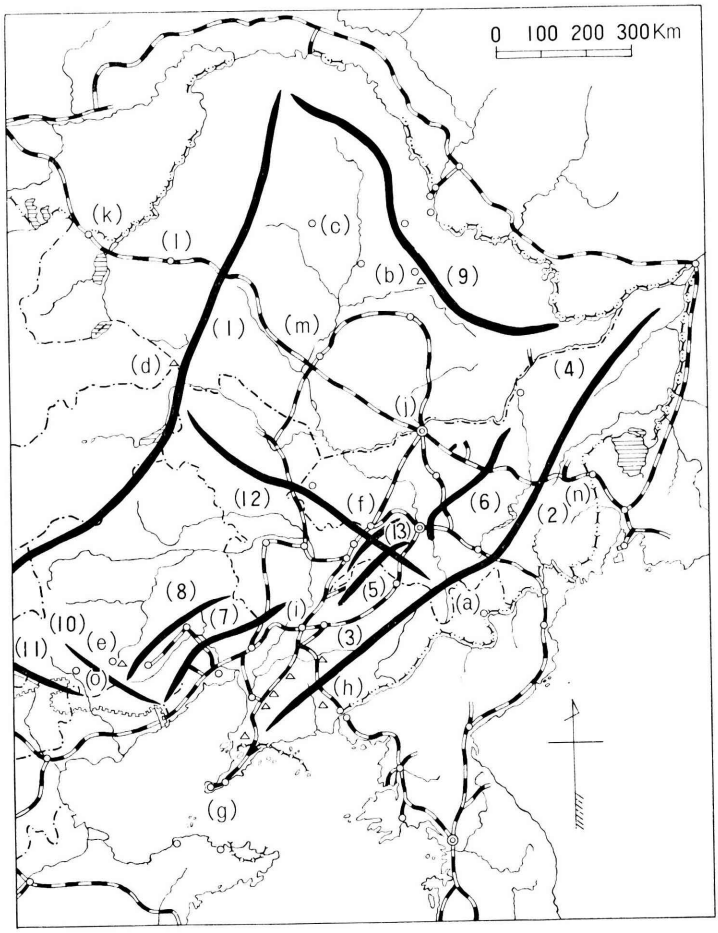

Fig. 1. Outline of Physiography of Manchuria.

1. Great Khingan Range
2. Chang-pai Mountains
3. Backbone mountain range of Liao-tung Peninsula
4. Wan-ta Mountains
5. Sa-ha-liang Mountains
6. Lao-chang-kuang-sui-ling Mountains
7. Sung-ling Range
8. Ling-yuan Range
9. Small Khingan Range
10. Chi-lao-tu-shan Range
11. Yen-shan Range
12. Hei-liao Divide
13. Ta-hei-shan Mountains

a. Pai-tou Volcano
b. Wu-ta-lien-chih Volcanic Group
c. Shatir Volcano
d. Harhin Volcano
e. Wan-pao-shan Volcano
f. Chang-chun
g. Ta-lien
h. An-tung
i. Mukden (Feng-tien)
j. Harbin
k. Man-chou-li
l. Hailar
m. Chi-chi-ha-erh
n. Sui-fen-ho
o. Jehol

the general trend of the mountain systems follows the Korean direction, the ridges have a different trend, NE-SW. This indicates that the formations constituting these ridges strike in the Sinian direction. This is a very important fact in considering the tectonic structure of Manchuria.

Of the above mountain ranges, the Great Khingan Range is remarkable in character. From the train travelling from Man-chou-li to Sui-fen-ho on the China-U.S.S.R. border via Ang-ang-chih and Harbin, one notices the following topography: Between Man-chou-li and Hailar a plateau-like, 500~600 m elevation is predominant, but advancing eastward the altitude increases gradually, finally attaining 900 m above sea level at Khingan, a station located in the Great Khingan Range. Farther east, the railroad runs down a steep slope and reaches Nien-tzu-shan where the altitude is 300 m, and then enters the great plain drained by the Nen-chiang and Sungari Rivers. Ang-ang-chih, An-ta and Harbin are the cities scattered in this vast plain. Eastward from the vicinity of I-mien-po the altitude begins to increase again, as in the passage over the Great Khingan Range. West of Heng-tao-ho-tzu, the railroad crosses the Lao-chang-kuang-sui-ling Mountains, and near Hai-lin enters a basin 200 m above sea level. Toward the end of this basin the altitude rises for the third time and reaches about 600 m in the vicinity of Mu-leng, then gradually drops eastward down to a basin 300 m above sea level. At Tai-ping-ling, an increase in altitude is noticed for the fourth time. The railroad crosses another basin east of Tai-ping-ling, and nears the station of Sui-fen-ho where the elevation is recorded at 400 m. East of the station lies a lowland.

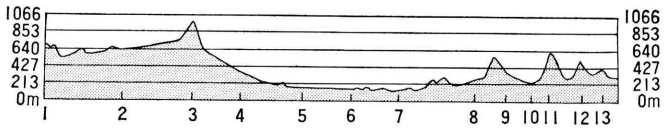

Fig. 2. Outline of the Physiographic Profile along the Pin-chou and Pin-sui Lines.

1. Man-chou-li 2. Hailar 3. Khingan 4. Nien-tzu-shan
5. Ang-ang-chih 6. An-ta 7. Harbin 8. I-mien-po
9. Heng-tao-ho-tzu 10. Hai-lin 11. Mu-leng 12. Tai-ping-ling
13. Sui-fen-ho

The topographic features seen along the North Manchurian Railway in the east-west section are found also in the southern part of Manchuria. Consequently, the Great Khingan Range is suitably named only when viewed from the east. When viewed from the west, the range appears to be no more than hilly land rising from a plateau.

According to F. von RICHTHOFEN, the above characteristic topography of Manchuria can be explained by assuming the presence of three great faults running NE-SW. When this assumption is applied to the physiographical facts presently known, a close similarity will be noticed between Manchuria and northern apan. TheJ Mongolian block and the Manchurian block are bounded on the east

by the Great Khingan Range and the Chang-pai Mountains, respectively, and the slopes of both ranges are gentle on the west and steep on the east. Thus, his view is quite reasonable from the standpoint of modern physiography, too.

Khingan Province and part of Jehol Province are in the plateau-like hilly land on the west slope of the Great Khingan Range. The region, dotted with sand dunes and grassland covered by aeolian sand, serves as grazing land. Salt lakes and vanishing rivers are found everywhere. There are two large lakes, Dalai (or Hu-lun) Lake and Bayer Lake. The water-storage area of the former lake is 300～400 km², half the area of the latter. The depth of water is 9 m in both lakes.

The area between the eastern foot of the Great Khingan Range and the Chang-chun～Ta-lien Railway is a plain of unlimited expanse, drained by three large rivers, the Nen-chiang, Sung-hua-chiang (Sungari) and Liao-ho. This great plain abounds in salt lakes and alkali earth. A chain of rolling hills stretches NW-SE in the center of the plain, and constitutes a divide separating the Hei-lung-chiang and Liao-ho River systems. This divide was named the Hei-liao Divide by Kunitaro NIINOMY. According to NIINOMY, the Hei-laio Divide was formed after the Pleistocene Epoch of the Quaternary Period, and by this divide the Nen-chiang and Liao-ho Rivers, which were previously one, were formed; the former became the Sung-hua-chiang River in the lower reaches and, joining the Mu-tan-chiang, flowed into the Hei-lung-chiang, the latter, after joining such tributaries as the Ching-ho, Hun-ho and Tai-tzu-ho, finally reached Po Hai (Gulf of Chihli). However, some geologists hold the opionion that the Liao-ho, not the Nen-chiang, was the upper stream of the Sung-hua-chiang.

Surrounded by the Sa-ha-liang Mountains, Lao-chang-kuang-sui-ling Mountains and Chang-pai Mountains there are two plains, one along the Feng-chi Railway that connects Feng-tien, Hai-lung and Chi-lin, and the other along the Mu-tan-chiang River, including the Ching-po Lake area. Both plains are fertile and good crops of rice and corn are cultivated there.

In eastern Manchuria and Tung-pien-tao, the slopes of the Wan-ta and Chang-pai Mountains form a plateau and are covered with dense virgin forests.

The physiography of the Small Khingan Range requires some comment. The axis of the range is composed of granite gneiss and basalt, and the northern and southern flanks consist of three to four terraces composed of Pleistocene gravel. This suggests that the flanks of the range were uplifted at least three or four times since the Pleistocene. A similar feature is noticed on the slopes of the Great Khingan Range also.

Volcanoes are scarce in Manchuria, and yet about 17 groups of volcanoes are known. Of them, the most noticeable is Mt. Pai-tou-shan (Chang-pai-shan), which is a dormant volcano rising on the Korea-Manchuria border. With an elevation of 2,751 m and an area of about 1,400 km², this volcano is indeed a *dominant* figure of the Chang-pai Mountains.

The Wu-ta-lien-chih volcanic group is also worth mentioning. It consists of fourteen truncated-conical homate-type volcanoes that are aligned NE-SW in three

rows, about 100 km east of Nen-chiang City in Lung-chiang Province. They are not high, the highest (Lae-hei-shan) being only 500 m or so, but standing side by side on a vast plain in northern Manchuria, they provide a spectacular sight. Similar homate-type volcanoes are found in the northern part of Lung-chiang Province, in the central part of Hei-lung-chiang Province, in the lower drainage area of the Sung-hua-chiang and other districts. Prominent ones are I-chia-shan on the southern bank of the Hei-lung-chiang River and Erh-ko-shan in the vicinity of Ko-tung-hsien-cheng, Lung-chiang Province.

Further remarkable topography related to volcanic activity is displayed by mesas composed of basalt lava flows. Tremendous flows of basalt lava form the Pai-tou volcanic group covered the ground, and the mesas came into existence when the ground was uplifted, or was subjected to intense weathering, leaving behind only the resistant portion of lava. Such basalt mesas are found in the neighborhood of the Pai-tou volcanic group and along the railroad between Tu-men and Chia-mu-ssu.

Rivers in Manchuria usually have a gentle gradient. Although rapids are found in such mountainous regions as Tung-pien-tao. The Great Khingan Range and the Jehol mountainland, the streams become very gentle as soon as they leave the mountains and enter the flat alluvial plains. The gradient is as small as 1/10,000 in some areas. As a consequence, these rivers meander greatly and are accompanied by numerous crescent-shaped or oxbow lakes and broad swamps. Meandering is especially remarkable in the Tao-li-ho, A-pu-hsin-ho, Chi-hu-lin-ho, Mu-leng-ho and Hei-lung-chiang Rivers in the lower reaches of Sung-hua-chiang, all along the China-U.S.S.R border, and in the Argun and San-ho Rivers.

2. Physiography of Northwestern Manchuria

What is called northwestern Manchuria here is the area occupied by the former North Khingan Province and was known in olden times as Barga or Hulunbayer. It is a plateau region west of the watershed of the Great Khingan Range.

The Great Khingan Range stretches NNE-SSW with an elevation of 1,100～1,400 m. Some peaks constituting the divide are 1,500 to 1,600 m or more above sea level. The elevation gradually diminishes westward. It is 1,100 m in the upper reaches of the Weatho, I-na-ho and I-min-ho Rivers, but it increases again southward and reaches 1,300 m in the upper reaches of the Ha-la-ha River where high peaks occur in groups. The western margin of the mountainous zone is composed of hilly land, 800～900 m in elevation, which ends in land of gentle relief covered with aeolian sand.

The area between the right bank of the I-min-ho and west of the Wu-erh-sun-ho across the Hui-ho River is part of the so-called Mongolian plateau, and is 600～800 m in elevation. The area, showing a gentle undulation, is a semi-desert waste land covered by aeolian sand with sporadic grassland, and is suitable only for nomads. Along the right bank of the Hailar River in the north, an undulating

plateau has developed. Similar to the above area, this plateau is a semi-desert dry land heavily covered with aeolian sand. Its elevation is 600～700 m. Going eastward from the left bank of the Tuenebe River the area becomes mountainous by degrees. To the north it is demarcated by a roughly east-west line passing through the lower reaches of the Mo-erh-ko-ho River and Tou-chan, and adjoins the northern mountainland. Except for the previously mentioned sand dune area, northwestern Manchuria is hilly land stretching away from the northern Great Khingan Range, and as the elevation increases northward the hilly land changes to somewhat rugged mountainland.

Almost all rivers belong to the Hei-lung-chiang water system. The Argun River and its upper stream the Hailar River, are the principal ones. The Hailar River begins in the Great Khingan Range and flows westward joining many small streams; then it meets the Dja-tun River at Ya-ko-shih and the Tuenebe River in the vicinity of Dja-la-mu-teh. Near Hailar, the river is joined by the I-min-ho, and by the Morkoho (Mo-erh-ko-lo-ho) River north of Wu-ko-no-erh. Downstream of Ho-lo-huang-te, the Hailar River meanders in an S shape and turns northeastward north of Dja-lai-no-erh. Downstream from Abagadz, the river is called the Argun and forms the border between Manchuria and the U.S.S.R. The Ken, Te-erh-pu-erh and Ha-wu-erh Rivers flowing through the San-ho district are tributaries of the Argun River.

A tributary of the Ha-la-ha River flows along the southern nationl border and drains the arid land before it pours into Bayer Lake. Another tributary flows directly into the Wu-erh-sun River. The Wu-erh-sun-ho coming out of Bayer Lake, is joined by the Kerlen (Ko-lu-lun) River which originates in the Kento (Keng-teh) Mountains in Outer Mongolia and flows eastward; after draining the southwestern part of the Barga plateau it flows into Dalai Lake.

The Moutonaya River, between Dalai Lake and the Argun River, seems to flow toward Dalai Lake. Consequently, the Dalai and Bayer Lakes may be called inland lakes under these circumstances. The water-storage area of Dalai Lake is 1,100 km² or more; the lake is 100 km long and 40 km wide, with a depth of 6～9 m, the lake is 545 m above sea level. Bayer Lake has an area of 600～700 km², is 50 km long and 30 km wide, and is situated 660 m above sea level.

Besides the above two large lakes, many smaller ones are found in the area east of Kan-chu-erh-miao. Some are salt and soda lakes, yielding natural salt and soda.

3. Physiography of Northern Manchuria

What is called northern Manchuria here consists of former East Khingan, South Khingan, Lung-chiang and Hei-ho Provinces and part of Pin-chiang Province. This region is bounded on the west by the Great Khingan Range stretching NE-SW, and on the north to northeast by the Small Khingan Range. Between the two ranges spreads a vast plain with Chi-chi-ha-erh in the center.

Important rivers are the Hei-lung-chiang and the Nen-chiang; the former flows along the Manchuria-U.S.S.R. border roughly parallel to the Small Khingan Range. Except the water system of Hei-lung-chiang, other rivers flow toward the great plain on the slopes of the Great and Small Khingan Ranges. The Nen-chiang River irrigates approximately the central part of great plain. Small volcanoes are scattered in the southwestern part of the Small Khingan Range. An arid topography is found in an area between Tao-nan and Tu-chuan, as well as in part of the plain.

The Great Khingan Range is 1,000 to 1,600 m above sea level, and the height gradually decreases toward the great plain in the east. Several terraces are observed on its slope. The part between Ying-chi-erh-ko-chi-ta-ling and Ta-hsing-an-ling is a ridge of almost uniform height at 1,200～1,300 m, and the slope between this ridge and the flat terrace surface, about 250 m in elevation facing the great plain, can be divided into four terraces at altitudes of 900～1,000 m, 600～700 m, 500～600 m and 350～450 m. This stepped topography may be partly attributed to upheaval of the piedmont area and partly to the development of step faults. These movements may have taken place in a period corresponding to the Nan-ling stage, i.e., Oligocene～Miocene in age.

In northern Manchuria, the northwestern end of the Small Khingan Range adjoins the northern tip of the Great Khingan Range. The Small Khingan range stretches NW-SE and forms the northern boundary of the great plain. It also extends along the Hei-lung-chiang River and serves as a divide, separating this river from the Nen-chiang and Sung-hua-chiang Rivers. Its elevation is generally around 1,000 m. The northwestern part, where older rocks are exposed, is somewhat higher but the altitude decreases toward the central part which is a plateau consisting of Pleistocene formations and basaltic lava flows. The elevation increases again in the southwestern part where formations of older rocks seem to follow an approximately NE-SW direction.

The tableland which consists of the Small Khingan Range stands from the great plain in North Manchuria and the altitude of its marginal part is estimated to be 300 $m^{\pm}$, then it increases gradually and attains 500～800 m in the vicinity of the divide. From these, the altitude changes more or less toward the bank of the Hei-lung-chiang River where it is estimated to be about 400 m. Thus, the Small Khingan Range is a continuation of the low undulating hilly topography; in the southern part where the valleys are shallow and slopes are gentle, its relative height from the great plain is estimated to be 40～60 m. On the contrary, in the northern part, the slopes are relatively steep and the relative height is estimated to be 100 m or more.

A "verebene" (level plane) 300 m in elevation has developed well along the Hei-lung-chiang River. This is probably a terrace formed by the river, but its boundary with a Pleistocene plateau that constitutes the main body of the range is not distinct. That is, the terrace grades into the plateau.

Many small volcanoes are found in the northwestern part of the Small Khingan

Range, especially into the west of Lung-chen in the vicinity of Mergen and to its north and west. Volcanic topography is found also on the eastern slope of the Great Khingan Range. Of these volcanoes, notable ones are as follows:

Wu-ta-lien-chih volcanoes (Wu-yun-ho-erh-tung-chi volcanic group), located at long. 125°0′ to 37′ E and lat. 48°40′ to 50′ N.

Chien-shan volcano, located at long. 124°4′ E and lat. 48°27′ N.

Erh-ko-shan, at long. 126°18′ E and lat. 48°3′ N.

Ko-lo-nan-shan volcanic group, scattered around long. 125°13.5′ E and lat. 49°13.5′ N.

Volcanic group along the Kung-pie-la-ho River.

Santir volcanic group, consisting of eight volcanoes aligned in a southwest direction 160 km northwest of Mergen, where the No-min-ho River turns abruptly south.

I-chia-shan, long. 127°40′ E and lat. 49°42′ N, about 40 km southeast of Ai-gun.

In addition to the above, there is Lake Onenor, which is a crater lake. It is located at long. 121°17′ E and lat. 47°34.5′ N, near the confluence of the Chai and Cho-erh-ho Rivers on the eastern slope of the Great Khingan Range.

All the above volcanoes are composed chiefly of basaltic lava flow. Since the lava flows cover the Pleistocene deposits, the volcanoes must have formed in a period extending from late Pleistocene to early Alluvium. Some volcanoes, such as the Huo-shao-shan and Chien-jen-shan of the Wu-ta-lien-chih volcanic group, have a record of eruption in 1720, but all the volcanoes are either dormant or extinct now.

A great plain stretches on the east and west sides of the Nen-chiang River south of Pu-hsi. It is a semi-desert steppe, with nothing whatever to obstruct the view. Careful observation reveals, however, that the plain undulates with low sand dunes and shallow depressions of aeolian origin. Many of the depressions are filled with water forming so-called playa lakes.

Major rivers in northern Manchuria are the Hei-lung-chiang flowing along the Manchuria-U.S.S.R. border, the Nen-chiang rising in the Great Khingan Range and draining the great plain, and the Hu-lan-ho that originates in the Small Khingan Range and flows southward to join the Sung-hua-chiang east of Harbin.

In the upper reaches the Hei-lung-chiang is known as the Argun River flowing west of the Great Khingan Range. After joining the Onon River it changes course at right angles and flows eastward. It continues round the north side of the Small Khingan Range and proceeds southeastward parallel to the range. From the vicinity of its confluence with the Sung-hua-chiang River, the Hei-lung-chiang turns northeast and flows through Maritime Province of Siberia until it empties into the Heilung Strait in the neighborhood of Nikolayevsk. The course of the river shows two principal trends, one northeastward and the other southeastward, corresponding respectively to the "Sinian direction" and the "Korean direction" that control the geologic structures of East Asia. Important tributaries of the Hei-lung-chiang are the Kung-pie-la-ho, the Puerhmandinhe and the Sung-pi-la-ho.

The Nen-chiang River rises in the east at the northern end of the Great Khingan Range, flows approximately southward, drains the great plain with Chi-chi-ha-erh at the center and joins the Sung-hua-chiang to flow northeastward. It was believed that the Nen-chiang in ancient days had been one with the Liao-ho River and flowed into the Po Hai (Gulf of Chihli), but a recent investigation indicates that it was one with the Zeya River until the Small Khingan Range came into existence. The water system of the Nen-chiang has a dendritic pattern, consisting of a large number of small streams coming from the Great and Small Khingan Ranges. Of these tributaries, notable ones are the Nomorho (No-mo-erh-ho) River rising in the Small Khingan Range, the Kan-ho, No-min-ho, A-lun-ho, Yin-ho, Cho-erh-ho and Tao-erh-ho, all from the Great Khingan Range.

The Hu-lan-ho comes from the southern slope of the Small Khingan Range, the area centering around Tien-shan-pao, and flows west or southwest to join the Tung-ken-ho; then it turns south and southeast, passes through Hu-lan and flows into the Sung-hua-chiang at Harbin. Besides the Tung-ken-ho, the Hei-ni-ho is also a tributary of this river.

In addition, there are vanishing rivers that rise from the slopes or feet of the Great and Small Khingan Ranges and disappear into the great plain or end in basins in the marginal areas of the mountains. Of them, the Hu-yu-erh-ho, Shuang-yang-ho, A-li-ko-tu-ho, Holen and Urgen Rivers are well known.

4. Physiography of Northeastern Manchuria

The region includes the former San-chiang Province, Mu-tan-chiang Province, Pin-chiang Province and part of Tung-hua Province.

Immature peneplains of early Neogene Tertiary age and roughly contemporaneous basalt plateaus constitute the original topographic features of northeastern Manchuria. The present physiographies represent the processes of eroision that began on the original topographic features.

The greater part of the region belongs to the northern Chang-pai-shan mountain system, comprising a number of mountain ranges aligned in the so-called Sinian direction. It is obvious that the principal plateaus also stretch in this direction.

Examining the relief, one notices the following: Elevation exceeding 1,000 m are restricted to the Lao-chang-kuang-sui-ling Mountains, the Chang-pai Mountains and to the southeastern mountainous region where the highest peak, 1,566 m, of the Pan-ling Range is found The zonal arrangement of mountains and lowlands in the Sinian direction is remarkable, and the following seven zones are found: From northwest to southeast, (1) a central great plain, (2) the Small Khingan Range, (3) a plain along the lower course of the Sung-hua-chiang River and a lowland between Tung-pin and the Wu-chi-mi-ho River, (4) from the A-erh-ha-wo Mountains to the Lao-chang-kuang-sui-ling Mountains, (5) a lowland along the Tao-li-ho River, another around Po-li and still another stretching

from Ning-an to Tun-hua via the Ching-po Lake, (6) Wang-ta and Chang-pai Mountains, (7) the southeastern mountainous region.

Such a relief pattern is, of course, due to crustal movements in the region, but differential erosion resulting from the geologic structure also accounts for the characteristics of the present-day topography. For example, the lowlands (3) are composed of soft Tertiary deposits, whereas the lowlands (5) are made of Mesozoic sandstone.

Most rivers in the region belong to the Hei-lung-chiang water system. Only two rivers in the southeastern part, Sui-fen-ho and Tu-men-chiang, gather water in relatively small areas and empty directly into the Sea of Japan. The Hei-lung-chiang bounds the northern limit of the region and has two large tributaries, Sung-hua-chiang and Wu-su-li-chiang. The Sung-hua-chiang drains the western part of the region, with the Mu-tan-chiang as a tributary. The Wu-su-li-chiang flows on the Manchuria-U.S.S.R. border and, after joining the Mu-leng-ho and Tao-li-ho, empties into the Hei-lung-chiang. Major lakes are Ching-po-hu and Hsing-kai-hu.

The southeastern mountainous region stretches from the vicinity of Hsing-kai-lu to Chien-tao, and belongs to the late young stage of erosion and basaltic plateaus are extensively distributed within these mountainous land. The land consists of mountain ranges elongated in the Sinian direction. Of these ranges, a most remarkable one extends from the northwest of Hsing-kai-hu to the drainage area of the Ka-ya-ho, passing through Tai-ping-ling and running along the Pin-sui railroad; its height is recorded at 1,100 m northeast of Tai-ping-ling and over 1,000 m north of Lo-tzu-kou.

The Chang-pai Mountains extend from the southwest and enter the region, and are called the Ha-erh-pa-ling Range, which gradually decreases in elevation northeastward and finally disappears under basalt. The elevation near Ha-erh-pa-ling is about 1,000 m.

The Wan-ta Mountains begin to rise in the northeast of Tai-ma-kou and extend northeastward. At Hsiao-chia-chi, they are cut by the Tao-li-ho, but extension across the river forms a small massif. The range is demarcated by the north-flowing Wu-su-li-chiang. On the whole, the Wan-ta Mountains are of a late young to early mature stage, seldom exceeding 800 m in elevation, but they present a unique topography contrasting with the surrounding lowlands.

The Lao-chang-kuang-sui-ling Mountains coming from the southwest extend south of San-hsing, via Chang-kuang-sui-ling and Kao-ling-tzu. In general, elevation exceeds 1,000 m, the highest peak southwest of Kao-ling-tzu being 1,438 m. It is most likely that the ancient monadnocks that survived the Tertiary peneplanation have been uplifted to form the rugged mountain range of today.

The A-erh-ha-wo mountain range starts from the east of San-hsing and stretches roughly east-northeast until disappearing in the plain. As separate remnants of the range are sporadically found in the plain, the total extension of the range can be estimated.

The volcanic topography of the region is represented by basalt plateaus and lava flows, but in spite of their extensive distribution the location of vents has not been determined yet.

Basalts of this region are divided into three groups according to the age of eruption; older basalt (late Cretaceous), middle basalt (Neogene Tertiary) and younger basalt (late Tertiary to early Pleistocene). Eruption of the older basalt took place before the peneplains were formed, so that the original features were completely destroyed. Therefore, the latter two groups constitute the volcanic topography of the region. The middle basalt is most important, forming extensive plateaus. The younger basalt occurs as lava flows, filling valleys here and there.

Notable basalt plateaus are the following: (1) A plateau south of Tung-ning, stretching 80 km east-west and 70 km north-south over the Manchuria-U.S.S.R. border. (2) A plateau west of Mu-leng-wo-chi-ling, which stretches from the vicinity of Pan-chieh-ho through Tai-ping-ling to as far as the vicinity of Li-shu-chen. (3) A broad plateau spreading from the vicinity of Hsia-cheng-tzu to the east bank of the Mu-tan-chiang via the upper reaches of the Mu-ling-ho. (4) A plateau south of Lao-sung-ling, stretching from the vicinity of Ching-po-hu to Tun-hua; another along the Ka-ya-ho River. (5) One around Hsiao-shih-tou-ho-tzu of Hua-chuan Prefecture, and another east of Yung-feng-chen of the same prefecture.

Of the lava flows, a most remarkable one is found to come down a valley west of Ching-po-hu to enter the valley of the Mu-tan-chiang and extend farther downstream. It has a total extension of about 80 km and a maximum width of 10 km. On its way, this lava flow created three lakes by damming, the Pei-hu, Yu-chuan-hu and Ching-po-hu.

Ching-po-hu Lake was formed when the main stream of the Mu-tan-chiang was dammed by the lava flow. It is located about 50 km southwest of Ning-an, and has an elongated S-shape. The lake is about 300 m above sea level. The lake has an outlet in the north, known as the Tiao-shui-lo waterfalls, with a height of 20 m. Another remarkable lava flow is found near Tun-hua, filling the main valley and branch valleys of the Mu-tan-chiang.

Hills are found in the following areas: (1) Between Harbin and Ping-hsien, (2) in the lower reaches of the Mu-tan-chiang between Hsiao-lo-la-mi and San-hsing and (3) along the Wo-ken-ho River.

The hills of area (1) are about 200 m high, their tops forming a very flat plane. There is another level plane 20 m below the top. The upper plane was formed by deposition, probably in the Upper Pleistocene period. The lower plane is an erosion plane of the river terrace that was formed perhaps by the main and branch streams of the Mu-tan-chiang.

The mountain ranges of northeastern Manchuria are elongated in the Sinian direction, with lowlands in between which also stretch in the Sinian direction.

Significant plains are found in the lower reaches of the Sung-hua-chiang and around Hsing-kai-hu Lake. The plain along the Sung-hua-chiang River has the

shape of a parallelogram, stretching east-west and northeast-southwest. Its northwestern side is bounded by the southeastern edge of the Small Khingan Range, the south side by the line connecting Chia-mu-ssu and Hsia-chia-chi, and the southeast and north sides fall within the territory of the U.S.S.R. This plain, 50 m above sea level, is penetrated by the Hei-lung-chiang which is joined by the Sung-hua-chiang and Wu-su-li-chiang. It is a vast plain and with great development of swamps and marshes. Near the southern end of the plain, small hilly blocks having an "Inselberg" appearance are scattered.

Between the lower reaches of the Mu-ling-ho and Hsing-kai-hu Lake there is an extensive alluvial plain. Hsing-kai-hu Lake, situated in the southern part of this plain, is the source of the Wu-su-li-chiang which consists of the waters of the Sung-ho, Cha-ho, Hsiao-mu-ling-ho, Mu-ling-ho, Chi-hu-lin-ho and A-pu-hsin-ho Rivers, and flows northward to serve as a boundary between Manchuria and U.S.S.R.

Besides the Wu-su-li, important rivers of the region are the Tu-men-chiang, Sui-fen-ho, Mu-tan-chiang, Wo-ken-ho and Sung-hua-chiang.

The Tu-men-chiang flows on the Manchuria-U.S.S.R. border and empties into the Sea of Japan. It originates in the vicinity of Pai-tou-shan and flows north-northeast. After passing Musan, the river curves until it reaches Hoeryŏng, then flows northward passing Tu-men. Subsequently it turns east again and at Hsun-chieh turns east-southeast and empties into the sea. The total length of the Tu-men-chiang is 520 km and the drainage area exceeds 41,000 km^2. The major tributaries are the Ka-ya-ho and the Hun-chun-ho.

The Sui-fen-ho in the upper reaches splits into the Ta-sui-fen-ho and the Hsiao-sui-fen-ho; the former rises southeast of Lo-tzu-kou and the latter from north of the town of Sui-fen-ho, and they come together west of Tung-ning and enter the territory of the U.S.S.R. to empty into Amur Bay. The drainage area exceeds 17,000 km^2.

The Mu-tan-chiang is one of the largest tributaries of the Sung-hua-chiang. It rises in the vicinity of Chuang-nien-shan south of Tun-hua, and flows roughly northward to enter Ching-po-hu Lake. It then passes through the town of Mu-tan-chiang and the vicinity of Ning-an and flows farther north to join the Sung-hua-chiang in the vicinity of San-hsing.

The Wo-ken-ho begins in A-erh-ha-wo-chi-ling. It flows first approximately south until reaching Tao-shan of Po-li Prefecture, then turns abruptly northwest. After collecting the waters of the Chi-hu-li and Pa-hu-li Rivers it flows west and joins the Su-mu-ho. Then it turns northwest again and flows into the Sung-hua-chiang at San-hsing.

The Sung-hua-chiang flows from Tien-chih Lake on Mt. Pai-tou-shan. In the upstream area of Hua-shu-lin-tzu it joins the Hui-fa-ho coming from the west and, after great winding, is joined by the La-fa-ho. Then it flows northwestward, passes through the Chi-lin provincial castle, traverses the Harbin~Chang-chun railroad at Sung-hua-chiang Station, is joined by the I-tung-ho on the left bank,

flows still northwestward along the west side of Po-tu-na and joins the Nen-chiang. After that, the river becomes much larger in both width and quantity of water before reaching Harbin. It begins to have broad alluvial plains after passing through Chi-lin. After joining the Nen-chiang, meandering also becomes conspicuous. In the vicinity of Harbin numerous distributaries and sand bars are found. Downstream from Harbin, the river is joined by the A-shih-ho on the right bank and later by the Hu-lan-ho on the left.

In the neighborhood of Lao-shan-tou the Sung-hua-chiang turns east and flows east of Tung-ho where it changes course to the northeast. At San-hsing, it is joined by the Mu-tan-chiang and the Wo-ken-ho, and flows toward Tang-ho. From Tang-ho downstream the river flows through a vast plain, and freely meandering on a large scale goes east-northeast reaching Tung-chiang where it flows into the main stream of the Hei-lung-chiang. All through the lower course the river is dotted with sand bars; swamps are frequent on both banks of the river.

5. Physiography of Southeastern Manchuria

The backbone range of the Liao-tung Peninsula has a NE-SW trend, in the so-called Sinian direction. In this area, granite, gneiss and quartzite are predominant. The Ta-ho-shang-shan series of the Sinian system is widely exposed in the basal and marginal parts of the peninsula. Older Paleozoic formations are developed relatively well in the western part. Mesozoic formations and terrace deposits are sporadically distributed throughout the area.

In the Liao-tung Peninsula, erosion surfaces are well developed. The level plane that was regarded as the final form of these erosion surfaces was once called the Liao-tung peneplain. Discontinuous peaks are found as monadnocks in this peneplain. The highest peak is Mien-yang-ting-tzu-shan, 1,061 m above sea level, in the central part of the peninsula. Few other peaks exceed 1,000 m.

Zenkyo IMAMURA and Sadajiro TSUCHIDA made a detailed analysis of this Liao-tung peneplain and divided it into three level planes, the Pi-tzu-wo, Kuang-ning-ssu and Ping-shan. In the Liao-tung Peninsula, the Ai-chuan level plane comes below the Pi-tzu-wo plane, and the Ta-ho-shang-shan monadnock remains on the Ping-shan plane.

The Pi-tzu-wo plane, 20~50 m above sea level, is developed in the eastern part of the peninsula with Pi-tzu-wo as its center. It is traceable east, west and north of the area, is very flat and where it faces the sea looks like a marine terrace. The boundary of this plane with the Kuang-ning-ssu plane is distinct, especially between Liang-chia-tien station and Tsan-chang-tien station on the railroad from Chin-chou to Pi-tzu-wo.

The Ai-chuan plane, less than 10 m above sea level, is found in various parts of the Pi-tzu-wo peneplain, mostly along the sea coast. This is a flood plain, dotted with salt fields, salt swamps, sandy plains and cultivated fields. Its typical development is seen in the village of Ai-chuan northwest of Chin-chou station.

The Kuang-ning-ssu plane occupies the greater part of the central area, and broadly extends in a NNE-SSW direction. It is 120 to 200 m above sea level, and is typically developed in the vicinity of Kuang-ning-ssu plane has a horizontal skyline.

The Ping-shan plane is found only as sporadic remnants 300～400 m above sea level. It is represented by the flat-topped Ping-shan hill north of Chin-chou station.

The Ta-ho-shang-shan monadnock, rising 340 m above the Ping-shan plane, was already a monadnock when the Ping-shan plane was completed.

The above three planes are easily seen along the railroad from Ta-lien to Chang-chun in the north, at least as far as the vicinity of Wa-fang-tien. Of them, the Kuang-ning-ssu plane is traceable farther north.

These level planes are also seen around the Wu-hu-tsui coal field in Fu-chou. The hills surrounding the coal field correspond to the Pi-tzu-wo plane. The top of the Pai-shan hill correlates with the Kuang-ning-ssu plane, and the top of the Tai-shan hill with the Ping-shan plane. The Ai-chuan plane occurs as broad salt swamps around Wu-hu-tsui.

Also in the An-tung area at the base of the Liao-tung Peninsula, level planes are well developed. Along the north bank of the Ya-lu-chiang River from An-tung to Feng-shan, monadnocks 760～800 m in elevation are found. In this area the Ping-shan plane occurs at an elevation of 360～440 m, which is 40 m higher than that in the central area of the peninsula. The Kuang-ning-ssu plane, 120～200 m in elevation, is extensively developed and well preserved. The Pi-tzu-wo plane is 10～14 m in elevation. The Ai-chuan plane of 10 m elevation is also seen, though on a much smaller scale.

Described thus far are the level planes in the border areas of southeastern Manchuria. Turning inland, one finds the Chang-pai Mountains most outstanding. This is a mountain range separating Manchuria from Korea and stands opposite the Great Khingan Range to the north across the Sung-hua-chiang. From this range the Wan-ta Mountains fork out to the northeast and the divide to the southwest forming the backbone range of the Liao-tung Peninsula and Tung-pien-tao.

The divide range, with Lao-tu-ting-tzu-shan (1,367 m) east of Hsien-chang as the main peak, stretches south-southwest, passes through the vicinity of Lien-shan-kuan on the An-feng Line, and through Ma-tien-ling (720 m) and the prefectural border of Liao-yang and Hsiu-yen, to connect with Tang-mao-tzu-shan (896 m). It then forms the Mien-yang-ting-tzu range that comprises such peaks as Mien-yang-ting-tzu-shan (1,672 m), Tien-chiao-shan (851 m) and I-mien-shan (774 m), and extends into the province of Kuan-tung.

Nearly parallel to, and on the south of the divide range, there is the Kuo-tou-ku range with Kuo-tou-ku-shan (1,041 m) as the main peak. San-chien-tzu-shan (468 m), I-mien-shan and Kao-ling are located in the southwestern extension of this range.

Also parallel to the divide range but to the north are the massif comprising Mu-la-tung-tzu-shan (780 m), Hung-miao-tzu-shan (922 m), Ta-lung-wan-shan (959 m), etc., and farther north stretches the Lao-yen-kang range constituting the backbone of the northern area of South Manchuria. The latter extends from the northeast of Shan-cheng-chen to the vicinity of Tieh-pei-shan east of Ying-pan, and contains Lung-kang-shan (1,065 m), Hsi-ta-ting-shan (948 m), Pei-ta-la-tzu-shan (642 m) and other peaks (600～1,000 m).

Volcanic topography of southeastern Manchuria is represented by Chang-pai-shan, known also as Pai-tou-shan, which is the highest peak in Manchuria. It stands on the Manchuria-Korea border at an elevation of 2,751 m. On the top it has an oval caldera lake, Tien-chih, 11.3 km in circumferance, 3 km east-west, 4 km north-south, with a water depth of 365 m. The lake water flowing out of Ta-men, a barranco, to the north is the source of the Erh-tao-pai-ho, an upper branch of the Sung-hua-chiang. In the middle of the Tertiary period an eruption of basalt occurred in this area, and in the latter part of the period alkali-trachyte erupted to form the main body of Pai-tou-shan. In the early Quaternary Period, a large scale outflow of basalt lava took place, but the lava flowed down northeastward without covering the top of Pai-tou-shan, and formed the so-called Hei-shan basalt plateau.

Other noteworthy volcanoes are Huang-i-shan of the Lung-wan volcanic group, volcanic cones in the neighborhood of I-tung and some hills near Fan-chia-tun.

Hung-i-shan, located at Kuan-tien southwest of the Hei-shan plateau, has a gently sloping cone, is 513 m above sea level and is composed of basalt.

The Lung-wan volcanic group is found in the Lung-kang mountain range that stretches over the two prefectures Chin-chou and Meng-chiang of Tung-hua Province. Seventy-two craters of various sizes are found on the lava plateau, and at least six are crater lakes filled with water. The lakes are 500～1,000 m in diameter. Of them, the Ta-lung-wan Lake and the San-chiao-lung-wan Lake are noteworthy.

In the area (5～15 km across) around I-tung of Chi-lin Province, there are five volcanic cones, Tung-chien-shan in the north, Hsi-chien-shan, Ma-an-shan and Mo-li-ching-shan in the northwest, and Ta-ku-shan in the south. These cones, 270～390 m in elevation, are aligned in a NE-SW direction and are easily recognized on account of their topographic features.

In the neighborhood of Fan-chia-tien are found four hills along the railroad between Kung-chu-ling and Chang-chun; Chien-shan, Ping-ting-shan and Ta-tun-tung-shan on the east side of the railroad, and Ta-tun-ping-ting-shan on the west. These hills are 225～280 m in elevation, have a shield-like shape, are composed of basalt and are aligned in two rows with a NE-SW trend.

Important rivers are the Ya-lu-chiang, Tai-tzu-ho and Hun-ho.

The Ya-lu-chiang is 540 km long. Rising from the western foot of Pai-tou-shan, it flows northeast to southwest along the Manchuria-Korea border, passing

through Chang-pai, Lin-chiang, Chi-an and An-tung. The stream is swift, accompanied by few alluvial plains on both banks and thus entirely different from the rivers of North Manchuria. But downstream from I-chou and Chiu-lien-cheng the stream becomes gentler, and where the river flows through plains it has a braided channel. Finally, the river empties into the northern corner of the Gulf of Korea.

The largest tributary of the Ya-lu-chiang is the Hun-chiang. It rises from the vicinity of the Lao-yeh-ling pass of the Chang-pai Mountains, and passes through Tung-hua Prefecture. From the vicinity of the Huan-jen-hsien Castle it turns south and markedly meanders before being joined by the Pan-la-chiang northeast of Tai-ping-hsiao. It travels a distance of 318 km before joining the Ya-lu-chiang at Hun-chiang-kou.

Other tributaries are the Pu-shih-ho and the Ai-ho; the former has few plains along its banks, but the latter has a large drainage area and flood plains are found in the Feng-huang-cheng area and to the east.

The Tai-tzu-ho is about 170 km long. Rising east of Ping-ting-shan of Pen-chi Prefecture, it flows westward collecting water north of the divide range, and passes through Pen-chi-hu and Liao-yang to enter the plain. Then, with much meandering and distributaries the river flows through the plain and joins the Hun-ho at Hsiao-pei-ho. During its course the river flows through an anticedent valley west of Laio-yang where 100~200 m high cliffs flank the gorge. Its tributaries are the Hsi-ho, Tang-ho and Hsiao-sha-ho.

The Hun-ho begins in Tsao-shih of Hai-lung Prefecture and flows west. East of Ying-pan it is joined by the Su-tzu-ho which rises in the vicinity of Hsing-ching, and flows northwest. Then, passing through Fu-shun and Feng-tien, the Hun-ho enters the great plain of the Liao-ho. From there it turns southwest, and above Hsiao-pei-ho-chen the Li-liao-ho branches off to the southwest. South of Hsiao-pei-ho-chen the Hun-ho combines with the Tai-tzu-ho coming from the east, and flows southwest penetrating the Liao-chung plain, and joins the Liao-ho at San-cha-ho.

In addition to the above rivers, there are the Ta-hun-ho, Pi-li-ho and Teng-sha-ho, all flowing south from the divide and empty into the Yellow Sea.

6. Physiography of the Central Great Plain

The present district contains the great plain which is covered by the water system of the Liao-ho River and is located at the south of the Hei-liao Divide. The great plain may be divided into three as follows: The area that is covered with alluvial deposits and encircles Tung-liao, Shuang-shan and Liao-chung; that at a higher level covered for the most part with sand and loess, comprising the area south of the Silamulun River and also where Kai-lu, Lu-pei and Kai-tung are located; hilly land composed of sand, gravel and loess-like clay in the vicinity of Li-shu west of Kung-chu-ling and Ssu-ping-chieh.

The latter hilly land is the southern end of the flat hilly land found around Harbin in North Manchuria.

In general, however, the great plain is flat land with a somewhat undulating surface, dotted with playa lakes. A semi-desert character is noticed everywherer. The monotony of the topography is broken only by hills rising in the area west of Kai-yuan between Fa-chung-men and Chiu-hsin-hou, and by the volcanic cones in the vicinity of Cheng-chia-tun.

The volcanic cones of the Cheng-chia-tun area are known as Chi-hsing-shan (Seven Stars); they are Po-po-tu-shan, Tung-ha-la-pa-shan and Pei-ha-la-pa-shan in the northeast, all about 300 m in elevation, Nao-pao-shan (170 m) in the southwest, Ta-tu-ko-chi-shan (267 m) and Hsiao-tu-ko-chi-shan (283 m) about 55 km west of Cheng-chia-tun, and Po-li-shan (278 m) 25 km north of Cheng-chia-tun. They are composed of basalt, but at their foot the rock exposure is poor because of a sand cover.

Almost all rivers flowing through this great plain belong to the Ta-liao-ho system, except for the Wurtchaonung River on the east slope of the Great Khingan Range in the west.

The stream below the confluence (San-chiang-kou) of the Tung-liao-ho and the Hsi-liao-ho is called the main stream of the Ta-liao-ho. The Tung-liao-ho begins east of Ta-ko-tsang. The Hsi-liao-ho rises in the Great Khingan Range in Ko-shih-ko-teng Chi of West Khingan Province, and flows eastward as the Wurhshunmur River, flowing through Kai-lu and Pai-yin-tai-lai it reaches Cheng-chia-tun, and turns southeast to join the Tung-liao-ho River at San-chiang-kou. From there the river is called the Ta-liao-ho and flows south, cutting the borders of Chang-tu, Kang-ping and Fa-ku prefectures, and reaches the vicinity of Tieh-ling where it turns southwest to flow through the prefectures of Hsin-min and Liao-chung. At San-cha-ho in the western part of Hai-cheng Prefecture it is joined by the Tai-tzu-ho and flows by Tien-chuang-tai reaching Ying-kou where it empties into the Po Hai (Gulf of Chihli). With a total length of about 1,700 km, the Ta-liao-ho is the largest river in Manchuria. Both meandering and distributaries become obvious south of Hsin-min as the river advances into the great plain, especially so in the area south of San-cha-ho. Large oxbow lakes are scattered east of Tien-chuang-tai.

The Wurhshunmur River rises from the slope of Mt. Pa-yen-wu-lan-feng on the northern border of Pa-lin-tso-i Chi, and flowing southeast is joined by the Puyanatoi and Kuluto Rivers. Then it flows eastward entering A-lu-ko-erh-chin Chi where it combines with the Hokotochiyonon coming from the southeast. Continuing on its eastward course, the river then enters Ta-erh-kan Chi and disappears into sand. Where the river flows through the loess area, some flood plains have developed on both sides.

7. Physiography of Southwestern Manchuria

The region comprises the so-called Jehol mountainland and adjacent areas. From the structural viewpoint, the region can be divided into four parts, the Khingan Range, the Yin-shan Mountains, the Mongolian Plateau and the Jehol Massif.

The Khingan Range corresponds to the southern end of the Great Khingan Range. The main ridge runs through the western part of West Khingan Province to the north of To-lun. The highest peaks are 1,500~1,700 m above sea level. West of Lin-hsi the watershed does not coincide with the highest ridge, but deviates far to the west where the valley-head erosion of the Silamulun River has advanced across the Khingan Range and is already beginning to invade the Mongolian Plateau. The range has generally lower elevation in the north, but stands on the whole between 1,400 m and 1,700 m, except for a peak 1,800 m high northwest of Ching-peng and a 1,910 m peak in the south.

In an east-west cross-section of the range between Ching-peng and Lin-hsi and farther east, it would be seen that the range has a stepped decrease in elevation, from 1,700 m to 1,500 m, to 1,400 m, and then to 1,000 m, until ending in a lowland in the vicinity of Kai-lu.

Topographic features of the Khingan Range suggest a stage of maturity. Creases on the slopes are dense, but the valleys are usually broad. When viewed eastward from the Mongolian Plateau, the top of the range is remarkably flat without any significant relief.

The Yin-shan Mountains at a range extending eastward from Sui-yuan Province of China, and rises in the southwestern corner of Jehol Province of Manchuria. Its height near To-lun is 1,500~1,700 m above sea level. In the Chahar area, the range shows typical old stage topography. The Yin-shan Mountains meet the Khingan Range in the vicinity of To-lun, both showing an abrupt decrease in elevation, by 200~300 m, to the Mongolian Plateau.

The Jehol massif, rectangular in shape, projects eastward from the eastern edge of the Mongolian Plateau, and separates the lowland of Central Manchuria from the North China plain. The massif is bounded on the north by the Silamulun River, on the south by the Great Wall of China and on the east by a narrow coastal plain that stretches NE-SW along the west coast of Liao-tung Bay. It is divided into two parts, the western half and the eastern half.

The western Jehol Massif has steep peaks south and northwest of Cheng-te, but in the western border area it shows a plateau-like topography with gentle valleys, in spite of the high elevation.

Wu-lung-shan, 2,500 m above sea level, is the highest peak of the western Jehol Massif. It rises directly from the North China plain. In the west, high peaks around 1,800 m are crowded along the national border, and constitute the "Roof of Jehol". Of them, Chung-sheng-tang-shan (1,890 m), La-ma-shan (1,910 m) and Yun-mu-shan (1,967 m) are most obvious.

Mountains in the area enclosed by Chih-feng, Lung-hua, Cheng-te and Ping-chuan are also high, noteworthy ones being Tiao-yu-shan (1,450 m), Ta-hsi-kou-shan (1,460 m) and Ping-ting-shan (1,944 m).

The Yen-shan range is part of the western Jehol Massif. It serves as the watershed of the Chao-ho and Luan-ho Rivers, and includes the previously mentioned Wu-lung-shan and adjacent Jen-tou-shan (1,649 m). Another range, Chi-lao-tu-shan, separates the water of the Lao-ha-ho system from that of the Luan-ho, and contains Ping-ting-shan and other high peaks.

The eastern Jehol Massif consists of three mountain ranges, Ling-yuan, Ta-ching-shan and Sung-ling, all of which trend in the Sinian direction. Their elevation gradually decreases to the east.

These ranges are steep in the south, showing a mature stage of topography, but in the north grades into foothills ending with a lowland along the Silamulun River.

The Ling-yuan range is bounded on the west by valleys of the Lao-ha-ho and Pao-ho, and on the east by valleys of the Ching-lung-ho and Lien-ho and by a lowland connecting the towns of Ling-yuan, Yeh-pai-shou and Ssu-chia-tzu. Major peaks are Chien-tzu-shan (1,095 m) and Pai-shih-la-tzu-shan (1,129 m), southeast of Ping-chuan.

The Ta-ching-shan range is located between the main stream of the Ta-liao-ho and the Ling-yuan range. Its main peak is Ta-ching-shan (1,115 m), northwest of Chao-yang. Ta-hei-shan (1,080 m) and other high peaks are also found in this range.

The Sung-ling range constitutes the easternmost part of the Jehol Massif. It runs parallel to the west coast of Liao-tung Bay and stretches from northwest of Shan-hai-kuan to the vicinity of Fu-hsin in the northeast. Hei-shan (1,258 m), east of Ling-yuan, and Wu-ting-shan (743 m) are included in this range.

As to the volcanic topography of the region, the lava plateaus and volcanic cones along the west coast of Lake Talinor of the Mongolian Plateau and the mesas in the vicinity of Wei-chang are most obvious.

Lava plateaus occur in two rows, one parallel to the national boundary and the other following an east-west direction. They are 70～150 m in relative height, standing on the Mongolian plateau which is 1,190 m above sea level. The lava plateaus are composed of 20～30 m high volcanic domes. Some of the domes have a typical crater at the top from which lingulate lava flows issued.

Three to four mesas are found in the area between Wei-chang and Chang-san-ying. They are 100 m above the present river-bed and have a flat top.

The Mongolian Plateau is the easternmost part of the so-called Mongolian Great Plateau. It is located west of the Khingan Range and northwest of the Yin-shan Mountains. Its height is between 800 m and 1,200 m above sea level. It slopes down to the north, with a level surface like a peneplain. The Talinor lacustrine basin west of Lin-hsi contains Lake Talinor and Lake Wang-niu-pao-tzu. Northwest of Lin-hsi, beyond the national boundary, broad marshy valleys

and plains, drained by vanishing streams, are found between the mountains of an old stage. The development of sand dunes is remarkable on the plateau in the vicinity of To-lun.

In the drainage basins of the Lao-ha-ho in the northeast and of the Ta-ling-ho in the eastern part of the Jehol Massif, low hills are found between the mountains or at their foot. These hills are composed of Mesozoic formations that yield many fish fossils. The hills undulate with a relative height of around 100 m. The most notable feature of the hills is the thick cover of loess, and gullies characteristic of a loess region are found everywhere.

Plains and lowlands of southwestern Manchuria are generally small in area, except for the northeastern part of the Jehol Massif, the coastal plain of Chin-chou and part of the North China Plain.

Major rivers are the Silamulun, the upper course of the Ta-liao-ho, the Lao-ha-ho and the Luan-ho. Lesser ones are the Ta-ling-ho, Hsiao-ling-ho and Liu-ku-ho.

The Silamulun River, bounding the northern side of the Jehol massif, takes a straight course west to east. Its upper stream, flowing west of Ching-peng, is found to cut through the Khingan Range and continues farther west to cut young V-shaped valleys, deeper than 100 m, on the Mongolian plateau. Eastward from Pa-lin-chiao the river becomes wider and is accompanied by a broad area of sand dunes along its south bank.

The Lao-ha-ho is one of the tributaries of the Silamulun, and its drainage area covers most of the northeast of the Jehol Massif. It rises about 18 km north of Ping-chuan in the south, and flows northward and irrigates the broad alluvial plain. Then it passes Hei-shui 40 km southeast of Chih-feng, and goes northeast, meandering occasionally before joining the Silamulun. The river is about 44 km long and has a large number of tributaries showing a pinnate pattern of branching and dissecting the northwestern Jehol District. The largest tributary is the Hsi-lu-ka-ho, whose tributaries, such as the Cho-su-ho, the Ying-chin-ho, the Hsi-po-ho and the She-li-ko-ho, present a radial drainage pattern with the Chih-feng basin at the center.

The main stream of the Luan-ho begins as the Shan-tien-ho far west of To-lun. It rises in the eastern end of the Yin-shan Mountains and joins the Ta-luan-ho north of To-lun. It is probable that the Shan-tien-ho was once an inland river, but was later captured by the Luan-ho through stream piracy.

The Luan-ho in the area south of Ta-ku-shan 35 km east of To-lun-no-erh flows roughly southeastward. Where it passes through the Jehol massif the river forms several gorges, and in the Chang-cheng mountainland it shows incised meanders. It has such tributaries as the I-ma-tu-ho, the Je-ho and the Ching-lung-ho.

The Pai-ho flows through the southwestern corner of the Jehol Massif, and after traversing the Chang-cheng mountainland enters the North China Plain to pour into Po Hai at Tien-chin.

The Ta-ling-ho has its drainage basin in the eastern part of the Jehol Massif. In the area west of the Sung-ling range, the river flows through a valley following the tectonic line, but in the middle reaches it becomes an obsequent stream cutting across the Sung-ling range, and then flows into Liao-tung Bay. The upper course of the river consists of two branch streams, one flowing southeast through Ling-yuan, and the other running northeast through Ling-nan. They join in the broad basin of Ta-cheng-tzu.

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Topography of the Liao-Tung Peninsula

Sadajirō Tsuchida

General Description

The backbone range of the Liao-tung Peninsula runs northeast to southwestward and consists of part of the mountain range running in the Sinian direction* (R. Pumpelly).[1]** The shape of this peninsula is controlled by geologic structure. Since it deviates somewhat more to the north than in the Sinian direction proper, it is called the "Liao-tung direction."[2] The area has been investigated by many geologists[3-11] whose results have already been published, according to which granite, gneiss and quartzite predominate in the peninsula. Especially, the Sinian Ta-ho-shang-shan series[10] is distributed extensively in the beginning and terminal parts of this peninsula. No Tertiary sediments are found there, and the only Quaternary sediments are peat[26], which contains *Nelumbo* sp., and terrace gravel which is distributed sporadically. Fossils that are useful for age determination [index fossils] have not yet been found in the strata.

Here and there in this region, erosion surfaces exist which truncate the complicated geologic structures. These surfaces were once recognized as the ultimate plane of the eroded topography, which was called the "Liao-tung peneplane".[13,32]

The existence of an erosion surface in the Liao-tung Peninsula has already been reported by several geologists, namely Hanzō Murakami[4] (1915; p. 3, 8, 12), Otoji Aoji[5] (1924; p. 3, 5), Susumu Matsushita[3] (1930; p. 2), Toshio Ōtani[11] (1933) and Heiichi Takehara[32] (1934). It was also reported by students of topography, such as Jūji Hanai[13] (1928) and Masahide Kajiyama[14] (1932). The writer and the late Zenkyō Imamura[28] investigated the erosion surfaces in the northern part of the former Kuan-tung Province under the kind direction of Dr. Riuji Endō.

Blackwelder[24] (1907; p. 86) once stated that "the topography of the preceding cycle was so completely removed that the original topographic forms were not preserved." However, remnants of an old flat surface came to be known by each of the investigators described above.

* In the direction of China.

** Numbers in parentheses designate corresponding references at end of translation.

1. Analysis of the erosion surfaces

It became clear that three planes had devoloped on the Liao-tung Peninsula, as a result of investigating the detailed classification and history of the topographic forms. Among these forms, the relatively complete surface of the P'i-tzu-wo peneplane, which is situated in the lowest position, 20 to 50 m above sea level, is preserved. The Kuang-ning-ssu peneplane exists 120 to 300 m above the P'i-tzu-wo peneplane, and is much more dissected. At the highest altitude, 300 to 400 m above present sea level, remnants of the Ping-shan peneplane, which occupies small areas, are distributed sporadically.

Using all 1:25,000 topographic maps (52 sheets), the author compiled restoration maps, with 50 m contour intervals, in which valleys 250 m wide are "buried" [E.N.; literal translation; probably meaning an imaginary topography for the purpose of coordination assuming that all valleys are 250 m wide and are filled with sediment]. Referring to these restoration maps and the geologic map,[5] 27 planes, each with remarkable features, were selected.

The 27 planes selected were divided into squares, 4 km per side, and several methods of geomorphometry were employed for each plane. For convenience, areas are designated a, b, c, etc. (see Fig. 1).

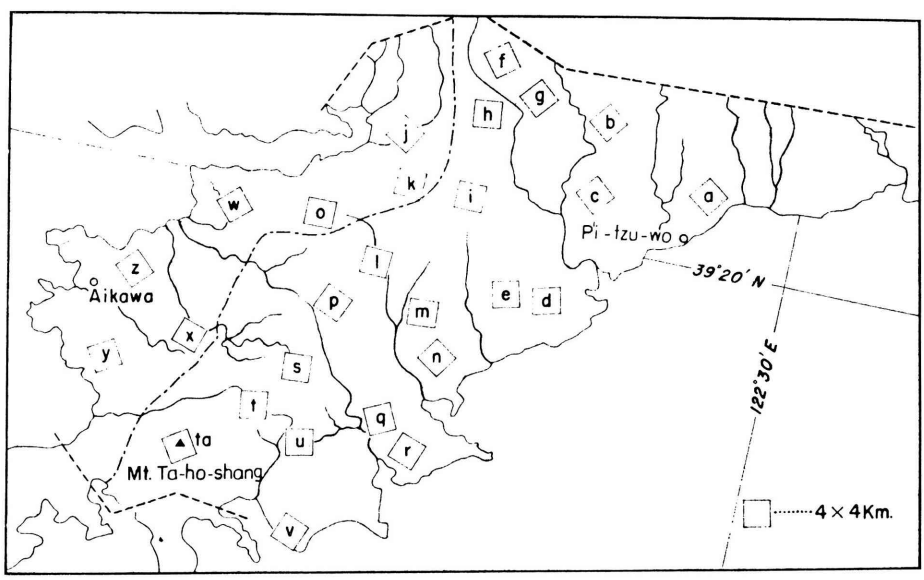

Fig. 1. Distribution Map of Measured Areas.

Prior to measurement, this region was divided into two parts, eastern and western, because each erosion plane included in the area to be measured is different. In addition, erosion surfaces are sometimes different, even if they were subjected to the same erosion during the same period. TAYAMA[22] indicated the

following four causes for differential erosion; (1) difference in lithology, (2) difference in the stratigraphical sequence, (3) difference in meteorological conditions (especially in the amount of rainfall) and (4) inclination of plane.

Remarkable differences in this region are seen in lithologic features. Gneiss occurs extensively in the eastern area while Ta-ho-shang Shan quartzite crops out along the coast in the southern part. In the western part, Sinian and post-Sinian sedimentary rocks predominate. The rock formations of the western part and the gneiss group of the eastern part contact unconformably,[3] and by thrust[23] and normal faults. Consequently, the boundary line between these two rock groups was applied as the dividing line of this region, that is, between the eastern and western parts. However, Ta-ho-shang Shan and the area east of it were included in the eastern part, because it was found that the characteristics of the surface are similar to those of the eastern part when referring to a restoration map with a 50 m contour interval.

According to investigations on the structure of this region by Hanzō MURAKAMI,[4] Otoji AOJI,[5] Susumu MATSUSHITA,[7] Mitsuo NODA[23] and others, the region had been subjected to moderately complicated faulting and folding. However, since the movements were old, they may not be shown directly by topographic features at the present time. These were not recognized in the field work. Jūji HANAI[13] states that any faults that truncated and displaced the dissected planes after their formation were not found either (see HANAI, 1928 and 1933, p. 358 and MATSUSHITA, 1930 p. 5).

It is assumed that the amounts of rainfall in these two areas are approximately the same because of their proximal location; therefore, as already described, this region was divided into eastern and western parts according to lithology alone. (see Fig. 1).

A. Erosion surfaces of the eastern part

1. *Classification of planes according to length of contour lines*

Gneiss is predominant in the eastern part of this region, except for several small areas. However, classification was made assuming that all areas were the same.

It is thought that these areas were very flat at the time the Liao-tung peneplane was completed. If this is true, it may be assumed that this plane was subjected to the same degree of dissection at the same time. If there are several planes in this region, it may also be assumed that the older plane was subjected to a higher degree of dissection than the younger plane. Therefore, if the degree of dissection (r_1) of each plane is measured, the number of planes and the relationship between new and old planes may be estimated.

As one method, the author measured the length of contour lines. If the conditions for erosion, except for the time factor, are the same throughout all areas, the length of the contour line in the unit area indicates not only the density of the valleys, which represents the degree of dissection, but also the degree of inclination of the surface formed during the same period in each area of measurement. Two

Table 1. Results of Measurement (50 m contour map)

	a						b						c						d						e					
S.R.	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Σ	1.8	1.8	1.8	3.3	4.3	4.1	40.9	20.0	16.1	11.8	10.6	10.1	35.1	23.6	18.3	12.4	9.3	8.0	0.0	0.0	0.0	0.0	0.0	0.0	27.5	21.0	19.6	17.4	13.8	10.8
r_1	0.1	0.1	0.1	0.2	0.3	0.3	2.6	1.3	1.0	0.7	0.7	0.6	2.2	1.5	1.1	0.8	0.6	0.5							1.7	1.3	1.2	1.1	0.9	0.7
Δ							1.3	0.3	0.3	0.0			0.7	0.4	0.3	0.2									0.4	0.1	0.1	0.2		
r_2							2.0	0.7	0.4	0.1	0.1		1.7	1.0	0.6	0.3	0.1								1.0	0.6	0.5	0.4	0.2	
ha	50						100						70						40						70					
hm	20						50						50						20						40					
m_1	0.18						1.15						1.12												1.15					
m_2							0.66						0.72												0.54					
m_3							0.40						0.40												0.20					
L.C.	G						G						G						G						G					

	f						g						h						i						l					
S.R.	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Σ	51.0	32.3	23.6	20.3	19.9	16.9	45.0	27.3	20.8	16.8	14.6	13.1	42.6	29.4	20.0	15.1	12.9	12.8	46.5	32.6	22.1	15.5	11.6	10.6	0.6	0.6	0.6	1.5	1.5	1.5
r_1	3.2	2.0	1.5	1.3	1.2	1.1	2.9	1.7	1.3	1.1	0.9	0.8	2.7	1.8	1.3	0.9	0.8	0.8	2.9	2.0	1.4	1.0	0.7	0.7	0.04	0.04	0.04	0.1	0.1	0.1
Δ	1.2	0.5	0.2	0.1			1.2	0.4	0.2	0.2			0.9	0.5	0.4	0.1			0.9	0.6	0.4	0.3								
r_2	2.1	0.9	0.4	0.2	0.1		2.1	0.9	0.5	0.3	0.1		1.9	1.0	0.5	0.1			2.2	1.3	0.7	0.3								
ha	150						150						130						170						50					
hm	70						50						50						60						30					
m_1	1.71						1.45						1.33						1.45						0.03					
m_2	0.72						0.78						0.88						0.90											
m_3	0.42						0.45						0.38						0.44											
L.C.	G						G						Ss, Sh, Cg						G						G					

Table 1. (Continued)

	m						n						p						q						r					
S.R.	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Σ	24.0	19.8	16.9	14.9	11.5	11.0	0.0	0.0	0.0	0.0	0.0	0.0	18.6	16.3	12.6	8.8	4.0	1.8	0.6	0.6	0.6	0.6	0.6	0.6	88.9	64.1	54.4	47.6	46.6	42.5
r_1	1.5	1.2	1.1	0.9	0.7	0.7							1.1	1.0	0.8	0.5	0.3	0.1	0.04	0.04	0.04	0.04	0.04	0.04	5.6	4.0	3.4	3.0	2.9	2.7
Δ	0.3	0.1	0.2	0.2									0.1	0.2	0.3	0.2									1.6	0.6	0.4	0.1		
r_2	0.8	0.5	0.4	0.2									1.0	0.9	0.7	0.4	0.2								2.9	1.3	0.7	0.3	0.2	
ha	70						40						100						50						320					
hm	50						20						60						30						50					
m_1	1.02												0.63						0.04						3.60					
m_2	0.38												0.64												1.08					
m_3	0.16												0.20												0.58					
L.C.	G						G						G						G						Q, Ssl					

	s						t						u						v						ta					
S.R.	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Σ	41.8	28.0	20.8	13.1	12.5	10.4	41.6	24.8	16.3	11.5	10.4	10.4	93.5	59.1	35.6	29.8	26.0	23.8	82.5	58.2	49.6	43.2	36.8	34.3	124.6	107.9	86.1	72.2	66.6	66.6
r_1	2.6	1.8	1.3	0.8	0.8	0.7	2.6	1.6	1.0	0.7	0.7	0.7	5.8	3.6	2.2	1.9	1.6	1.5	5.2	3.6	3.1	2.7	2.3	2.1	8.7	6.7	5.4	4.5	4.1	4.1
Δ	0.8	0.5	0.5				1.0	0.6	0.3				2.2	1.4	0.3	0.3			1.6	0.5	0.4	0.4			2.0	1.3	0.9	0.4		
r_2	1.9	1.1	0.6	0.1	0.1		1.9	0.9	0.3				4.3	2.1	0.7	0.4	0.1		3.1	1.5	1.0	0.6	0.2		3.7	2.6	1.3	0.4		
ha	190						170						250						270						660					
hm	100						110						20						50						60					
m_1	1.33						1.22						2.77						3.17						5.43					
m_2	0.76						0.62						1.52						1.28						1.60					
m_3	0.38						0.38						0.86						0.62						0.74					
L.C.	G						G						G						Q, Ls, Sh						Q					

Table 2. Results of Measurement (10 m contour map)

	a						b						c						d					
S.R.	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Σ	67.5	47.6	37.8	35.9	28.9	25.4	120.9	82.0	62.1	53.0	47.4	45.7	126.5	82.3	59.4	45.2	36.1	32.2	60.6	46.9	39.1	34.0	30.0	24.4
r_1	4.2	3.0	2·3	2.2	1.8	1.6	7.5	5.1	3.9	3.4	3.0	2.9	7.9	5.1	3.7	2.8	2.3	2.0	3.3	2.9	2.4	2.1	1.9	1.5
Δ	1.2	0.7	0.1	0.4	0.2		2.4	1.2	0.5	0.4	0.1		2.8	1.4	0.9	0.5	0.3		0.9	0.5	0.3	0.2	0.4	
r_2	2.6	1.4	0.7	0.6	0.2		5.6	3.2	2.0	1.5	1.1		5.9	3.1	1.7	0.8	0.3		2.3	1.4	0.9	0.6	0.4	
m_1	2.52						4.13						3.95						2.43					
m_2	1.10						2.68						2.36						1.12					
m_3	0.52						1.12						1.18						0.46					

	e						f						g						h					
S.R.	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Σ	93.9	68.3	52.4	41.4	33.1	28.3	230.1	161.5	116.4	97.6	88.9	79.5	185.2	121.8	97.2	83.1	75.9	70.4	174.5	129.4	79.1	83.8	75.0	74.4
r_1	5.9	4.3	3.3	2.6	2.1	1.8	14.4	10.1	7.2	6.1	5.6	5.0	11.6	7.6	6.1	5.2	4.7	4.4	11.0	8.1	6.1	5.2	4.7	4.6
Δ	1.6	1.0	0.7	0.5	0.3		4.3	2.9	1.1	0.5	0.6		4.0	1.5	0.9	0.5	0.3		2.9	2.0	0.9	0.5	0.1	
r_2	4.2	2.6	1.6	0.9	0.4		9.4	5.1	2.2	1.1	0.6		7.2	3.2	1.7	0.8	0.3		6.4	3.5	1.5	0.6	0.1	
m_1	3.33						8.07						6.60						6.78					
m_2	1.94						3.68						2.64						2.42					
m_3	0.84						1.88						1.44						1.28					

Table 2. (Continued)

	i						l						m						n					
S.R.	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	II	II	III	IV	V	VI
Σ	195.1	139.5	100.6	77.9	67.5	64.0	40.8	28.9	27.8	26.5	22.1	19.4	67.5	52.9	43.5	38.6	28.1	24.9	40.5	34.0	29.4	25.8	24.9	23.0
r_1	12.2	8.7	6.3	4.9	4.2	4.0	2.5	1.8	1.7	1.7	1.4	1.2	4.2	3.5	2.6	2.2	1.8	1.6	2.5	2.1	1.8	1.6	1.6	1.4
Δ	3.5	2.4	1.4	0.7	0.2		0.7	0.1	0.3	0.2			0.7	0.7	0.4	0.4	0.2		0.4	0.3	0.2	0.2		
r_2	8.3	4.8	2.1	0.7	0.2		1.3	0.6	0.5	0.5	0.2		2.4	1.7	1.0	0.6	0.2		1.1	0.7	0.4	0.2	0.2	
m_1	6.72						1.72						2.67						1.83					
m_2	3.22						0.62						1.18						0.52					
m_3	1.60						0.26						0.48						0.22					

	p						q						s						t					
S.R.	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Σ	77.3	65.3	53.1	46.3	37.4	33.5	60.1	47.0	36.5	33.1	26.1	20.9	207.1	141.4	100.8	80.8	64.8	56.4	212.8	133.6	89.4	68.4	56.6	50.1
r_1	4.8	4.1	3.3	2.9	2.3	2.1	3.8	3.0	2.3	2.1	1.6	1.3	12.9	8.8	6.3	5.0	4.0	3.5	13.3	8.3	5.6	4.3	3.5	3.1
Δ	0.7	0.8	0.4	0.6	0.2		0.8	0.7	0.2	0.5	0.3		4.1	2.5	1.3	1.0	0.5		5.0	2.7	1.3	0.8	0.4	
r_2	2.7	2.0	1.2	0.8	0.2		2.5	1.7	1.0	0.8	0.3		9.4	5.3	2.8	1.5	0.5		10.2	5.2	2.5	1.2	0.4	
m_1	3.25						2.35						6.75						6.35					
m_2	1.38						1.26						3.90						3.90					
m_3	0.54						0.50						1.88						2.02					

methods were adopted for measuring the lengths of contours. One, restoration maps with 50 m contour intervals were made for the whole area, and the length of the contour lines included in the measured areas, 4 square km, which was determined previously, was measured during each stage of restoration; in the other method, the length of contour lines was measured from restoration maps which were made using a 10 m contour interval. The width of the valley buried during the restoration work and each stage of restoration are as follows:

The present topography ..... 1st stage (I)*
Topography in which valleys 200 m wide were buried,
on the basis of the present topography ..... 2nd stage (II)
Topography in which valleys 400 m wide were buried,
on the basis of the 2nd stage ..... 3rd stage (III)
Topography in which valleys 600 m wide were buried,
on the basis of the 3rd stage ..... 4th stage (IV)
Topography in which valleys 800 m wide were buried,
on the basis of the 4th stage ..... 5th stage (V)
Topography in which valleys 1,000 m wide were buried,
on the basis of the 5th stage ..... 6th stage (VI)

The results of measurement using the restoration map with a 50 m contour interval are given in Table 2. The meanings of the symbols used in these tables are as follows:

S.R. ..... Stage of restoration
Σ ..... Sum of contour lengths in each measuring area (unit km).
r_1 ..... $\frac{\Sigma}{s}$ Value of Σ divided by the measured area (16 sq. km), namely the average length (km) of the contour in 1 sq. km in each area.
Δ ..... Difference between r_1 in each stage and its following stage of restoration; (I r_1–II r_1), (II r_1–III r_1), (III r_1–IV r_1), (IV r_1–V r_1), (V r_1–VI r_1) and so on.
r_2 ..... Difference between r_1 in each stage of restoration (I to V) and r_1 of stage VI. (Exponent of dissection)
ah ..... Absolute height of the highest point in the present topography in each area (unit m).
mh ..... Mean height in each area (the longest contour within each area in the present topography) (unit m).
m_1 ..... Mean value of r_1 for all stages (unit km).
m_2 ..... Mean value of r_2 for all stages (unit km).
m_3 ..... Mean value of Δ for all stages (unit km).
L.C. ..... Rocks which constitute the foundation of each measured area (see references 3, 5, and 8).

G—gneiss Ss—sandstone Q—quartzite Sh—shale
Ls—limestone Cg—conglomerate Ssl—siliceous slate

* Roman numerals used in tables designate each stage.

a. Classification by r_1. The value of r_1 obtained in this work is related to the density of valleys, representing the inclination of each stage of restoration. Classification of each measured area by the density of the valleys represented by r_1 is shown in Tables 3 and 4. In these tables, the values of r_1 for each stage of restoration are arranged in order of size, where δ is the difference between adjacent stages. The fact that δ is almost the same for any group of areas means that r_1 changes gradually, and that the areas are included in the same plane. On the contrary, the fact that δ suddenly shows a large value means that those two areas are included in different planes and the boundary is δ. In Tables 3 and 4, these points are marked by bold lines (called transformation points).

Looking at Table 3, a boundary line can be drawn between the plane of the sixth rank and the plane of the seventh rank in the order of dissection.

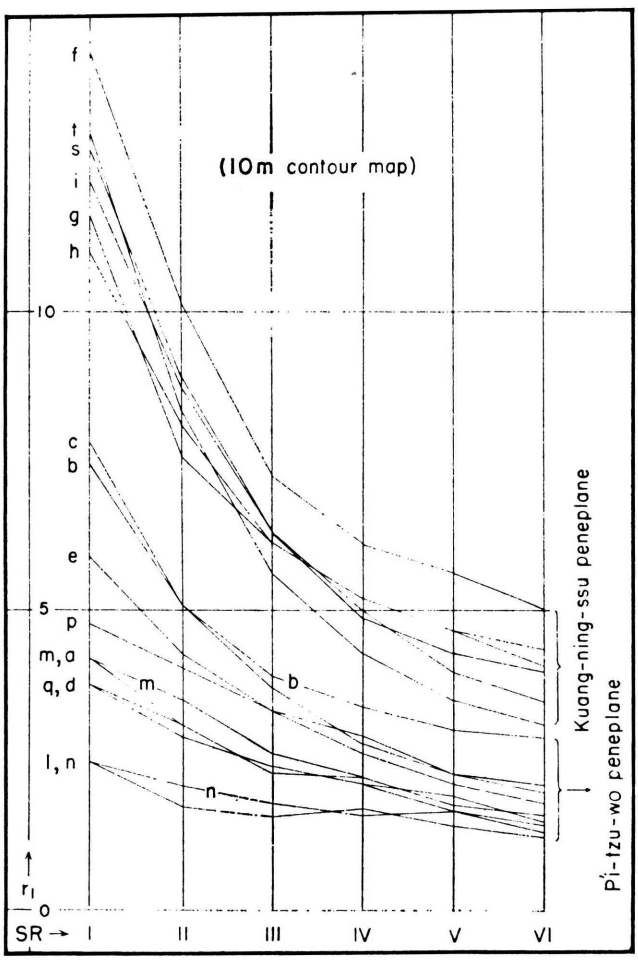

Fig. 2. r_1 (10 m contour map).

Table 3. r_1, δ (10 m contour map).

S.R.	Order of dissection	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
I	Area	f	t	s	i	g	h	c	b	e	p	a	m	d	p	n	l
	r_1	14.4	13.1	12.9	12.2	11.6	11.0	7.9	7.5	5.9	4.8	4.2	4.2	3.8	3.8	2.5	2.5
	δ	1.3	0.2	0.7	0.6	0.6	3.1	0.4	1.6	1.1	0.6	0.0	0.4	0.0	1.3	0.0	
II	Area	f	s	i	t	h	g	c	b	e	p	m	a	q	d	n	l
	r_1	10.1	8.8	8.7	8.3	8.1	7.6	5.1	5.1	4.3	4.1	3.5	3.1	3.1	2.9	2.1	1.8
	δ	1.3	0.1	0.4	0.2	0.5	2.5	0.0	0.8	0.2	0.6	0.4	0.0	0.2	0.8	0.3	
III	Area	f	i	s	g	h	t	b	c	e	p	m	d	a	q	n	l
	r_1	7.2	6.3	6.3	6.1	6.1	5.6	3.9	3.7	3.3	3.3	2.6	2.4	2.3	2.3	1.8	1.7
	δ	0.9	0.0	0.2	0.0	0.5	1.7	0.2	0.4	0.0	0.7	0.2	0.1	0.0	0.5	0.1	
IV	Area	f	g	h	s	i	t	b	p	c	e	a	m	d	q	l	n
	r_1	6.1	5.2	5.2	5.0	4.9	4.3	3.4	2.9	2.8	2.6	2.2	2.2	2.1	2.1	1.7	1.6
	δ	0.9	0.0	0.2	0.1	0.6	0.9	0.5	0.1	0.2	0.4	0.0	0.1	0.0	0.4	0.1	
V	Area	f	g	h	i	s	t	b	c	p	e	d	a	m	n	q	l
	r_1	5.6	4.7	4.7	4.2	4.0	3.5	3.0	2.3	2.3	2.1	1.9	1.8	1.8	1.6	1.6	1.4
	δ	0.4	0.0	0.5	0.2	0.5	0.5	0.7	0.0	0.2	0.2	0.1	0.0	0.2	0.0	0.2	
VI	Area	f	h	g	i	s	t	p	c	b	e	a	m	d	n	q	l
	r_1	5.0	4.6	4.4	4.0	3.5	3.1	2.1	2.0	1.9	1.8	1.6	1.6	1.5	1.4	1.3	1.2
	δ	0.4	0.2	0.4	0.5	0.4	1.0	0.1	0.1	0.1	0.2	0.0	0.1	0.1	0.1	0.1	

Figure 2 was plotted using the value of r_1 given in Table 3 as the ordinate and the stage of restoration as the abscissa. The figure shows that the six areas (group 1) that were advanced in dissection are different from the other ten areas (group 2), according to the shape of the curve. As described later, group 1 is a remnant of the Ping-shan peneplane and group 2 is part of the Kuang-ning-ssu peneplane.

Table 4 was compiled by arranging the values of r_1 derived from the 50 m contour map in order, beginning with the largest value. Transformation points were determined in the same way as previously, and the areas were divided into three groups.

From the results given in Tables 3 and 4, the twenty areas can be divided into four groups, each group belonging to a peneplane.

Table 4. r_1, δ (50 m contour map).

S.R.	Order of dissection	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
I	Area	ta	u	r	v	f	g	i	h	s	t	b	c	e	m	p	a	q	l	d	n
	r_1	7.8	5.8	5.6	5.2	3.2	2.9	2.9	2.7	2.6	2.6	2.6	2.2	1.7	1.5	1.1	0.1	0.0	0.0	0.0	0.0
	δ		2.0	0.2	0.4	2.0	0.3	0	0.2	0.1	0	0	0.4	0.5	0.2	0.4	1.0	0.1	0	0	0
II	Area	ta	r	u	v	i	f	h	s	g	t	c	b	e	m	p	a	q	l	d	n
	r_1	6.7	4.0	3.7	3.6	2.0	2.0	1.8	1.8	1.7	1.6	1.5	1.3	1.3	1.2	1.0	0.1	0.0	0.0	0.0	0.0
	δ		2.7	0.3	0.1	1.6	0	0.2	0	0.1	0.1	0.1	0.2	0	0.1	0.2	0.9	0.1	0	0	0
III	Area	ta	v	r	u	f	i	g	h	s	e	m	c	b	t	p	a	q	l	d	n
	r_1	5.4	3.1	2.7	2.2	1.5	1.4	1.3	1.3	1.3	1.2	1.1	1.1	1.0	1.0	0.8	0.1	0.0	0.0	0.0	0.0
	δ		2.3	0.4	0.5	0.7	0.1	0.1	0	0	0.1	0.1	0	0.1	0	0.2	0.7	0.1	0	0	0
IV	Area	ta	r	v	u	f	g	e	i	h	m	c	s	b	t	p	a	l	q	d	n
	r_1	4.5	3.0	2.7	1.9	1.3	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.5	0.2	0.1	0.0	0.0	0.0
	δ		1.5	0.3	0.8	0.6	0.2	0	0.1	0.1	0	0.1	0	0.1	0	0.2	0.3	0.1	0.1	0	0
V	Area	ta	r	v	u	f	g	e	h	s	b	i	m	t	c	a	p	l	q	d	n
	r_1	4.1	2.9	2.3	1.6	1.2	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.3	0.3	0.1	0.0	0.0	0.0
	δ		1.2	0.6	0.7	0.4	0.3	0	0.1	0	0.1	0	0	0	0.1	0.3	0	0.2	0.1	0	0
VI	Area	ta	r	v	u	f	g	h	i	e	m	s	t	b	c	a	p	l	q	d	n
	r_1	4.1	2.7	2.1	1.5	1.1	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.5	0.3	0.1	0.1	0.0	0.0	0.0
	δ		1.4	0.6	0.6	0.4	0.3	0	0.1	0	0	0	0	0.1	0.1	0.2	0.2	0	0.1	0	0

Group 1: ta....Ta-ho-shang Shan monadnock
Group 2: u, r, v....Ping-shan peneplane
Group 3: f, g, h, i, s, t....Kuang-ning-ssu peneplane
Group 4: b, c, e, m, p, a, q, l, d, n....P'i-tzu-wo peneplane

b. Classification by r_2. Let r_1 of stage VI be the inclination of the original topography, assuming complete restoration of the original topography in the case

of a valley 1 km wide being buried (the terminal topography of the former cycle). In this case, r_2, the difference between r_1 of stage VI and r_1 of each stage from I to V is taken as the index number showing the degree of dissection in each stage of restoration.[22] The index number of dissection, r_2, represents the old and new planes, as the degree of dissection is proportional to the time, assuming that factors other than time remain constant. Therefore, we can divide each area into groups according to the value of r_2. Tables 5 and 6 are obtained by arranging them in order, beginning with the largest, in the same way as r_1, which was described before. The values of r_2 on the restoration maps with 10 m and 50 m contour

Table 5. r_2, δ (10 m contour map).

S.R.	Order of dissection	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
I	Area	t	f	s	i	g	h	c	b	e	p	a	m	q	d	l	m
	r_2	10.2	9.4	9.4	8.2	7.2	6.4	5.9	5.6	4.2	2.7	2.6	2.6	2.5	2.4	1.3	1.1
	δ	0.8	0	1.2	1.0	0.8	0.5	0.3	1.4	1.5	0.1	0	0.1	0.1	1.1	0.2	
II	Area	s	t	f	i	h	b	g	c	e	p	m	q	a	d	n	l
	r_2	5.3	5.2	5.1	4.7	3.5	3.2	3.2	3.1	2.6	2.0	1.9	1.7	1.4	1.4	0.7	0.5
	δ	0.1	0.1	0.4	1.2	0.3	0	0.1	0.5	0.6	0.1	0.2	0.3	0	0.7	0.2	
III	Area	t	i	f	b	c	g	h	e	p	m	q	d	s	a	l	n
	r_2	2.4	2.3	2.2	2.0	1.7	1.7	1.5	1.5	1.2	1.0	1.0	0.9	0.8	0.7	0.5	0.4
	δ	0.1	0.1	0.2	0.3	0	0.2	0	0.3	0.2	0	0.1	0.1	0.1	0.2	0.1	
IV	Area	c	b	s	t	f	i	g	e	q	p	d	h	m	l	a	n
	r_2	1.8	1.5	1.5	1.2	1.1	0.9	0.8	0.8	0.8	0.8	0.6	0.6	0.6	0.5	0.4	0.2
	δ	0.3	0	0.3	0.1	0.2	0.1	0	0	0	0.2	0	0	0.1	0.1	0.2	
V	Area	b	f	s	d	t	c	g	e	q	a	i	m	n	l	p	h
	r_2	1.1	0.6	0.6	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1
	δ	0.5	0	0.2	0	0.1	0	0	0	0.1	0	0	0	0	0	0	0.1

intervals are shown in Tables 5 and 6, respectively. This suggests that it is difficult to distinguish each group completely. Figure 3 (r_2 in Table 5) and Figure 4 (r_2 in Table 6) were drawn in order to distinguish the groups of areas. As these two

Table 6. r_2, δ (50 m contour map).

S.R.	Order of dissection	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
I	Area	u	ta	v	r	i	f	g	b	h	s	t	c	e	p	m	a	b	n	q	l
	r_2	4.3	3.7	3.1	2.9	2.2	2.1	2.1	2.0	1.9	1.9	1.9	1.7	1.0	1.0	0.8	0.0	0.0	0.0	0.0	0.0
	δ	0.6	0.6	0.2	0.7	0.1	0	0.1	0.1	0	0	0.2	0.7	0	0.2	0.8					
II	Area	ta	u	v	i	r	s	c	h	f	g	p	t	b	e	m	a	d	n	q	l
	r_2	2.5	2.1	1.5	1.3	1.3	1.1	1.0	1.0	0.9	0.9	0.9	0.9	0.7	0.6	0.5	0.0	0.0	0.0	0.0	0.0
	δ	0.4	0.6	0.2	0	0.2	0.1	0	0.1	0	0	0	0.2	0.1	0.1	0.5					
III	Area	ta	v	i	r	u	p	c	s	g	h	e	b	f	m	t	a	d	n	q	l
	r_2	1.3	1.0	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.0	0.0	0.0	0.0	0.0
	δ	0.3	0.3	0	0	0	0.1	0	0.1	0	0	0.1	0	0	0.1	0.3					
IV	Area	v	e	u	p	ta	t	c	g	i	r	f	m	b	h	s	a	d	n	q	l
	r_2	0.6	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
	δ	0.2	0	0	0	0	0.1	0	0	0	0.1	0	0.1	0	0	0.1					
V	Area	e	r	v	p	b	c	f	g	u	s	ta	t	i	m	h	a	d	n	q	l
	r_2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	δ	0	0	0	0.1	0	0	0	0	0	0.1	0	0	0	0	0					

figures were formed by plotting r_1 as the ordinate and the stage of restoration as the abscissa, the curve with the largest curvature is the oldest plane. That is, we can distinguish between the groups of areas through the figures.

The four curves of areas ta, u, r and v, based on Figure 4 because they do not exist in Figure 3, have larger curvatures than other curves.

Group 1: ta, u, v, r

Group 2: f, t, s, i, g, h

Sub-group 2: c, e
Group 3: a, b, d, p, q, m
Sub-group 3: l, n

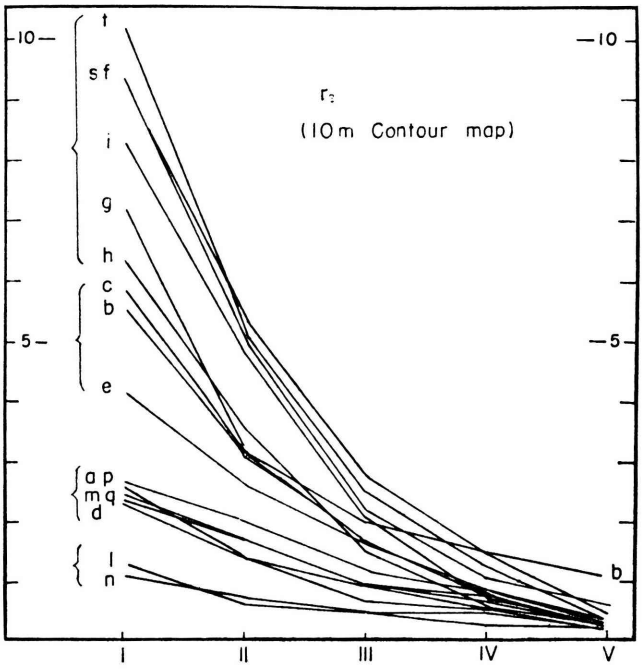

Fig. 3. r_2 (10 m contour map).

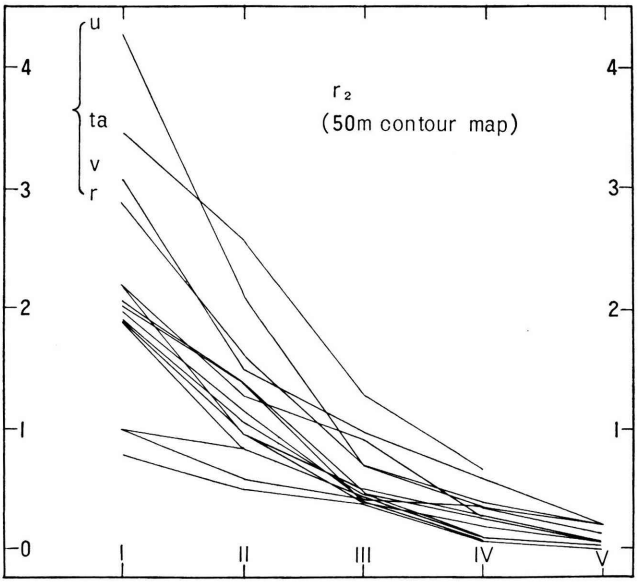

Fig. 4. r_2 (50 m contour map).

c. Classification by Δ. Δ is the difference between r_1 in each stage and its following stage of restoration. Therefore, the size of Δ is related to the curvature of r_2, and the old and new planes belonging to each area may be deduced from this relationship. Tables 7 and 8 are obtained by arranging Δ in order of size; Table 7 was based on the restoration map with a 10 m contour interval and Table 8 on the 50 m contour interval map. In these tables, the values of Δ to Δ_4 are the differences between the I and II, II and III, III and IV, and IV and V stages of restoration. Using these tables, Figure 5 was plotted using values of Δ as the ordinate and the stage of Δ as the abscissa. The following two groups can be seen in this figure.

Group 1: t, f, s, g, i, h, c, b

Group 2: e, a, q, d, p, l, m, n

Table 7. Δ_{1-4}, δ (10 m contour map).

S.R.	Order of dissection	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
I	Area	t	f	s	g	i	h	c	b	e	a	d	q	l	p	m	n
	Δ_1	5.0	4.3	4.1	4.0	3.5	2.9	2.8	2.4	1.6	1.2	0.9	0.8	0.7	0.7	0.7	0.4
	δ	0.7	0.2	0.1	0.5	0.6	0.1	0.4	0.8	0.4	0.3	0.1	0.1	0.3			
II	Area	f	t	s	i	h	g	c	b	e	m	p	a	q	d	n	l
	Δ_2	2.9	2.7	2.5	2.4	2.0	1.5	1.4	1.2	1.0	0.9	0.8	0.7	0.7	0.5	0.3	0.1
	δ	0.2	0.2	0.1	0.4	0.5	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.2	
III	Area	i	s	t	f	c	g	h	e	b	p	m	d	q	n	a	l
	Δ_3	1.4	1.3	1.3	1.1	0.9	0.9	0.9	0.7	0.5	0.4	0.4	0.3	0.2	0.2	0.1	0.0
	δ	0.1		0.2	0.2		0.2	0.2	0.1		0.1	0.1		0.1			
IV	Area	s	t	i	p	c	f	g	h	q	a	b	e	m	l	d	n
	Δ_4	1.0	0.8	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.2	0.0
	δ	0.2	0.1		0.2			0.1						0.1	0.1	0.2	

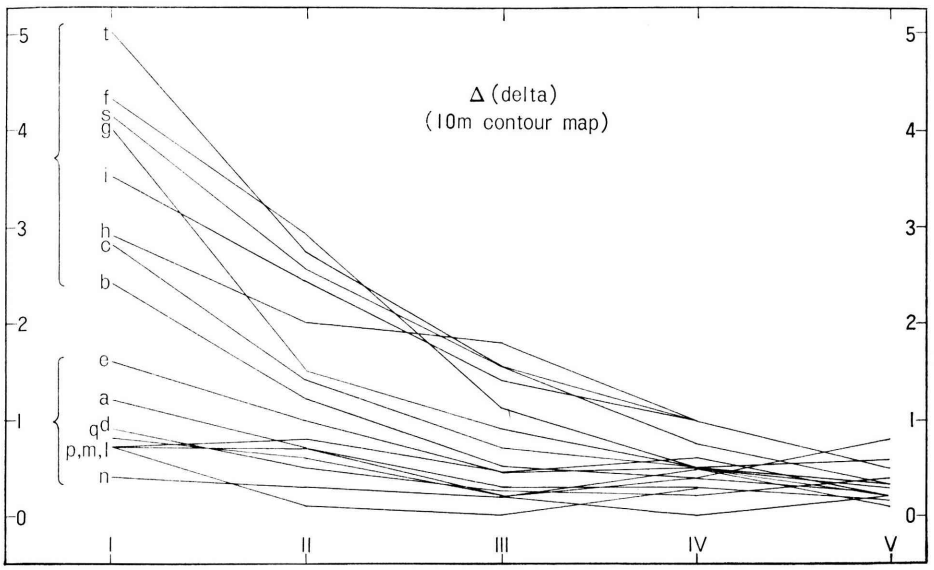

Fig. 5. Δ (10 m contour map).

In order to examine the four areas u, v, r and ta, which are not included in these groups, Table 8 was compiled from the restoration map with a 50 m contour interval. This table shows that the four areas should be included in group 1, and the value of Δ is larger than the area included in group 2. Adding these four areas:

Group 1: ta, u, v, r, t, f, s, g, i, h, c, b

Group 2: e, a, q, d, p, l, m, n

2. *Classification of planes by absolute height*

As older planes remained at higher altitudes, under the assumption that no crustal movement took place since the end of the preceding cycle in this region, it is believed that higher planes should be older than lower ones. To classify planes, the highest point (one point) within each area was applied to the height of the area (the height of the plane at the end of the preceding cycle). Table 9 was obtained by arranging the highest points in order of size; transformation points, at which remarkable changes in height can be seen, are marked by bold lines. The following six groups were found:

Group 1: ta

Group 2: r

Group 3: v, u

Group 4: s, i, t, f, g, h

Group 5: b, p

Group 6: c, e, m, a, q, l, d, n

3. *Classification of planes by relief*

a. Classification by growth curves. A circle with a radius of 1,500 m was used to measure the relief. Concentric circles, whose centers are three peaks at

Table 8. Δ_{1-4}, δ (50 m contour map).

S.R.	Order of dissection	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
I	Area	u	r	v	b	f	g	ta	t	h	i	s	c	e	m	p	a	d	n	q	l
	Δ_1	2.2	1.6	1.6	1.3	1.2	1.2	1.1	1.0	0.9	0.9	0.8	0.7	0.4	0.3	0.1	0.0	0.0	0.0	0.0	0.0
	δ	0.6		0.3	0.1		0.1	0.1	0.1		0.1	0.1	0.3	0.1	0.2	0.1					
II	Area	u	ta	i	r	f	h	v	s	t	c	g	b	p	e	m	a	d	n	q	l
	Δ_2	1.5	1.3	0.9	0.6	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
	δ	0.2	0.4	0.3	0.1					0.1		0.1	0.1	0.1		0.1					
III	Area	ta	s	h	i	r	v	b	c	u	p	t	f	g	m	a	e	d	n	q	l
	Δ_3	0.9	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0
	δ	0.4	0.1				0.1					0.1			0.1		0.1				
IV	Area	ta	v	i	u	c	g	e	m	p	f	h	r	a	b	d	n	q	l	s	t
	Δ_4	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	δ		0.1		0.1					0.1				0.1							

optional positions in each area, in order of decreasing height, were drawn with radii of 0.5, 1.0 and 2.0 km. The differences in height between the centers of the circles (peaks) and the lowest points were obtained in turn from the small to the large circle. Then the average values for the differences in height between these three circles (relief) were calculated for each area and each kind of circle. By plotting the area of the circle as the ordinate and the relief as the abscissa, the relative curve between the relief and the area of the circle was obtained, as shown in

Figure 6. This curve[12] is represented by the equation $y=A(1-Bx)$, and is called a growth curve: x is the area (dimension), y the relief energy, B a constant (less than 1) and A is the limiting value of y.

This shows that the rate of relief decreases remarkably at a 1,500 m radius; therefore, the circle with a radius of 1.5 km was used for measuring the relief in this region. As seen in the figure, the growth curves may be grouped. It is true that low relief signifies a small degree of dissection, and such a plane is a newer one. Group 1 is the oldest and group 3 the newest (the above statement is con-

Table 9. Highest Points within Measured Areas.

Order of dissection	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Area	ta	r	v	u	s	i	t	f	g	h	b	p	c	e	m	a	q	l	d	n
ah	660	320	270	250	190	170	170	150	150	130	100	100	70	70	70	50	50	50	40	40
δ	340		50	20	60	20	20		20	30	30		30		20			10		
Group	1		2	3			4				5				6					

Table 10. Summary of Eastern Part.

Group	Gr. 1	Gr. 2 Ping-shan P.			Gr. 3 Kuang-ning-ssu P.								Gr. 4 P'i-tzu-wo P.							
Order of dissection	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Δ (delta)	ta	u	v	r	t	f	s	g	i	h	c	b	e	a	q	d	p	l	m	n
r_1	ta	u	r	v	f	g	h	i	s	t	b	c	e	m	p	a	q	l	d	n
r_2	ta	u	v	r	f	t	s	i	g	h	c	e	a	b	d	p	q	m	l	n
ah	ta	r	v	u	s	i	t	f	g	h	b	p	c	e	m	a	q	l	d	n
Growth curve	ta	r	v	u	f	g	i	h	s	t	c	b	e	i	g	m	a	p	d	n
Relief	ta	u	v	r	h	g	i	t	f	s	l	n	d	a	q	m	e	p	c	b
Average relief	ta	r	v	u	t	s	i	g	c	b	f	h	p	e	m	q	a	d	n	l

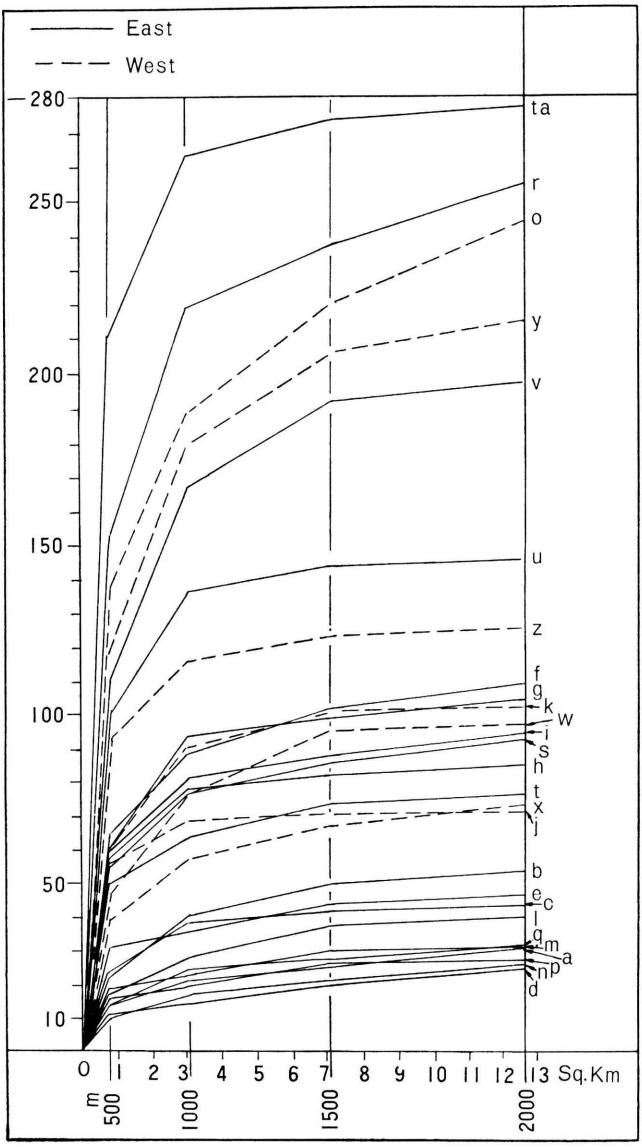

Fig. 6. Growth Curves—Eastern and Western Parts.

firmed in the eastern part of this region, and the growth curves for the western part have the same values as those for the eastern part).

b. Classification by frequency of relief. To obtain the relief, one area (16 sq. km) was covered with a net of 500 meter mesh. Placing the center of the 1.5 km (radius) circle described above on a point of intersection of the net, the difference between this crossing point (the center of the circle) and the lowest point within the circle were determined as the relief at this point. As a result, 81 relief values were obtained for one area. The curve of relief and frequency was made by plot-

ting the relief as the ordinate and the frequency obtained in each area as the abscissa. The fact that the curve with a higher inclination is nearer the ordinate means that the plane is flatter, and the curve that has a lower inclination and stretches toward the abscissa means that the plane is in a higher degree of dissection. Figure 7 was constructed by arranging each area in order from flat areas to

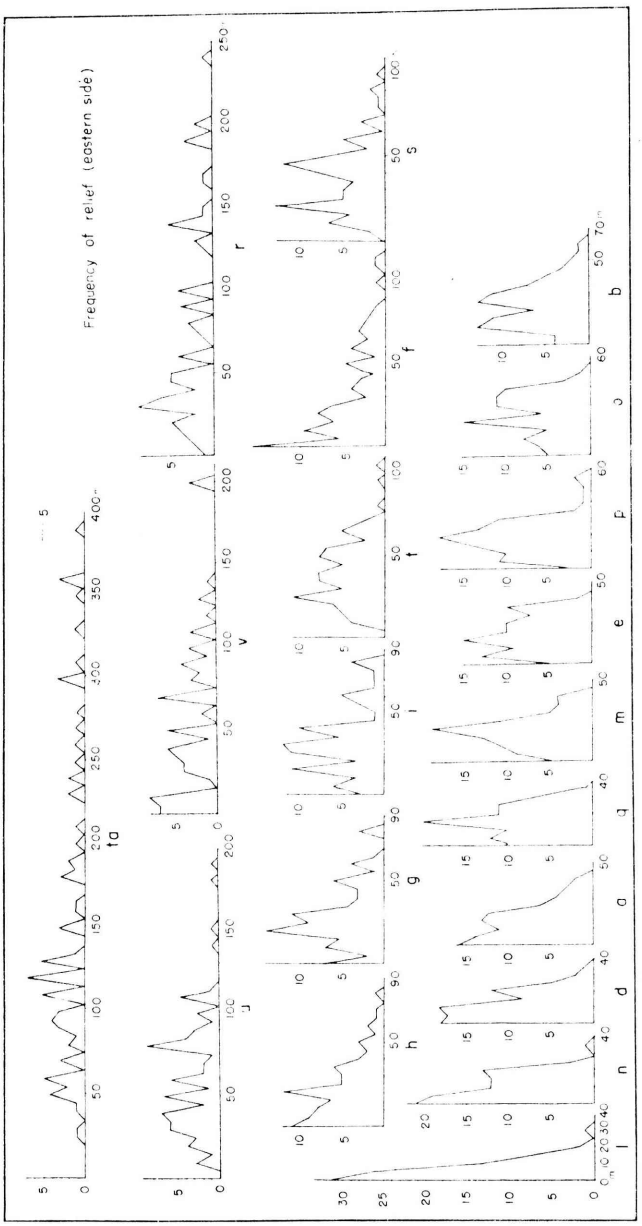

Fig. 7. Frequency of Relief.

areas with a higher degree of dissection. From the figure, the following four groups were found.

Group 1: ta
Group 2: u, v, r
Group 3: h, g, i, t, f, s
Group 4: l, n, d, a, q, m, e, p, c, b

Group 1 has the largest relief, and group 4 the smallest; that is, group 4 is of the youngest plane which was subjected to the lowest degree of dissection.

c. Classification by average relief. As described previously, 81 values of relief were obtained for each area. We obtained the arithmetical mean, and let it be the average relief of that area. A curve was obtained by arranging these values in order and plotting them as the ordinate and the relief as the abscissa, as in Figure 8.

Group 1: ta
Group 2: r, v, u
Group 3: t, s, i, g, c, b, f, h, p, e, m, q, a, d, n, l

4. *Summary of the eastern part*

The results of measuring, by various methods, the erosion surfaces of the eastern part distinctly confirmed that each area does not belong to one simple plane, as described above. Table 10 summarizes the results. Four groups were found using the means of distinction most common to each measuring method. On the map, the area belonging to group 4 is named the P'i-tzu-wo peneplane by the author and others.[28] The six areas in group 3 are included in a plane surface at a higher altitude than the P'i-tzu-wo peneplane, and in a higher degree of dissection. This is the Kuang-ning-ssu peneplane whose center is around Kuang-ning-ssu station

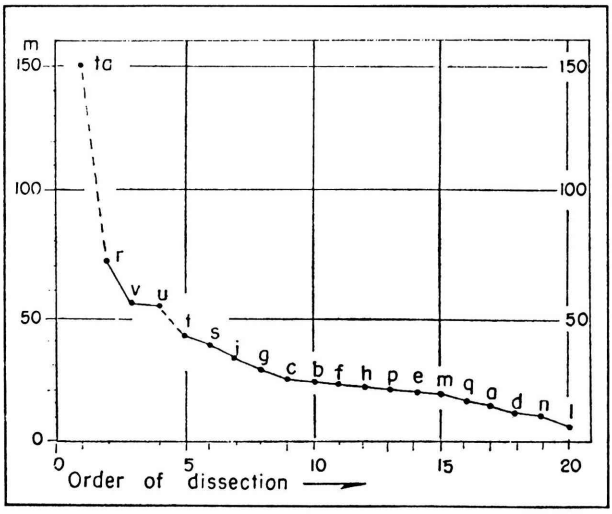

Fig. 8. Average Relief.

of the Chin-fu Railway. As shown in Table 10, this is distinguished from groups 2 and 3 by distinct boundaries and is not included in the same plane.

The second group (u, v, r) consists of areas which belong to the Pingshan plane[3] or the Ping-shan peneplane.[28] This shows greater dissection than the former peneplane, and is recognized only from its remnants, as shown in the table.

The fourth group (ta) was isolated in all methods of measurement, and is 200～300 m higher in absolute height than the Ping-shan peneplane; none compare with it. This already existed as a monadnock when the Ping-shan peneplane was completed, and is called the Ta-ho-shang Shan monadnock from the name of the mountain that exists in this area.

The heights of these peneplanes were obtained from Table 9, considering that the height of the highest peak in area a is near that of the original topography of the preceding cycle, to which that area belongs. According to Table 9, the Ping-shan peneplane is more than 250 m high, the Kuang-ning-ssu peneplane more than 130 m high and the P'i-tzu-wo peneplane more than 40 m high.

B. Erosion surfaces of the western part

Classification of the erosion surfaces of the western part was carried out in the same way as for the eastern part.

Table 11 summarizes each measured area classified by the various methods described above. All areas are classified into two groups; the first group is part of the Ping-shan peneplane and the second part of the Kuang-ning-ssu peneplane.

Table 11. Summary of Western Part.

Group	Gr. 1 Ping-shan P.		Gr. 2 Kuang-ning-ssu P.				
Order of dissection	1	2	3	4	5	6	7
Δ (delta)	y	o	k	x	w	j	z
r_1	y	o	k	z	x	w	j
r_2	y	o	k	x	w	z	j
ah	o	y	k	w	z	x	j
Growth curve	o	y	z	k	w	x	j
Relief	y	o	k	w	x	z	j

2. Distribution of erosion surfaces

The previous description shows that among the 27 areas measured, ta is the monadnock of Ta-ho-shang mountain and the other 26 areas are the products of peneplanation that occurred three times as follows.

1. Ta-ho-shang monadnock: ta
2. Ping-shan peneplane: u, v, r, y, o
3. Kuang-ning-ssu peneplane: t, f, s, g, i, h, k, x, w, j, z
4. P'i-tzu-wo peneplane: c, b, e, a, q, d, p, l, m, n

Figure 9 shows the distribution of each erosion surface on the restoration map with a 50 m contour interval, referring to the classification of these areas. In order to make the distribution of these three peneplanes more clear, Figure 10 was constructed.

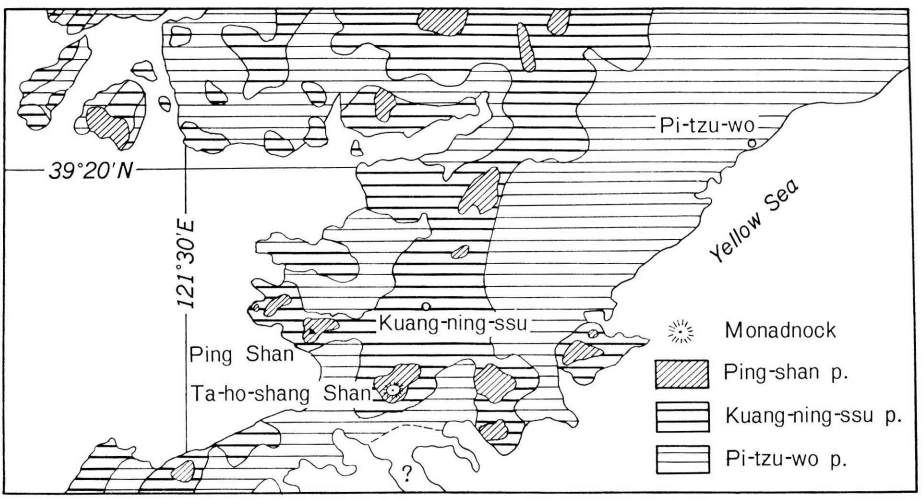

Fig. 9. Distribution of Erosion Surfaces (based on 50 m contour restoration map).

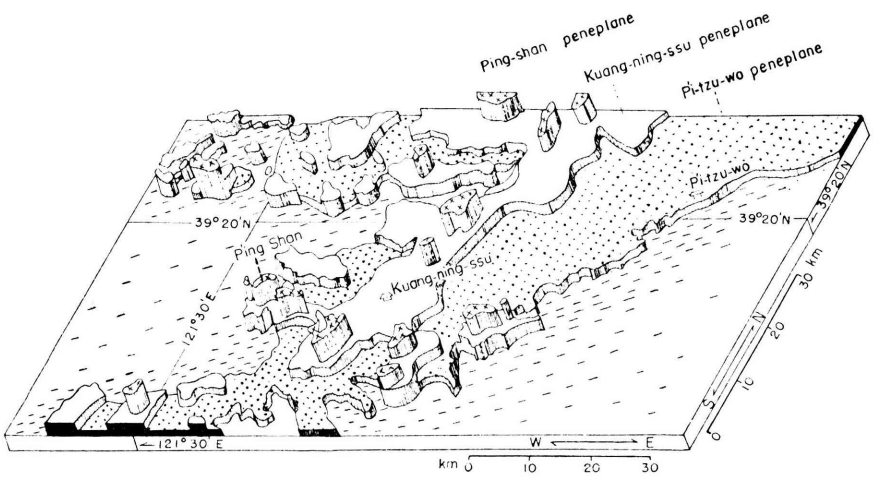

Fig. 10. Distribution of Ping-shan, Kuang-ning-ssu and P'i-tzu-wo Peneplanes.

A. P'i-tzu-wo peneplane

The P'i-tzu-wo peneplane is roughly 20 to 50 m above sea level and is quite

extensive in this region. The center is located at P'i-tzu-wo in the eastern part of this region, and the peneplane is traceable east and west.

B. Aikawa plane

On the P'i-tzu-wo peneplane, a comparatively lower plane, 10 meters above sea level, exists mainly along the shore-line. This plane can be distinguished from the P'i-tzu-wo peneplane through field examination.

C. Kuang-ning-ssu peneplane

As shown in Figure 10, remnants of the Kuang-ning-ssu peneplane occupy most of the central part of this region, and extend north-northeast to south-southwest. It is quite extensive in the region centered at Kuang-ning-ssu, 120 to 200 meters above sea level.

D. Ping-shan peneplane

Remnants of the Ping-shan peneplane are found at an altitude of 300 to 400 meters, and is scattered in various places, assuming the shape of monadnocks in the field. A typical remnant of the Ping-shan peneplane is Ping Shan, rising north of Chin-chou station, on the top of which exists a flat plane with dolines. It has attracted the interest of geologists from early times[8,32] (Fig. 11).

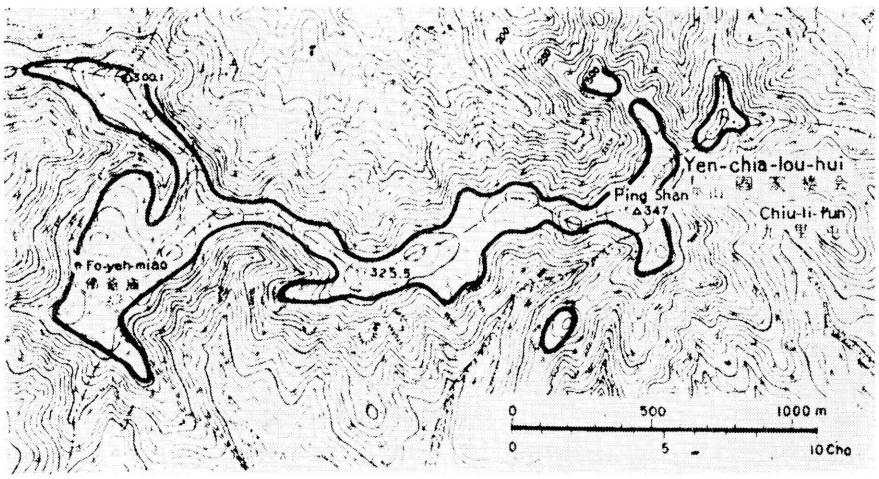

Fig. 11. Topographic Map of Ping-shan Peneplane (monadnock-like terrace).

E. Ta-ho-shang Shan monadnock

The Ta-ho-shang Shan monadnock rises higher than any other peak on the Ping-shan peneplane that is scattered as a monadnock-like terrace.* This moun-

* The monadnocks, like Ta-ho-shang Shan monadnock, are distributed in the northern part of the Liao-tung Peninsula. However, topographic maps of the northern district had not yet been published at the time when the author carried out measurements in this region.

tain already existed as a monadnock, more than 340 meters higher than the Ping-shan plane, at the time when the plane was completed.

3. Transformation point of the river valley

In the longitudinal section of the river in the middle of the Liao-tung Peninsula,

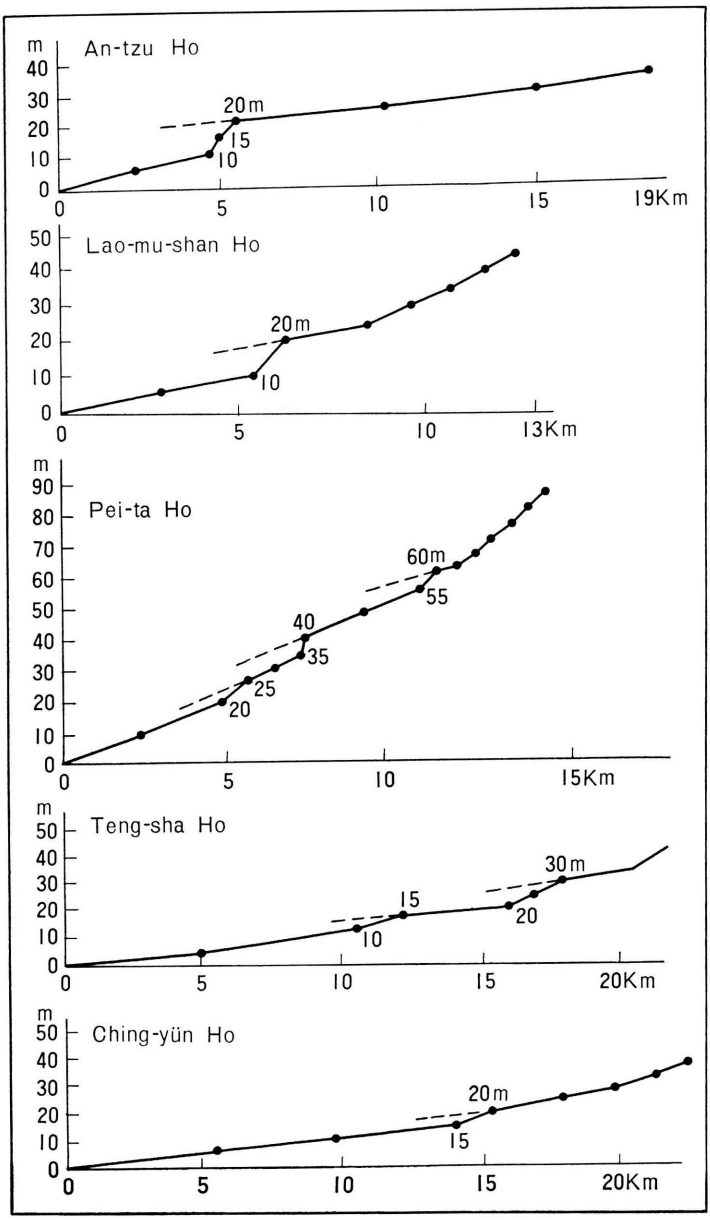

Fig. 12. Longitudinal Profiles of Rivers and Anomalies of the Profiles of Equilibrium.

transformation points where rapids occur are found. From the longitudinal sections of fifteen rivers, such anomalies in the profiles of equilibrium were discovered for many. Figure 12 shows one example. Figure 13 was constructed by plotting the Wendepunkts* on the map. One series of transformation points exists 10 to 20 meters above sea level; when connected on the map they almost parallel the coast line at the upper streams about five kilometers from the coast line. The lines connecting the Wendepunkts at 30 to 40 meters and 50 to 60 meters approximately parallel the main watershed of the peninsula. Therefore, they are distributed symmetrically along both sides of the watershed of the peninsula.

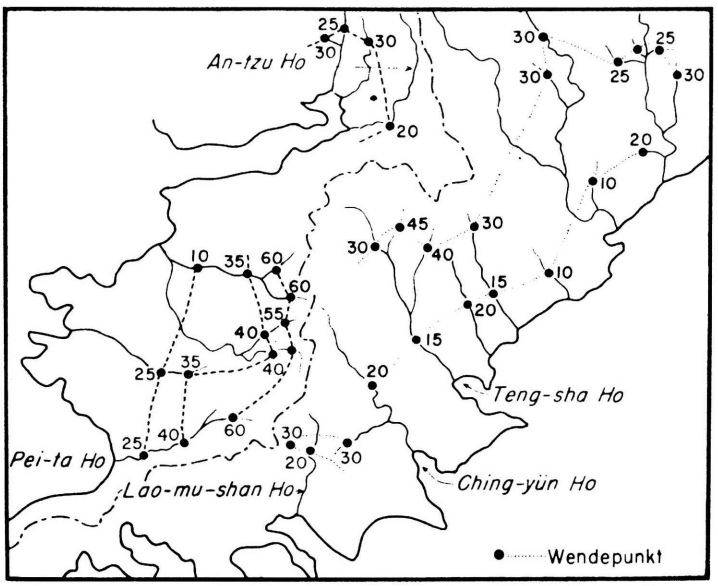

Fig. 13. Distribution of Wendepunkts.

These anomalies are not thought to be the results of stream piracy. The Wendepunkts in the eastern part are distributed over, and cut, the P'i-tzu-wo peneplane and the Aikawa plane, and the foundation rocks consist of the same gneiss, but faulting, warping or volcanic activity after completion of the P'i-tzu-wo peneplane are not thought to have been the cause of Wendepunkts. Consequently, they may be attributed to either crustal movement, positive to land and negative to sea, or a change in climate after the completion of the P'i-tzu-wo peneplane. There are two steep terraces in the vicinity of Ta-lien (Dairen) to Port Arthur which were formed chiefly by uplift of the land from the sea,[17] and in the same way, the distribution of Wendepunkts is thought due to uplift of the land. That is, slight uplift took place after the completion of the Aikawa plane, and each river on the aikawa plane flowed rapidly to the mouths of rivers. These points where rapids

* Where stream rapids occur as the result of rejuvenation of the river; named Wendepunkt by Sokol (R. Sokol, Geol. Rundschi, 12, p. 123–228, 1921).

occurred gradually receded upstream while they continued to cut the Aikawa plane, and it is believed that these points are distributed as shown in Figure 13.

The transformation point of each river flowing into the Yellow Sea exists 20 to 50 m from the mouth of the river, distributed at an altitude of about 60 m above sea level, and is even seen in the interior to the vicinity of the southern end of Chi-lin (Kirin), Province in the northern part.[31]

4. Periods of peneplanation

Cenozoic deposits are scanty in this region. As a matter of course, there were few deposits in the period when peneplanation occurred, and deposits regarded as an interpeneplanation stage do not exist. Therefore, we must estimate the age of peneplanation in this region, referring to the data obtained for each place of circumference.

A. Ping-shan stage

It is known from earlier times that the flat plane at the top of Ping Shan can be traced halfway up Ta-ho-shang Shan. Susumu MATSUSHITA[8] called it an imaginary flat plane, which corresponds to the Ping-shan peneplane named by IMAMURA and the author.[28] At the present time, remnants of this peneplane are recognized at an altitude of 350 to 400 m, and Ta-ho-shang mountain, more than 660 m high already existed as a monadnock at that time. Remnants of the Ping-shan peneplane can be traced to the northern part of the Liao-tung Peninsula. Tracing this to the east, the Roppyakuzan plane in Korea, named by Teiichi KOBAYASHI,[18] is found. This is the peneplane that was completed in the middle of the Miocene Epoch, and it is known that the uncompleted peneplane existed before that time.

In China, the Yen-shan crustal movement occurred in the latter part of the Mesozoic Era, which then elapsed into quiet for a long time. This erosion period corresponds to the Pei-tai stage, named by B. WILLIS,[24] and the whole area of North China was subject to peneplanation at that time. A flat-topped crest on Pei-tai mountain, the highest mountain of the Wu-tai Shan reported by B. WILLIS, is 3,080 m high. Afterward, it became known that the lower plane such as Hsi-shan of Pei-p'ing (Peking) and the truncated plane in the porphyry massif east of Chang-chia-kou correspond to the Pei-tai peneplane.

BERKEY and MORRIS[25] believe that the Pei-tai peneplane may be correlated with the Khangai (Hang-ai) peneplane in Mongolia, which is about 3,000 m high. Since the Himalayan orogenic movement appeared in the stage next to the Pei-tai period in North China, faulting and folding structures were formed and volcanic activity occurred; a good example is found in Nan-ling in South China. The period is called the Nan-ling stage. It is believed that the Pei-tai peneplane was destroyed by this crustal movement and the height of some peneplane in North China was also changed.

Remnants of the Pei-tai peneplane, which was completed in the period of Pei-tai

dissection, can be seen over a very wide area throughout North China, Mongolia and Korea. The Ping-shan peneplane is a remnant, which is thought to have been completed in the middle Miocene.

B. Kuang-ning-ssu stage

After completion of the Ping-shan peneplane, there was again calm in the Tang-hsien stage during the Nan-ling stage of crustal movement in North China, and the Pei-tai peneplane was subject to erosion. The plane that reaches a height of 90 to 120 meters at present in Tang-hsien, west of P'ei-ping, is the peneplane that was completed at the end of this period, and was traced by B. WILLIS to a height of 1,000 to 1,500 meters within the circumference of Pei-tai mountain of Wu-tai Shan. During this erosion period, fluviatile gravels and red clays were deposited on the lowland. This period is called the Pao-te stage. L. von LOCZY[27] reported that the river beds of this Pao-te stage contain Pliocene fossils in Kan-su Province. BERKEY and MORRIS[25] thought that the Mongolian peneplane, about 2,000 meters high in Mongolia, was formed in the T'ang-hsien stage. In Korea, this is the piedmont lowland[18], which was formed in the Pliocene. Sand and gravel beds occur at an altitude of more than 50 meters at Kangdong near the eastern margin of the Nangnang (Rakuro) peneplane, and an apparent nonuniformity exists between this plane and the lower one. A plane that is situated between the Roppyakuzan and Kishyu planes (P'i-tzu-wo plane) occurs over a wide area in the basin of Il-ha-myön, Tok-ch'on-gun in the northern part of P'yong-an-nam-do. That is, in the Pliocene, peneplanation occurred over the whole region of eastern Asia, and the Kuang-ning-ssu peneplane resulted.

After completion of the Kuang-ning-ssu peneplane, there came the Ma-lan stage through the Fen-ho dissection stage, San-men stage (deposition period of lacustrine and red clay), and Ching-shui dissection stage. The Ma-lan stage is the period when loess accumulated in North China and red clay[18] was deposited in Korea. In Mongolia, the Pang-kiang[25] period of dissection can be correlated with this stage. In the Liao-tung Peninsula, beds of loess-like clay, or red clay, cover the Kuang-ning-ssu plane in the vicinity of Chou-chia-kou at the northern foot of An-tzu Shan northwest of Ta-lien (Dairen), that is, the bed of red clay that accumulated after completion of the Kuang-ning-ssu peneplane is believed to have been dissected in the next stage from the fact that it did not accumulate on the P'i-tzu-wo peneplane.

The Manchurian plain is a vast flat surface which is thought to have resulted from erosion. The part of the plain covered with loess is found only in high-altitude regions, and the foundation plain on which the loess accumulated is thought to be a plain that was completed before the Ma-lan loess accumulated. Such a vast plain developed not only in the region of this plain, but it also connects with the Kuang-ning-ssu peneplane in the Liao-tung Peninsula. This is thought to be a product of the peneplanation that occurred over the whole of eastern Asia in the Tang-hsien stage; on the contrary, the Manchurian plain, not being covered with the loess,

is distributed at altitudes lower than the former, and is considered to be connected with the P'i-tzu-wo peneplane.

C. P'i-tzu-wo stage

In North China, the Pan-chiao dissection stage followed the Ma-lan loess-accumulation stage. In this period, the loess beds were dissected and the gravel beds accumulated at lower levels; that is in the period between the Diluvial and Alluvial epochs. During this period in Korea, the surrounding peneplane (Kisyu plane), in the region of the western coast, was completed. The plane that forms part of the above-mentioned plane and is especially well developed on the banks of the above-mentioned plane and is especially well developed on the banks of the Tae-dong River in P'yeongyang is called the Rakuro peneplane. It corresponds to the Musashino plane (M plane)[20] in the vicinity of Tokyo, Japan.[18] The Pan-chiao stage is recognized as the Pang-kiang dissection stage in Mongolia,[25] and corresponds to the P'i-tzu-wo stage of construction in the Liao-tung Peninsula.

D. Aikawa plane

Uplift of the land has taken place since the completion of the P'i-tzu-wo peneplane. In the Liao-tung Peninsula, a slight depression occurred in the marginal part, and a peat bed accumulated in the vicinity of Pu-lan-tien, and the low plane in the vicinity of the shoreline, that is now a salt field, was completed. In Korea, a peat bed of this period was also found. These are deposits which were laid down after the completion of the P'i-tzu-wo peneplane, and the inundated flood plain that resulted from the slight depression in the marginal part of the continent. It seems that the low plane, which is cultivated in the Aikawa village, is quite typical. The peat bed in the vicinity of Pu-lan-tien was deposited recently in view of the fact that it contains *Nelumbo* sp., which is a semi-fossil that still has the ability to germinate. The plane, which is lower than the Rakuro peneplane and 3 to 10 m above sea level, occurs on the coast of the Taedong River in Korea.Typical development of this plane is found in Choni, south of P'yeongyang City, and is called the Souri plane[29] by the author.

Slight uplift of the land followed, resulting in lower terraces, and causing transformation points in rivers.

5. History of topographic development

In conclusion, the history of topographic development will be given in the following correlation table.

Table 12. Correlation Table

	North China	Liao-tung Peninsula	Korea
Recent	Present stage (dissection / alluvium)	Slight uplift {wendepunkt / Aikawa plane} Slight subsidence (Peat)	Slight uplift (Souri plane) Slight subsidence (part of peat bed)
		(slight uplift)	(Slight uplift)
	Pan-chiao stage {dissection / valley gravel}	Pi-tzu-wo Peneplane (20–50 m)	Rakuro Peneplane (20–50 m)
Pleistocene	Ma-lan stage (Loess)	(Red clay in Chou-chia-kou)	(Aqueous löess, red clay) Flood of yellow sea
			(Subsidence)
	Chin-shui stage {dissection / rock terrace}		
	(Warping)	(Uplift of Peneplane)	(part of lava-flow / Uplift with slight tilting)
	San-men stage (Fluvio-Lucustrine condition / San-men Series)		
	(Slight Warping)		(Saikiho marine Formation)
Pliocene	Fen-ho stage {Gorge-cutting / Flood plane}		(Subsidence of Tusima Basin)
	(Fold, Fault, Tilt)		(Up & Down Warping)
	Pao-te stage (Gravel bed—Pliocene fossils) Red clay	Kuang-ning-ssu Peneplane (120–200 m)	Piedmont lowland
			(En-niti series)
	Tan-hsien stage (dissection of plane and lava plateau)	(dissection)	(subsidence of Eastern coast-region)
Oligo-Miocene	Nan-ling stage {volcanism, / fault, fold'} (Himalayan Orogeny)	(faulting)	fault (low relief)
	Pei-tai stage Peitai Peneplane	Ping-shan Peneplane (300–400 m) Ta-ho-shang-shan Monadonock	Roppyakuzan Plane Transgression (*Mya, Vicarya* Bed) Monadnocks

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The Sinian System of Kuan-Tung Province

Susumu MATSUSHITA

Of all areas where the Sinian system is found (China proper, Mongolia, the eastern part of Tien-shan Mountains, South Manchuria and the northern half of Korea), it is most predominant (more than 7,000 m) in Kuan-tung Province*, South Manchuria, with an abundance of strata, apart from the basal part.

1. Distribution

In Kuan-tung Province, the Sinian System is widely distributed, except in the gneiss zone northeast of Chin-chou. It is distributed (a) on the northwest side of the gneiss zone (mainly on the northwest side of the railroad between Chin-chou and Pu-lan-tien), (b) on the south side of the gneiss zone in an area from Chin-chou via Ta-ho-shang-shan, Tung-chia-kou, mouth of the Ching-yun Ho (river) to the mouth of the Teng-sha Ho, and (c) at the tip of the Liao-tung Peninsula southwest of Chin-chou. The area where Dairen and Port Arthur are located consists almost entirely of the Sinian system. It is also distributed on many islets which are scattered along the shores of Po Hai (Pechili Bay) and the Yellow Sea.

2. Stratigraphy

Von RICHTHOFEN was the first geologist to investigate the Sinian System in Kuan-tung Province. While on a survey of South Manchuria in 1869, he viewed from a distance on a boat, from Chi-fu to Ying-kou, Sinian rocks exposed on the coast of Po Hai of the province. Then, BLACKWELDER observed briefly the northern part of Kuan-tung Province in 1903 when he traversed the Fu-chou district. After the Sino-Japanese War and during the Russo-Japanese War, the province was surveyed by several Japanese geologists. After the establishment of the South Manchuria Railway Co., geologists of the company surveyed the province. In 1915 a report on the geological survey in Kuan-tung Province accompanied by a

* Kuan-tung Province consists of the southwestern tip of the Liao-tung peninsula, South Manchuria, which was formerly territory held by Japan.

geological map was made public by Hanzō MURAKAMI,[1] geologist of the South Manchuria Railway Co. (SMR). Thanks to his work, the distribution and stratigraphy of the Sinian system in the province were made fairly clear. Then, in 1924, the geological sheet map "Dairen" on a scale of 1:400,000 and its explanatory text by Otoji AOJI[2], geologist of SMR, were published. Though the name "Sinian System" was not used in this report, the stratigraphy of the system was farther clarified. Riuji ENDŌ's preliminary report[3] on the Ordovician, Cambrian and Sinian Systems was published in 1928, in which he mentioned the Sinian System of Kuan-tung Province.

In the same year, Otoji AOJI[4] summarized and published his studies on the Sinian System in South Manchuria. The present author carried out a field survey of the Sinian System in Kuan-tung Province during his tenure of office at Ryojun College of Engineering at Port Arthur from 1926 to 1931, and published the results. The Geological Institute of SMR began the geologic mapping of Kuan-tung Province on a scale of 1:25,000, in 1931. In this project, the Sinian System was investigated in detail, although the results have not been published. Since that time, however, the stratigraphy, fossils, ripple marks, etc., of the Sinian System in Kuan-tung have been reported by several researchers in succession as follows: stratigraphy[5] by Riuji ENDŌ, Hisao ŌTANI, and Rinji SAITŌ, separately; ripple marks[6] by Tsutomu OGURA, and Shigeyuki MONDEN, separately; cross-bedding[7] by Hiroshi OZAKI; suncracks[8] by Rinji SAITŌ. *Manchuriophycus*[9] and *Collenia*[9] were formally described by Hisakatsu YABE and Riuji ENDŌ.

At first the author in 1930 divided the Sinian System into two series, the Kuan-tung Series and the Ta-ho-shang-shan Series. Then in 1932,[10] he subdivided each series into stages, giving them alphabetical symbols. Next, in 1934,[11] he named each stage, and transferred the Nan-shan Stage from the base of the Cambrian System to the uppermost part of the Kuan-tung Series.

In 1940[12], the author separated the Nan-shan Stage from the Kuan-tung Series and established the Nan-shan Series. After that, Rinji SAITŌ carried out a detailed survey of the relationship between the Nan-shan Series and the Kuan-tung Series, assuming an unconformable relation between them. As a result, he found an unconformity in the uppermost part of the Ying-cheng-tzu Stage of the Kuan-tung Series, and considered that the Shih-san-li-tai, Ma-chia-tun Stages and the uppermost parts of the Ying-cheng-tzu Stage should be removed from the Kuan-tung Series and be placed in the Nan-shan Series.

The author followed SAITŌ's suggestion and placed the boundary line between the Nan-shan Series and the Kuan-tung Series at the zone of contact between the Shih-san-li-tai and Ying-cheng-tzu Stages. An improved stratigraphic division of the Sinian System was published after the war[13] (1947), which is given in Table 1.

The Ta-ho-shang-shan Series composes Mt. Ta-ho-shang (664 m), the highest peak in Kuan-tung Province, east of Chin-chou, and the author named the series after that mountain. The series is developed extensively in an area between

Table 1. Stratigraphical Succession of the Sinian System in Kuan-tung Province.
(MATSUSHITA, 1932, 1934, 1940, 1947)

Nan-shan Series	14. Nan-shan Stage	Consists essentially of grayish-green clay slate with quartzite, siliceous sandstone and limestone	400–800 m
	13. Ma-chia-tun Stage	Pale-colored, thin-bedded siliceous limestone	50–200 m
	12. Shih-san-li-tai Stage	*Collenia* limestone	50–150 m
Kuan-tung Series	11. Ying-cheng-tzu Stage	Black, thick-bedded limestone	370–400 m
	10. Onoda Stage	Black, blue-black or blue-grayish thin-bedded limestone (intercalated with *Collenia* beds)	270–700 m
	9. Kan-ching-tzu Stage	Dolomite and limestone (intercalated with *Collenia* beds)	450–700 m
	8. Nan-kuan-ling Stage	Limestone; the lower part consists of impure limestone	800–1,000 m
	7. Chang-ling-tzu Stage	Grayish-green or greenish-gray phyllitic clay slate intercalated with siliceous limestone in the upper part	? 700 m
Ta-ho-shang Shan Series	6. Lung-tou Stage	White quartzite	450 m
	5. Ying-ke-shih Stage	Phyllitic limestone and calcareous phyllite	30–200 m
	4. Cha-kou Stage	Quartzite (with clay slate)	1,000 m
	3. Lung-wang-tang Stage	Siliceous slate and quartzite	800 m
	2. Wai-tou-shan Stage	Quartzite (with siliceous slate)	500 m
	1. Huang-ni-chuan Stage	Calcareous phyllitic clay slate	330 m †
	(Base unknown)		

Dairen and Port Arthur. In addition, the same series constitutes more than half of the hilly land along the seashore, eastward from Chin-chou to the mouth of the Teng-sha-ho River. It is also distributed in an area between San-shih-li-pu and Wa-fang-tien.

The Kuan-tung Series is developed extensively in the district stretching from Chin-chou through Chou-shui-tzu and Ying-cheng-tzu to Chang-ling-tzu. It is also found in the vicinities of Erh-shih-li-tai, San-shih-li-pu and Tung-chia-kou, at the eastern foot of Mt. Ta-ho-shang and south of the Ching-yun-ho River.

The name Nan-shan Series came from Nan-shan Hill south of Chin-chou. It is distributed in the district between the southern foot of Mt. Ta-ho-shang and Tung-chia-kou, in the neighborhood of Erh-shih-li-tai, in an area between San-shih-li-pu and Chi-ting-shan and on the islets of Hsi-ma-i Tao and Miao Tao.

3. Fossils

Fossils of the Sinian System in Kuan-tung Province are *Collenia* found in the limestone and dolomite of the Kuan-tung Series as well as in the limestone of the Nan-shan Series, and *Manchuriophycus* in the quartzite of the Ta-ho-shang-shan Series. Both of them are regarded as algal remains.

Fossils of *Collenia* are contained in the dolomite of the Kan-ching-tzu Stage and limestones of the Onoda and Shih-san-li-tai Stages. *Collenia* of the Shih-san-li-tai Stage forms a *Collenia* limestone with the characteristic color of reddish-purple or bluish-gray. For many years, *Collenia* limestone was called "Uzumaki" (whirl) limestone by Japanese geologists in Manchuria, and some geologists thought its origin to be organic, while others presumed inorganic and mechanical.

In 1937, ENDŌ[5] described it as a kind of fossil. *Collenia* in the Shih-san-li-tai Stage are described as *C. cylindrica* (Grabau) and *C. grabaui* (Resser and Endo). Those in the Kan-ching-tzu and Onoda Stages have not yet been studied. However, they may be *C. fuchouensis* and *C. tahoensis*, which were established by ENDŌ in the Fu-chou and Tai-tzu-ho Districts.

Manchuriophycus is the generic name of algae which was given by ENDŌ in 1933 to some marks on the bedding plane of quartzite of the Chiao-tou quartzite at Chiao-tou on the Mukden—An-tung Railroad. After that, in 1936, YABE[9] described a kind of *Manchuriophycus* which was found in the Sinian quartzite at Port Arthur, and named it *M. sawadai*.

4. Correlation of the Sinian System between Kuan-tung Province and Fu-chou District.

Even though these two districts stand side by side, only separated from each other by Pu-lan-tien (A-tang) Bay, there are no definite suggestions concerning correlation of the Sinian System between these two districts. The following three correlations have been previously proposed.

(1) In 1928 AOJI thought that the Wu-hsing-shan series is not restricted to the vicinity of Chin-chia-cheng-tzu in Fu-chou District, but is distributed in Kuan-tung Province also. That is, it seemed that the Wu-hsing-shan Series may be correlated with the present author's Kuan-tung Series (1930). Later, SAITŌ confirmed this correlation by field work (1938).

(2) ENDŌ insisted (1928 and later) that the Wu-hsing-shan Series in the neighborhood of Chin-chia-cheng-tzu is distinct from the limestone group of Kuan-tung Province (his Kuan-tung Group, or the present author's Kuan-tung series). He named the former the Pechili Group on the grounds that the *Collenia* species of the Pechili Group is different from that of the Kuan-tung Group. He described (1937) *Collenia fuchouensis* and *C. tahoensis* from the Pechili Group and identified *Collenia* from the Kuan-tung group as *C. cylindrica* (Grabau) and *C. grabaui* (Endo). In addition, ENDŌ thought that the Kao-chia-tun Shale and Sandstone Group

and the Chiao-tou Group may correspond to the Nan-shan Group in Kuan-tung Province. If this is true, the complete Sinian System in Kuan-tung may be equivalent to the Hsiho Series of AOJI. Teiichi KOBAYASHI was of the same opinion as ENDŌ, and the author also once believed that ENDŌ was correct (1935).

(3) In 1943, SAITŌ correlated the whole Hsi-ho Series with the Nan-shan Series and considered that the Kuan-tung and Ta-ho-shang-shan Series are much older. The author agreed with this opinion formerly (1947).

Recently, the author reconsidered the problem of correlation and arrived at the conclusion that the opinion stated in (1) is correct. Namely, the quartzite formation along the northern frontier of Kuan-tung Province is equivalent to the upper part of the Ta-ho-shang-shan Series, and at the same time to the Chiao-tou quartzite of the Hsi-ho Series; the overlying Kao-chia-tun shale and sandstone and the Chin-chia black limestone are nothing but the Kuan-tung Series. Consequently, SAITŌ's observations and interpretation in 1938 must be said to be correct.

It is noted that in Fu-chou District, the Nan-shan Series, (the upper part of the Sinian System) does not occur, and that furthermore at Feng-chia-tun, the Kb of the Kao-chia-tun shale and sandstone is overlain directly by the Cambrian System. Therefore the relation between the Cambrian and Sinian Systems in Fu-chou district is interpreted as a clino-unconformity, slight but distinct, the magnitude of the hiatus becoming larger northward.

As mentioned in the preceding paragraph, ENDŌ distinguished the species of *Collenia* in Fu-chou district from those of Kuan-tung Province. The formation containing *Collenia* in Fu-chou district may correspond to some horizon of the Onoda Stage in the province under consideration, while *Collenia* limestone of the province mentioned by ENDŌ is the Shih-san-li-tai Stage. Therefore, it seems quite probable that the species of *Collenia* are different between the two districts under consideration.

In 1938, SAITŌ insisted that the Ta-ho-shang-shan Series as a whole may be equivalent to the Chiao-tou quartzite, and that the Nanfen and Tiao-yu-tai Formations may not occur in Kuan-tung Province. The Huang-ni-chuan Stage, however, may be correlated with the upper part (Nb) of the Nan-fen shale-marl Formation, and the formations beneath the Huang-ni-chuan Stage are concealed underground.

Accordingly, it may be proper to consider that the formations corresponding to the Nan-fen and Tiao-yu-tai Formations may exist underground in Kuan-tung Province as well.

Since each member of the Sinian system is more predominant in the southern part of Kuan-tung Province than in Fu-chou district, it may be inferred that Kuan-tung Province must have been situated closest to the most subsiding part of the geosyncline in which the Sinian System was deposited. Also, there may have existed formations of the horizon lower than the Tiao-yu-tai quartzite in Kuan-tung Province. This idea is presented diagramatically in Fig. 1.

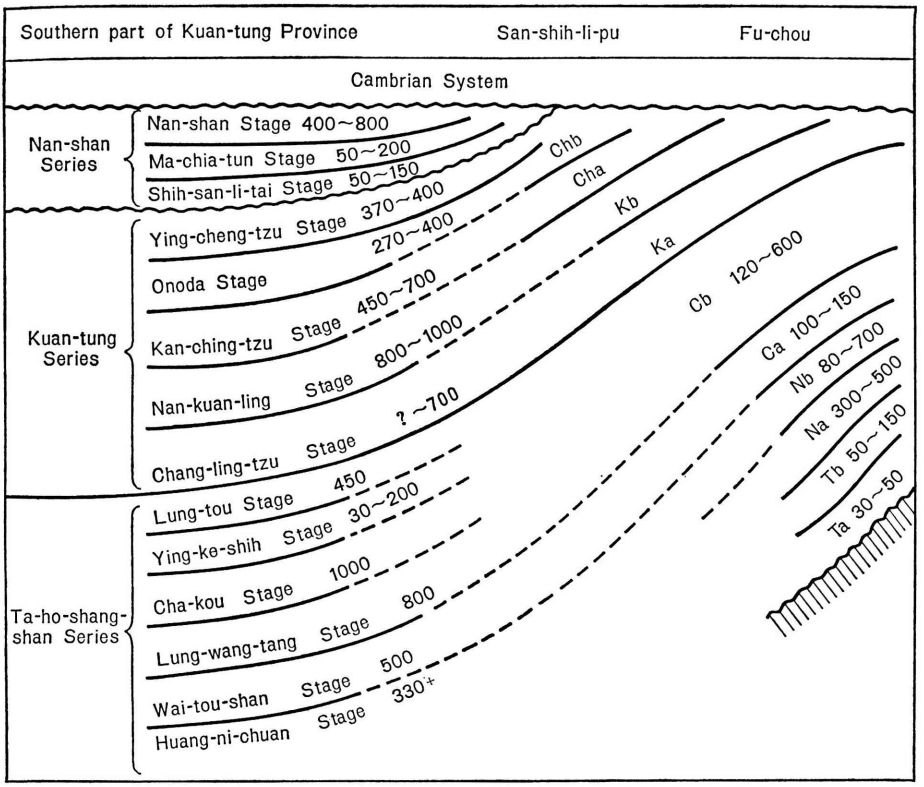

Fig. 1. Idealized Cross-section Showing the Correlation of the Sinian System between Kuan-tung Province and Fu-chou District (MATSUSHITA, 1952).

5. Lower limit of the Sinian system in Kuan-tung Province

As mentioned in the preceding paragraph, the basal part of the Sinian System is not found in the area between Dairen and Port Arthur where the Ta-ho-shang-shan Series, the lower part of the Sinian System, is best developed. Therefore, the lower limit of the Sinian System is unknown. The author previously stated (1930, 1934) that its basal part is found at Mt. Ta-ho-shang. From observation, the Ta-ho-shang-shan Series rests disconformably on the author's Hsiang-shui-ssu Series consisting of metamorphic rocks of sedimentary origin. Later, since Bunkichi BESSHO found gneiss injected into the Ta-ho-shang-shan Series, SAITŌ inferred that the Hsiang-shui-ssu Series may belong to the metamorphosed parts of Units 1 and 2 of the lower part of the Ta-ho-shang-shan Series. The author agrees with this opinion.

According to Michitaka SAWATARI's study, a low-angled overthrust divides the author's Hsiang-shui-ssu Formation from the underlying Liao-tung System of SAWATARI. If this is true, the lower limit of the Ta-ho-shang-shan Series remains unknown, even at Mt. Ta-ho-shang. To the east of San-shih-li-pu, the Ta-ho-

shang-shan Series becomes rather thin. This fact is inferred due to the low-angled overthrusting of the Ta-ho-shang-shan Series on the gneiss group.

In conclusion, the lower limit of the Sinian System in Kuan-tung Province is unknown.

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Carboniferous and Permian Systems of Manchuria

Mitsuo NODA

I. Introduction

There are two different kinds of sedimentary facies in the Manchurian Carboniferous and Permian Systems. One is the South Manchurian type which is represented by the Taitzuho System, containing coal and marine formations, and the other is the North Manchurian type which is represented by the Touman and Chilin Formations of marine facies. The boundary between the two types is not clear-cut, but they can be distinguished as follows: The vicinities of Hoeryeong in Korea and Yen-chi Hsien north of the former are situated at the western rim of the Touman formation; the vicinity of Chiao-yang-chen on the Shen-Chi Railway is located at the southern end of the Chilin Formation; the Carboniferous and Permian Systems in the vicinities of Fu-sung, Meng-chiang and Hui-nan in Antung Province belong to the Taitzuho System. Farther west, the Taitzuho System is most typically developed along the Tai-tzu Ho river and is not found in any area north of the watershed between the Tai-tzu Ho and Hun Ho rivers.

In the southwestern part of Manchuria, the South Manchurian type is extensively developed south of the railroad between Chiao-yang and Cheng-te, whereas the North Manchurian type is largely distributed in the vicinity of Lin-hsi in the upper reaches of the Shramuren River and in the area farther north. Therefore, the boundary between the two types may cross the northwestern part of Jeho Province and extend farther west to the north side of the Yen-shan Mountains.

What, then, is the geological meaning of this boundary line? It may have only paleogeographical meaning, or it may also have some tectonic meaning. In any case, this problem needs more detailed studies in association with the investigation of the so-called Mongolian Geosyncline.

II. The Carboniferous and Permian Systems in South Manchuria

1. General description

In South Manchuria the marine Middle Carboniferous System rests extensively in parallel unconformity on the marine Middle Ordovician System. The marine,

lacustrine, and fresh-water sediments of the coal measures of the Permian system are developed, in turn, parallel-unconformably on the Middle Carboniferous System. Since these stratigraphic relations are completely the same as in North China and Korea, one must refer to the stratigraphy of these districts to study the later Paleozoic System in South Manchuria.

A. Taitzuho district and southern part of the Liao-tung Peninsula

The name Taitzuho System was given by Takao SAKAMOTO[42] to the Carboniferous and Permian Systems in South Manchuria. The writer[24-26, 28, 30-32, 35-37] studied the geology of this system for many years and the results of this study in the Tai-tzu-ho district and the southern part of the Liao-tung Peninsula are summarized in Table 1.

Table 1. Stratigraphic Sequence in the Taitzuho System.

	Miyanohara formation	Lower Cretaceous
Taitzuho System	Tsaichia Series	Upper Permian
	Liutang Series	Lower Permian
	Huangchi Series (Yatang Series)	Lower most Permian
	Penhsi Series	Middle Carboniferous
	Ssuyen Series	Middle Ordovician

All boundaries are unconformable except the boundary between the Huangchi Series (Yatang Series) and the Liutang Series. Moreover, in the Niu-hsin-tai coal field, the strata of unknown age are developed unconformably between the Penhsi Series and Ssuyen Series.

The distribution area of the Taitzuho System in South Manchuria is divided into two districts, the Tai-tzu-ho district and the southern part of the Liao-tung Peninsula. To the Tai-tzu-ho district belong the coal fields of Yen-tai (Fig. 5), Chang-tai-tzu, Han-po-ling (where the Penhsi Series alone is developed), Penhsi-hu (Fig. 6), Niu-hsin-tai (Fig. 7), Tao-yuan-kou, Pien-ling, Hsiao-shih and Tien-shih-fu-. To the Liao-tung district belong the coal fields of Fu-chou (Fig. 8), Tiao-hu-chu (where the Penhsi Series alone is developed), Chien-shih-hui-yao-tun and Tung-chia-kou.

The generalized explanation for the Taitzuho System along the Tai-tzu Ho and in the southern part of the Liao-tung Peninsula is given below.

a. Penhsi (Penchi) Series

This series was named by LEE and CHAO[14] with Pen-hsi-hu as its type locality. In general, the Penhsi Series rests with parallel unconformity upon the Ssuyen Series of the Middle Ordovician, and belongs to the Middle Carboniferous Moscovian. It consists mainly of alternating shale and sandstone, intercalated with several layers of limestone. The predominant color of this series is characteristic reddish ochre. Reddish-ochre shales are remarkably developed in the basal part. It often contains aluminous shale, fire clay and thin coal seams. Nodular limonite

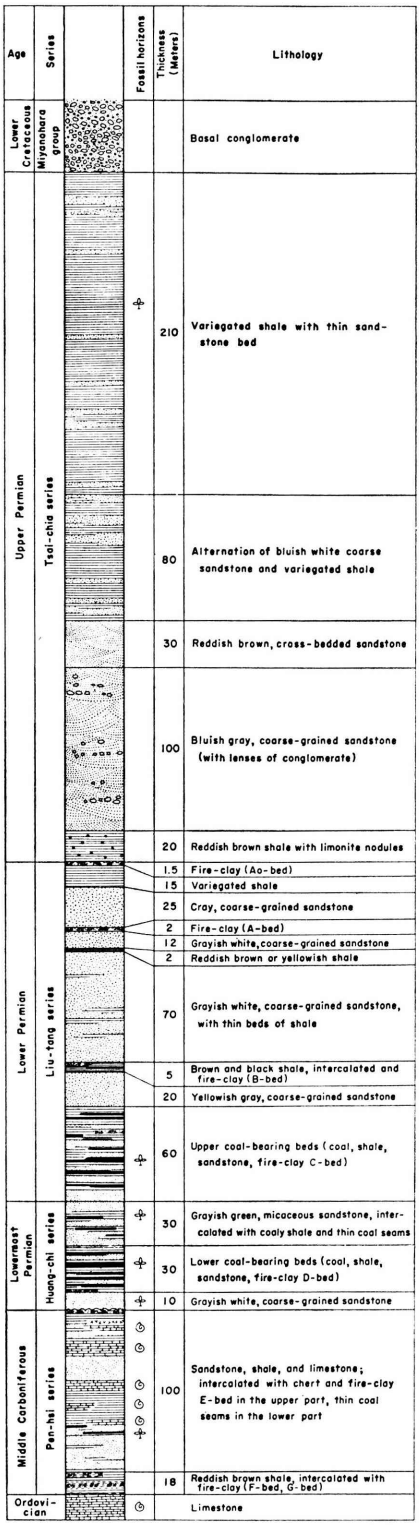

Fig. 1. Geologic Columnar Section of the Pen-hsi-hu Coal Field.

ore is found in the reddish-ochre aluminous shale. In the Tai-tzu-ho district, black to grayish lenticular cherts are sometimes found in the upper part of the series. The total thickness of this series is estimated to be 70 to 90 m in southern Liao-tung Peninsula, and about 120 m in the Tai-tzu-ho district. Its age is assigned to the Middle Carboniferous Moscovian on the basis of the following fossils:

Foraminifera

Nodosinella padangensis LANGE
Cribrogenerina cf. *permica* LANGE
Textularia exima D'EICHWALD
T. thorax LANGE
T. cf. *gibbosa* D'EICHWALD
Climacammina antiqua BRADY
Tetrataxis parviconica LEE and CHEN
Lagena permica LANGE
Bradyina nautiliformis V. MÖLLER
B. cf. *rotula* (D'EICHWALD)
Staffella spaeroidea (V. MÖLLER)
S. confusa LEE and CHEN
Ozawainella angulata (COLANI)
Fusulinella chaoi (LEE)
F. bocki V. MÖLLER
F. biconica (HAYASAKA)
F. colani (LEE and CHEN)
F. praesimplex (LEE)
F. irumensis HUZIMOTO
F. cf. *rhomboides* (LEE and CHEN)
Boultonia willsi LEE
Schubertella magna LEE and CHEN
Fusulina Konnoi (OZAWA)
F. cylindrica FISCHER DE WALDHEIM
F. teilhardi (LEE)
F. cf. *pankouensis* (LEE)

Brachiopoda

Spirifer (*Choristites*) *mosquensis* FISCHER
S. (*Ch.*) *jigulensis* STUCKENBERG
S. (*Munella*) *nikitini* TSCHERNYSCHEW
S. (*M.*) *tschernyschewformis* OZAKI
Squamularia asiatica CHAO
Martinia semiplana WAAGEN
Marginifera timanica TSCHERNYSCHEW
Camarophoria meyeri tetraplicata OZAKI

Corals

Arachnastraea manchurica YABE and HAYASAKA

A. manchurica forma *sinuoseptata* YABE and EGUCHI
A. manchurica forma *coreanica* YABE and EGUCHI
A. molleri STUCKENBERG
Cystiphora manchurica YABE and HAYASAKA
C. manchurica forma *podolskiensis* DOBROLIUBOVA
C. manchurica forma *humboldti* (STUCKENBERG)
C. manchurica forma *kikkawai* YABE and HAYASAKA
Syringopora reticurata GOLDFUSS
Chaetetes asiaticus YABE and HAYASAKA

Some plant remains, such as *Lepidodendron aculeatum* STERNB. and *Calamites* cf. *Suckowi* (BRONGN.), are found in the carbonaceous shale in the middle part of the series, which further justifies its assignment to the Moscovian.

b. Huangchi Series (Yatang Series)

The type locality of the Huangchi Series is Huang-chi-kou, about 3km west of Pen-hsi-hu. In both lithology and fauna, the series in the Tai-tzu-ho district is remarkably different from that in the southern Liao-tung district, as the former contains no limestone while the latter is intercalated with many layers of limestone; the features of the latter are quite identical with those of the lower part of the Jido Series in Korea and the Taiyuan Series in North China. Therefore, Shōshirō HANZAWA[7] proposed the name Yatang Series for the writer's Huangchi Series in the southern Liao-Tung, taking the name of Ya-tang Bay.

In every coal field of Manchuria, the unconformity at the base of Permian is very distinct paleontologically and stratigraphically.

Along the Hun Chiang river, Tung-pien-tao, a distinct unconformity is found between the Penhsi Series and the Takang Series, which is the Permian coal-bearing formation, as will be mentioned later. [29,35] The writer[34,29] also found an unconformity at the base of the Taiyuan Series in North China, which is equivalent to the Yatang Series. These unconformities are the most important data verifying the absence of the Upper Carboniferous Urlian. This is the basis on which the writer defined the base of Permian.

The Huangchi Series in the Tai-tzu-ho district consists of sandstone, sandy shale, shale, fire-clay and coal, and constitutes the so-called Lower coal-measures in this district. The total thickness of the series is estimated to be about 70 m.

In the shale of this series many plant fossils listed in Table 2 are found, and 15 genera and 20 species are identified. Among them, more than 8 genera, including *Lobatannularia, Emplectopteridium,* and *Tingia,* are characteristic to the Orient.

Thus, it is recognized that the Oriental flora was already rather remarkably differentiated. As an element of Mesozoic flora, there is only one species of genus *Cladophlebis*. By reference to 9 species common to Europe and the Orient, the geological age of this series is assigned to the Stephanian to Lower Rotliegende, as seen in Table 3.

For a detailed determination of the geological age, more precise correlation with North China and Korea is needed. The writer referred to the data by T. G.

Table 2. List of Fossil Plants in the Taitzuho System.

Series / Locality / Fossil	Penhsi series	Huangchi series (Yatang series)			Liutang series			Tsaichia series
	Pen-hsi-hu	Pen-hsi-hu	Yen-tai	Fu-chou	Pen-hsi-hu	Yen-tai	Fu-chou	Pen-hsi-hu
1. *Calamites Suckowi* (BRONGN.)	×	•	×	×	×			
2. *C.* cf. *Cisti* BRONGN.	•	•	×	•	×			
3. *C.* sp.	•	•	×	×	×	×		
4. *Annularia orientalis* KAWASAKI	•	•	×	•	×	×		
5. *A. stellata* (SCHLOTH.)	•	•	×	•	•	×		
6. *Lobatannularia sinensis* HALLE	•	•	×	•	•	×		
7. *L. inequifolia* (TOKUNAGA)	•	•	•	×	•	•	×	
8. *Sphenophyllum oblongifolium* (G. et K.)	•	•	×	•	×	×	×	
9. *Sph. emarginatum* BRONGN.	•	•	•	•	×			
10. *Sph. verticillatum* SCHLOTH.	•	•	×					
11. *Sph. orientale* KAWASAKI	•	•	•	•	×			
12. *Sph. Thonii* MAHR	•	•	•	•	×	×	×	
13. *Sph.* sp.	•	•	•	•	•	•	•	×
14. *Bowmanites laxus* HALLE	•	•	×					
15. *Pecopteris hirta* HALLE	•	•	•	•	×	×		
16. *P. polymorpha* BRONGN.	•	•	•	•	•	×	×	
17. *P. tuberculata* HALLE	•	•	•	•	×			
18. *P.* cf. *cyathea* (SCHLOTH.)	•	•	•	•	×			
19. *P.* sp.	•	•	•	•	×	•	×	×
20. *Pecopteridium manchuricum* KAW.	•	•	•	•	×			
21. *Cladophlebis Nystroemii* HALLE	×	•	×	•	×	•	×	×
22. *Neuropteris* spp. (n. sp.)	•	×	×	•	×	×	•	×
23. *Neuropteridium? yongwolensis* KAW.	•	•	×	×	×			
24. *Callipteridium koraiense* (TOKUNAGA)	•	•	×	•	•	×	×	
25. *Odontopteris? subcrenulata* (ROST)	•	•	×					
26. *O.* sp.	•	•	•	•	•	×	×	
27. *Emplectopteris triangularis* HALLE	•	•	•	•	×	×		
28. *Emplctopteridium alatum* KAW.	•	•	×	•	•	×	×	
29. *Protoblechnum Wongii* HALLE	•	•	•	•	•	×	×	
30. *Taeniopteris multinervis* WEISS.	•	•	•	•	×			
31. *T. Schenki* STERZEL	•	•	•	•	×			
32. *T. punctulata* KAW.	•	•	•	•	×			
33. *T. Nystroemii* HALLE	•	•	•	•	×			

Table 2. (Continued)

Fossil \ Series / Locality	Penhsi series	Huangchi series (Yatang series)			Liutang series			Tsaichia series
	Pen-hsi-hu	Pen-hsi-hu	Yen-tai	Fu-chou	Pen-hsi-hu	Yen-tai	Fu-chou	Pen-hsi-hu
34. *T. Tingii* HALLE	•	•	•	•	×			
35. *T. taiyuanensis* HALLE	•	•	•	•	•	•	×	
36. *T. serrulata* HALLE	•	•	•	•	•	•	×	
37. *T.* sp. *a* (n. sp.)	•	•	•	•	×			
38. *T.* sp. *b* (n. sp.)	•	•	•	•	•	•	•	×
39. *Gigantopteris nicotinaefolia* SCHENK	•	•	•	•	•	•	×	
40. *Chiropteris reniformis* KAW.	•	•	•	•	•	•	×	
41. *Lepidodendron oculisfelis* (ABB.)	•	×	×	•	×	•	×	
42. *L. orientale* KOIWAI	•	•	×					
43. *L. Yabei* KOIWAI	•	•	•	•	•	•	×	
44. *L. Gaudryi* RENAULT	•	×	×	•	×			
45. *L. aculeatum* STERNB.	×							
46. *L.* sp.	•	×	×	•	×			
47. *Lepidostrobus* sp.	•	•	•	•	•	•	×	
48. *Sigillaria* sp. (n. sp.)	•	•	•	•	×			
49. *Sigillariostrobus*? sp.	•	•	•	•	×			
50. *Stigmaria asiatica* JOHGM. et GOT.	•	×	×	•	×	×	×	
51. *S. ficoides* (STERNB.)	×	×	×	•	×	×	×	
52. *Cordaites principalis* (GERM.)	•	×	×	•	×	•	×	
53. *C. Schenkii* HALLE	•	×	×	×	×	×	×	×
54. *C. parvifolius* KAW.	•	•	•	•	×			
55. *C.* spp.	•	×	•	•	×	×		
56. *Cordaicarpus* sp.	•	•	•	•	×			
57. *Cordaianthus* sp.	•	•	•	•	×			
58. *Samaropsis*? *taiyuanensis* HALLE	•	•	×					
59. *S.* sp.	•	•	×	•	×	•	×	
60. *Trigonocarpus*? *Norinii* HALLE	•	•	•	•	×			
61. *Tingia carbonica* (SCHENK)	•	•	•	•	•	•	×	
62. *T. Hamaguchii* KONNO	•	•	×	•	×	•	×	
63. *T. Kikkawai* (TOKUNAGA)	•	•	•	•	•	•	×	
64. *T. elegans* KONNO	•	•	•	•	•	•	×	
65. *T.* sp. (n. sp.)	•	•	•	•	×			
66. *Baiera* spp.	•	•	•	•	•	×	•	×

Table 3. Vertical Range of the Plant Fossils in the Huangchi Series Which are Common with European Flora.

Specific Name \ Age	Carboniferous						Permian		
	Dinantian	Namurian	Westphalian			Stephanian	Rotliegende		Zechstein
			L.	M.	U.		L.	U.	
Calamites Suckowi (BRONGN.)	×	×	×	×	×	×	×	×	
C. Cisti BRONGN.	•	•	×	×	×	×	×		
Sphenophyllum oblongifolium (G. et K.)	•	•	•	•	•	×	×		
Sph. verticillatum SLOTH.	•	•	•	•	•	×	×		
Odontopteris subcrenulata (ROST)	•	•	•	•	•	×	×		
Callipteridium trigonum FRANKE (syn. *C. Koraiense* TOKUNAGA)	•	•	•	•	•	×	×		
Lepidodendron Gaudryi RENAULT	•	•	•	•	•	×	×		
Stigmaria ficoides (STERNB.)	×	×	×	×	×	×	×		
Cordaites principalis (GERM.)	•	•	×	×	×	×	×		

HALLE[6] in Shan-hsi and by KAWASAKI[10] in Korea, and recognized that the Huangchi Series is to be correlated with the lower part of the Yuehmenkou Series, namely the Taiyuan Series in Shan-hsi and the lower part of the Jido Series in Korea. Though characteristic fusulinid fossils of the Sakmarian have not yet been found, the writer concluded that the Huangchi Series belongs to the lowermost part of the Permian Period on the basis of the above considerations. Since then, many marine animal fossils have been found from the Huangchi and Liutang Series in the Tai-tzu-ho district, and these will be mentioned in the paragraph on the Liutang Series.

The Yatang Series in the southern part of the Liao-tung Peninsula is composed of the so-called black-rock group, and constitutes the Lower coal-measures, as in the Tai-tzu-ho district. At its type locality in the Fu-chou coal field (Fig. 8), the Yatang Series consists of shale, sandy shale, sandstone, limestone, chert, fire-clay and coal. The total thickness is about 100 m. The fire-clay beds are always developed at the base of this series.

In Fu-chou the following fossils are abundant in the limestone and shale of this series.

Foraminifera

Nodosinella padangensis LANGE
Textularia exima D'EICHWALD
T. thorax LANGE
Cribrostomum molleri LEE and CHEN
Climacammina sp.

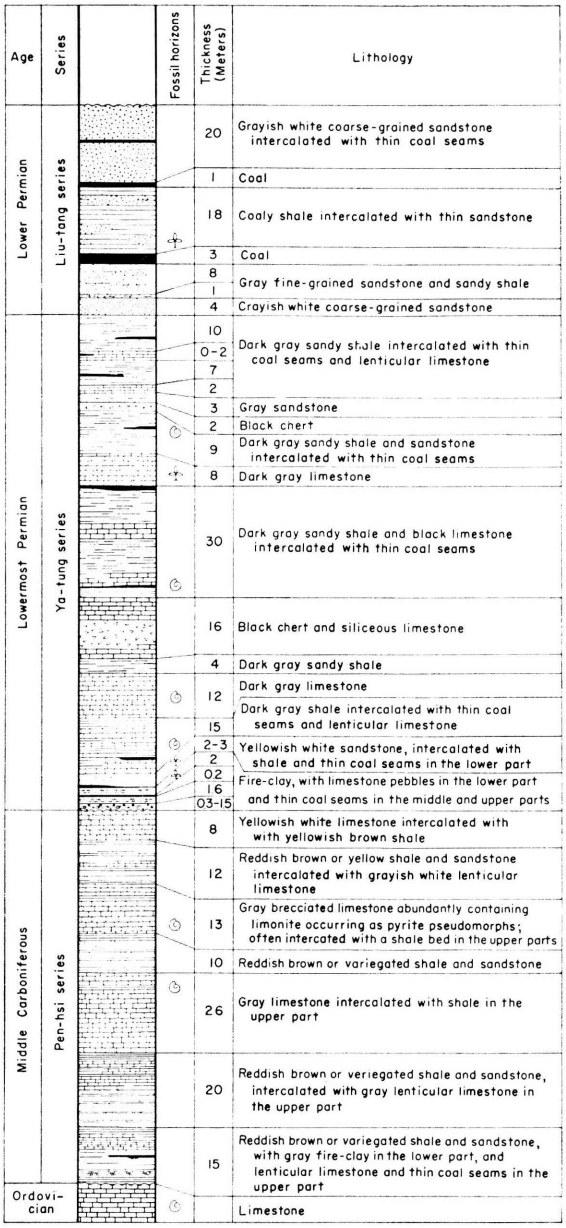

Fig. 2. Geologic Columnar Section of the Fu-chou Coal Field.

Tetrataxis parviconica LEE and CHEN
T. schellwieni OZAWA
T. planolocula LEE and CHEN
Ozawainella angulata (COLANI)
Quasifusulina longissima (v. MÖLLER)

Qu. longissima var. *tenuis* (LEE)
Schwagerina richthofeni (SCHWAGER)
Sch. expansa (LEE)
Sch. vulgaris cf. var. *kozui* (LEE)
Pseudoschwagerina glomerosa (SCHWAGER)
Ps. muongthensis (DEPRAT)

Brachiopoda
Productus taiyuanfuensis GRABAU
P. cf. *volgensis* STUCKENBERG
Derbyia hemispherica WAAGEN
Streptorhynchus kayseri SCHENK
Martinia semiplana WAAGEN
Chonetes semicircularis CHAO

Pelecypoda
Lima sp.
Limatulina sp.
Pseudomonotis sp.
Nuclopsis anthraconeilloides CHAO

Cephalopoda
Huanghoceras linchengense YIN

Bryozoa and crinoides
Genus and species indet.

There is no doubt that the geological age of this series is Sakmarian and is correlated with the Taiyuan series in North China, as well as with the lower part of the Jido series (coal-measures) in Korea.

Moreover, in Fu-chou, such plant fossils as *Calamites Suckowi* (BRONGN.), *Annularia stellata* (SCHLOTH.) and *Cordaites Schenkii* HALLE are found in shale accompanied by limestone in this series.

c. Liutang Series

The Liutang Series constitutes the so-called Upper coal-measures and rests conformably on the Huangchi Series. The type locality is the Liutang Mine, 2.7 km west of Pen-hsi-hu (Fig. 6). This series does not crop out in the southern part of the Liao-tung Peninsula except at Fu-chou, where its lower part alone is developed. However, its lithic character and fossils are almost identical with those of the Tai-tzu-ho district.

This series consists of sandstone, shale, fire-clay and coal, without limestone. Coal is found mostly in the lower part, while the sandstone is richly developed in the upper part. Shales of the lower part are carbonaceous, while those of the upper part are red-ochre or green and are associated with good aluminous shales and fire-clay bed A. The total thickness of the series is estimated to be about 170 m.

Many well-preserved plant fossils are found in the carbonaceous shales in the lower part of this series, and important species are listed in Table 2. Among them, 19 genera and 41 species are identified. Chatacteristic Oriental plants such as

Table 4. Vertical Range of the Plant Fossils in the Liutang Series Which are Common with European Species.

Species \ Age	Carboniferous						Permian		
	Dinantian	Namurian	Westphalian			Stephanian	Rotliegende		Zechstein
			L.	M.	U.		L.	U.	
Calamites Suckowi (BRONGN.)	×	×	×	×	×	×	×	×	
C. Cisti BRONGN.	•	•	×	×	×	×	×		
Annularia stellata (SCHLOTH.)	•	•	•	•	×	×	×		
Sphenophyllum Thonii MAHR	•	•	•	•	•	×	×		
Sph. oblongifolium (G. et K.)	•	•	•	•	•	×	×		
Sph. emarginatum BRONGN.	•	•	•	•	•	×	×		
Pecopteris polymorpha BRONGN.	•	•	•	•	•	×	×		
Callipteridium trigonum FR. (*C. koraiense* T.)	•	•	•	•	•	×	×		
Taeniopteris multinervis WEISS	•	•	•	•	•	•	×		
T. Schenki STERZEL	•	•	•	•	•	•	×		
Lepidodendron Gaudryi RENAULT	•	•	•	•	•	×	×		
Stigmaria ficoides (STERNB.)	×	×	×	×	×	×	×		
Cordaites principalis (GERM.)	•	•	×	×	×	×	×		

Lobatannularia, Pecopteridium, Emplectopteris, Emplectopteridium and *Tingia* are predominant, occupying about 2/3 of the total number. Therefore, the differentiation of the Far Eastern floral province in this series is more remarkable than in the Huangchi series. As seen in Table 2, 26 species make their first appearance in this series and are characteristic to it. However, *Neuropteridium, Chiropteris, Taeniopteris* and *Cladophlebis* are Mesozoic floral elements.

Among the flora in this series, 13 species are common with European species; their geological age is given in Table 4. *Taeniopteris multinervis* WEISS and *T. Schenki* STERIEL are especially characteristic to the Lower Rotliegende of Europe, and *Sphenophyllum Thonii* MAHR is abundant in the same age. Therefore, there would be no objection to assigning this series to the Lower Rotliegende.

The writer also compared the plant fossils of this series with that of Shan-hsi. The results indicate that this series almost corresponds to the upper part of the Yuehmenkou Series. If it is younger, it is perhaps equivalent to the basal part of the Lower Shihhotzu Series. It is clear, however, that this series is contemporaneous with the upper part of the Jido Series in Korea, from the comparison with the plant fossils in the Heian System.

Three collected specimens of *Chiropteris reniformis* KAWASAKI are noteworthy. This species is found only in the upper part of the Kobosan Series in Korea and

Shihhotzu Series in Shan-hsi. From this standpoint the geological age of the Liutang Series in Fu-chou must be reconsidered.

Mention should be made also of the sedimentation facies of the Huangchi and Liutang Series in the Tai-tzu-ho district. Formerly, Tsutomu OGURA[39] had found abundant radiolarian species and sponge spicules from the shale and pyritiferous nodules in the Huangchi Series at Pen-hsi-hu and Yen-tai, as well as *Ammodiscus*—siliceous foraminifera—from the shale in the Liutang Series, and he concluded that the coal-measures in these districts are of brackish deposition while the inter-coal beds are pure marine sediments.

Since then, the writer[31,32] collected many specimens of small gastropod fossils, namely *Sphaerodoma r-endoi* NODA, *Sph.* sp. and *Naticopsis* sp. from four layers of black limestone, 20–50 cm thick, intercalated within the black shale, about 5 m in thickness, that overlies the coal seam in the lower part of Huangchi Series, south of Chuan-chia-pu-tzu, Tien-shi-hu coal field. *Cordaites* sp. and *Stigmaria* sp. were collected from the gray sandstone, intercalated with black shale, which lies about 20 m above the uppermost layer of limestone. Therefore, it is clear that these limestone layers must belong to the Huangchi Series.

The writer also collected the following animal fossils from the dark gray shale in the lower part of the Liutang Series, which crops out in the gully west of Hsiao-nan-kou, Niu-hsin-tai coal field.

Brachiopoda

Chonetes latesinuata (SCHLOTH.)
Ch. pygmaea LOCZY
Ch. substromenoides HUANG
Ch. spp. (n. sp.)
Waagenoconcha cf. *purdoni* (DAVID.)
Productus taiyuanfuensis GRABAU
P. gruenewaldti KROTOW
Marginifera pusilla SCHELLW.
Linoproductus koninchianus (VERNEUIL)
L. sp.
Striatifera sp.
Schellwienella regularis HUANG
Sch. sp.

Pelecypoda

Aviculopecten manchuriensis CHAO
Lima striatoplicata CHAO
Nuclopsis sp.

Gastropoda

Paromphalus cf. *mapingensis* GRABAU

Cephalopoda

Orthoceras sp.
Aphelocerus sp.

Corals

Genus and species indet.

Crinoid stems

Plant fossil

Cordaites principalis (GERM.)

The fact that many marine animal fossils were found from the Huangchi and Liutang Series in several places in the Tai-tzu-ho district strengthens OGURA's and the writer's conclusions that marine sediments are often present in the Huangchi and Liutang Series. Naturally, some differences in lithic character may be found between the Huangchi Series in the Tai-tzu-ho district and the Yatang Series in the southern part of the Liao-tung Peninsula. However, the differences are largely whether the sediments are limy or sandy and whether *Pseudoschwagerina* and *Schwagerina* are present or not. Both series have undergone marine transgression.

d. Tsaichia Series

A thick complex of quartz sandstone and variegated shale, covering the Liutang Series, belongs to the Tsaichia Series. Its type locality is Tsai-chia-tun along the Tai-tzu Ho river, about 4 km south of Pen-hsi-hu. Its total thickness is estimated to be about 440 m. This series does not crop out in the southern part of the Liao-tung Peninsula but it is especially well developed in the vicinity of Pen-hsi-hu in the Tai-tzu-ho district.

At a glance, the relation between the Liutang and Tsaichia Series seems conformable. However, it is observed that the Tsaichia Series rests in distinct clino-unconformity on bed A of the upper part of the Liutang Series in the aluminous shale mine at Tzu-erh-shan near Yen-tai and Lao-tung-tai, Hsiao-shih.

B. Fun-chiang district

The Taitzuho System crops out extensively in the so-called Tung-pien-tao area, an eastern prolongation of the Tai-tzu-ho district. The writer[29] surveyed the Taitzuho System at Te-chang-tzu, Wu-tao-chiang, Ta-t'ung-kou and Lao-huan-tzu-kou, An-tung Province along the Hun Chiang river, and subdivided the system into the Penhsi, Takang and Techang Series in ascending order.

a. Penhsi Series

The Penhsi Series of the Hun-chiang district rests unconformably on the Ordovician limestone and consists mainly of black shale and gray sandstone intercalated with several thin seams of coal and limestone. A comparison of its lithic characters with those of the Tai-tzu-ho district shows the following differences: A basal conglomerate, 1–2.5 m thick, is developed in this district; the development of aluminous shale or fire-clay is remarkably poor; the color of the rocks is noticeably dark black, and ochre rock is rather rare; its total thickness is estimated to be about 100 m in general, but it sometimes reaches 270 m; limestone layers are found only in its upper part and are remarkably thin; many marine animal fossils are found in the limestone, indicating that it belongs to the Middle Carboniferous Moscovian. The most important fossils are listed below.

Foraminifera

Nodosinella sp.
Textularia exima D'EICHWALD
T. thorax LANGE
Climacammina antiqua BRADY
C. longissimoides (LEE and CHEN)
Tetrataxis minima LEE and CHEN
T. conica EHRENBERG
Lagena sp. (n. sp.)
Bradyina nautiliformis v. MÖLLER
B. cf. *rotula* v. MÖLLER
Staffella sphaeroidea (v. MÖLLER)
S. confusa LEE and CHEN
Ozawainella angulata (COLANI)
Fusulinella sp.
Fusiella cf. *paradoxa* LEE and CHEN
Fusulina konnoi (OZAWA)

Cephalopoda
Remelleoceras subquadrangulare GRABAU
R. grabaui YIN
Pleuronautilus sp.

Brachiopoda
Productus cf. *gruenewaldti* KROTOW
Schllwienella kweichouensis GRABAU
Marginifera sp.
Spiriferina sp.

Bryozoa
Fenestella sp.

Trilobita
Humilogriffithides someyai ENDŌ

Many fossils of gastropods, corals and crinoids were also found. However, since their preservation was very poor, identification was impossible. From the shale at Lao-huan-tzu-kou, the writer collected *Lepidodendron* sp. in association with fossils of cephalopods, brachiopods, bryozoans and trilobites.

b. Takang Series

The type locality of this series is Ta-kang-ling, Te-chang-tzu. This series is the main coal-bearing formation in Tung-pien-tao. It is composed mainly of gray white coarse-grained sandstones, often with shale, coal and fire-clay; its total thickness attains about 70 m.

An unconformity is found at the base of this series;[45,52] the present series rests in parallel unconformity on the Ordovician limestone, without fault or thrust, north of Te-chang-tzu, and the Penhsi Series is lacking between these two formations.

In this series, well preserved plant fossils are often found in the coaly shales which accompany the important coal seams. They are listed in Table 5.

Referring to the fossils listed above, the Takang Series may be contemporaneous with the Liutang Series of the Tai-tzu-ho district, and may therefore be Lower Permian (Lower Rotliegende) in age.

In connection with this conclusion, an important question in the geologic history of Manchuria is whether or not the Huangchi Series, situated between the Penhsi and Liutang Series in South Manchuria, is completely lacking in this area. It is impossible to discuss this problem in detail until more precise stratigraphic data and fossils are obtained. Hence, it would be wise to avoid using the same series names as those of South Manchuria in this district. The writer suggests using the name Takang Series, taking it as equivalent to the whole or part of the Jido Series in Korea and the Yuehmenkou Series in Shan-hsi.

Table 5. List of Plant Fossils from the Takang Series.
(○ indicates the presence of many individuals)

	Specific name \ Locality	Lao-huan-tzu-kou	Hsiao-tung-kou	Wu-tao-chiang	Te-chang-tzu
	Annularia orientalis KAWASAKI	×			
	Sphenophyllum oblongifolium (G. et K.)	×	•	•	×
○	*Sph. emarginatum* (BRONGN)	×			
	Sph. cf. *Thonii* MAHR	•	×		
○	*Neuropteris* cf. *gleichenoides* (STUR.)	×	×	×	×
	Pecopteris sp.	•	•	•	×
○	*Lepidodendron molle* JONGM. et. GOT.	•	×	•	×
○	*L. oculis-felis* (ABB.)	×	•	•	×
	L. Yabei KOIWAI	×			
	L. cf. *orientale* KOIWAI	×			
	L. sp.	×	×		
○	*Stigmaria asiatica* JONGM. et. GOT.	×	×	×	×
○	*Cordaites Schenkii* HALLE	×	×	×	×
○	*Cordaicarpus cordai* GEIN. forma *elongata* J. et G.	•	×	×	×
	C. sp.	•	•	×	

c. Techang series

The type locality is Te-chang-tzu. The series mainly composed of ochre sandstone, with ochre shale in the upper part. Its total thickness may attain more than 300 m. At the base of this series, hard, ochre sandstone, several to seventy cm in

thickness and with varying amounts of hematite is developed and serves as convenient index bed field work.

No fossils were collected from the Techang Series, so its geological age cannot be discussed in detail. However, there is no doubt that this series is equivalent to the Tsaichia Series of the Tai-tzu-ho district.

C. Chin-chou and Je-ho districts

The Permian System of the so-called South Manchurian type is extensively distributed in the Chin-chou and Jeho districts. Since coal and fire-clay are intercalated within this system, it has been a subject of interest to geologists for many years. Important localities are Hung-lo-hsien (Fig. 9), Yang-chia-chang-tzu (Fig. 10), and Nan-piao in the western part of the former Chinchou province, and Yang-shu-kou, Pao-kuo-tu, Wu-tao-ling, Sung-shu-tai, and Hsing-lung coal fields in Jeho province.

A comparison between the writer's[27] results and those of Toshiji TAKAHASHI[43] and Li-hsu CHANG[3,4] is shown in Table 6.

Table 6. Correlation Table of the Permian System West of Chin-chou.

NODA (1940)	TAKAHASHI (1944)		CHANG (1944)
Hamashan Series	Hsingcheng Series		Hungla Series Fulungshan Series
Hunglohsien Series	Upper	Chinchou Series	Sanchiatzu Series
	Lower		Nanpiao Series
Ordovician limestone	Ordovician limestone		Ordovician limestone

a. Hunglohsien Series

The writer's Hunglohsien Series comprises the coal-measures which rest unconformably on the Ordovician limestone. It consists of sandstone, shale, conglomerate, coal and fire-clay, and, rarely, lenticular limestone. (see Fig. 3 & fig. 9).

Abundant plant fossils are collected from the coaly shale which is associated with coal in this series in the Hung-lo-hsien, Yang-chia-chang-tzu and Nan-piao coal fields. The main species, as far as known to date, are summarized in Table 7. From these fossils, it is evident that the Hunglohsien Series is equivalent to the Huangchi and Liutant Series of the Tai-tzu-ho district of South Manchuria.

A thin limestone layer is sometimes intercalated in the Hunglohsien Series, and it is especially well developed in the western part of the Yang-chia-chang-tzu coal field. No fossils were found in the limestone. However, the writer collected the following fossils from the black shale in the middle part of this series on the eastern slope of Ping-tien-shan, about 10 km south of Yang-chia-chang-tzu; these

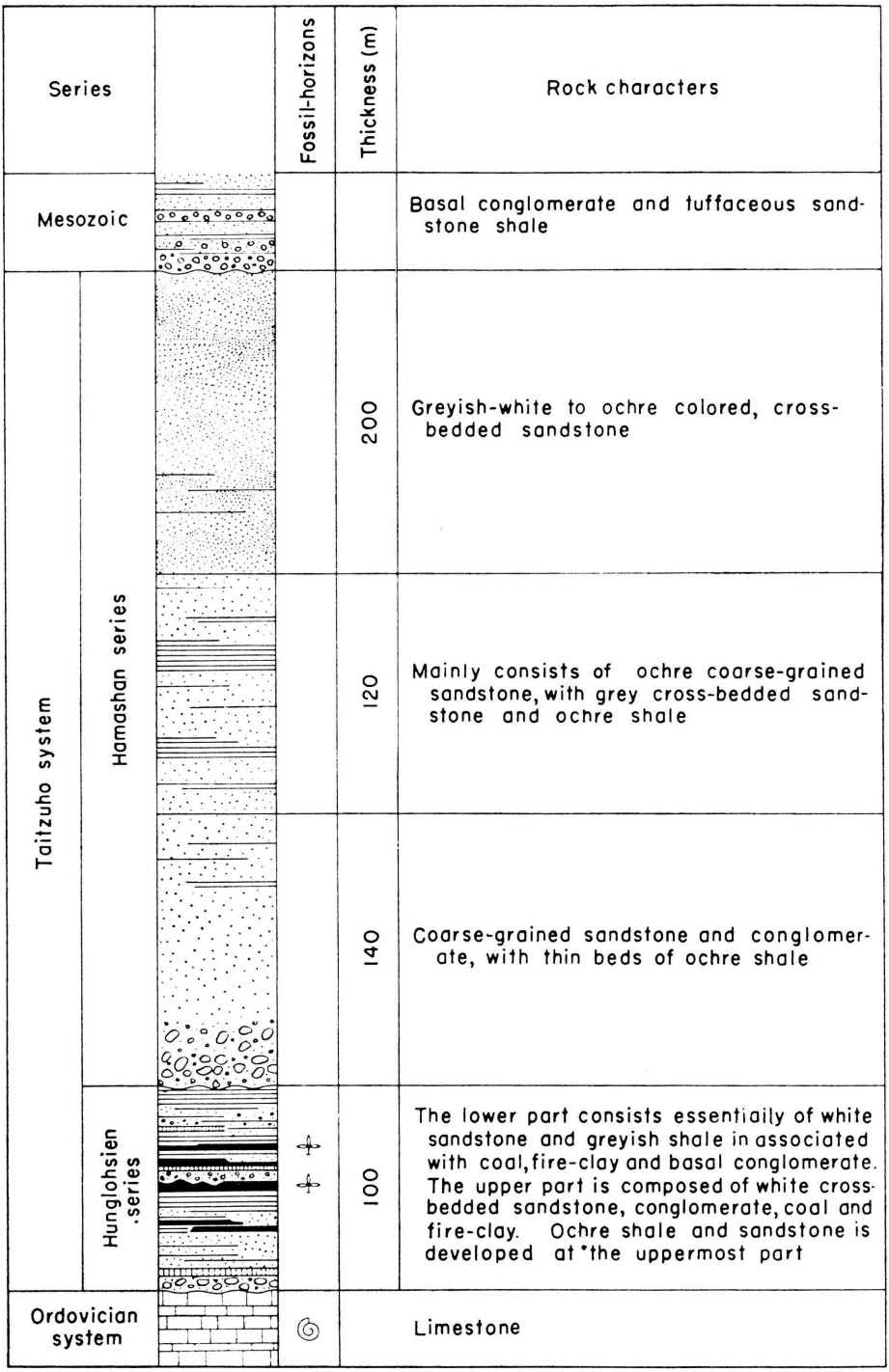

Fig. 3. Geologic Columnar Section of the Hung-lo-hsien Coal Field.

Table 7. List of Plant Fossils in the Hunglohsien Series.

Specific name \ Series and collector	Hunglohsien Series (Noda)	Chinchou Series (Takahashi)		Nanpiao Series (Chang)	Sanchiatzu Series (Chang)
		Lower	Upper		
Calamites Suckowi (Brongn.)	×	•	×	•	×
C. cf. *Cisti* Br.	•	•	×	•	×
Annularia macronata Schenk	×				
A. orientalis Kawasaki	×	•	•	•	×
A. gracilescens Halle	•	•	×		
A. ensifolius Halle	•	•	×		
A. cf. *stellata* (Schloth.)	•	•	•	•	×
Lobatannularia sinensis (Halle)	×	•	•	•	×
Macrostachia sp.	×				
Sphenophyllum orientalis Kaw.	×	•	•	•	×
Sph. oblongifolium (Germ. et Kadlf.)	×	•	•	•	×
Sph. verticillatum (Schloth.)	•	•	×		
Sph. emarginatum Br.	•	×	•	×	×
Sph. cf. *Thonii* Mahr	•	•	•	•	×
Sphenopteris Gothanii Halle	×				
Sph. tenuis Halle	•	•	•	•	×
Pecopteris polymorpha Br.	•	•	×	×	
P. Wongii Halle	×				
P. orientalis (Schenk)	•	•	•	•	×
P. candolleana Br.	•	•	×		
P. Anderssonii Halle	•	×			
P. arcuata Halle	•	•	•	×	
Cladophlebis Nystroemii Halle	×	•	•	•	×
Alethopteris ascendens Halle	×	×			
A. Norinii Halle	•	•	•	•	×
Emplectopteris triangularis Halle	×	•	×		
Emplectopteridum alatum Kaw.	×				
Callipteridium koraiense (Tokunaga)	•	•	×		
Neuropteris flexuosa Br.	×				
N. wutaolingensis Matsuzawa	×				
N. auricullata Br.	•	•	×		
Neuropteridium cf. *coreanicum* Kaw.	•	•	×		
Taeniopteris multinervis Weiss	•	•	•	•	×

Table 7. (Continued)

Specific name \ Series and collector	Hunglohsien Series (Noda)	Chinchou Series (Takahashi)		Nanpiao Series (Chang)	Sanchiatzu Series (Chang)
		Lower	Upper		
T. sp.	×	•	×		
Lepidodendron oculus-felis (Abb.)	•	•	•	×	
L. Gaudryi Renault	•	•	•	×	
L. orientale Koiwai	•	×			
Stigmaria ficoides (Sternb.)	×	•	×	×	×
Pterophyllum daihoensis Kaw.	•	•	•	•	×
Cordaites principalis (Germ.)	×	×	×	•	×
C. Schenkii Halle	×	×	×	×	×
Tingia elegans Konno	•	•	•	•	×
T. Hamaguchii Konno	•	•	•	•	×
T. ? carbonica (Schenk)	•	•	×	•	×
Tingiostachya tetralocularis Kon.	•	•	•	•	×
Astrocuplites acuminatus Halle	•	•	•	•	×
Cornucarpus sp.	×				
Samalopsis sp.	×	•	•	•	×
Cordaicarpus sp.	×	•	•	•	×
Trigonocarpus? Norinii Halle	×				
Largenospermum sp.	•	•	×		
Calpolithus sp.	•	×			

fossils are characteristic of the Taiyuan Series in North China and the Jisu Honguer limestone in Mongolia.

Brachiopoda

Chonetes cf. *latesinuata* Schell.

Productus taiyuanfuensis Grabau.

Streptorhynchus kaizeri Schell.

Pelecypoda

Sanguinolites cf. *olseni* Grabau.

Bryozoa

Genus and species indet.

Later, Takahashi treated this formation as the lower part of the Chinhsi Series, and added *Productus* cf. *gruenewaldti* Krotow and *Squamularia* sp. to the above list. The stratum from which these fossils were collected is in the middle part of the

Hunglohsien Series. It is doubtful whether the Penhsi Series is developed in this district.

b. Hamashan Series

The type locality is Ha-ma-shan Hill at the eastern end of the Hung-lo-hsien coal field (Fig. 9). It consists essentially of white and ochre coarse sandstone and ochre shale, the latter predominating in the middle part. Conglomerate is developed at its base and rests in parallel unconformity on the Hunglohsien Series.

The total thickness of this series is estimated respectively to be about 460 m, 1,200 m and 250 m in the Hung-lo-hsien and Yang-chia-chang-tzu coal fields and near Wei-tzu-kou in the Nan-piao coal field.

Formerly, the age of the Hamashan Series was assigned to Permo-Triassic or Triassic (?)[43,44]. However, since the writer collected *Calamites Suckowi* (BRONGN.), *Stigmaria ficoides* (STERNB.) and *Samaropsis* sp. from the coaly shale in the upper coal measures of this series at Shang-fu-erh-kou, Hsi-kou, south of Yang-chia-chang-tzu, it is concluded that this series still belongs to the Permian Period.

The Hamashan Series is overlain in parallel unconformity by thick basal conglomerate of the Mesozoic Era in the Hunglohsien and Nan-piao coal fields.

2. Special description

A. Tai-tzu-ho district

a. Yen-tai coal field

The Yen-tai coal field (Fig. 5) is located about 15 km east of Yen-tai Station on the Chung-chang Railroad (the main line of the former South Manchurian Railway) where the mountain lands open into the great Manchurian plain. The coal field is about 7 km N-S and 1–2.5 km E-W; a few rolling hills are found in the area.

In the Penhsi Series, ochre shales and sandstones about 50 m thick are developed in the lower half, while a complex of sandstones and shales with lenticular limestones, about 70 m thick, constitutes the upper half. Three beds of fire-clay are intercalated in this series, equivalent respectively to SAKAMOTO's E, F and G beds in descending order. These fire-clays are dark gray to gray-white and some of them are moderately good in both quantity and quality.

The Huangchi Series attains about 70 m in thickness; conglomerate to coarse sandstone is generally developed at the base where fire-clay bed D is distributed. This series is composed essentially of dark gray shales and coaly shales. Its lower part contains the Shang-chieh, Erh-chieh and San-chieh coal-beds, as well as several beds of semi-anthrathite or high grade bituminous coals called the "lower coal seam group; the upper part often includes sandstones and sandy shales.

The thickness of the Liutang Series is estimated to be about 170 m. Coal seams, inclusive of the Ta-tsao coal bed, are developed in its lower part. The middle to upper part consists essentially of blue-gray sandstone that turns yellow when weathered, often intercalated by thin beds of variegated shale, arenaceous shale and coal.

The fire-clay beds C, B and A are intercalated within the middle and upper part of this series, bed A, which is distributed in the vicinities of Pan-tao-ling, Tzu-erh-shan and Tsai-chia-shan, constitutes an especially good aluminous shale, and was formerly worked at Pan-tao-ling and Tzu-erh-shan.

From the standpoint of geological structure, this coal field constitutes a syncline which stretches from about north-northeast to south-southwest and is interrupted once in the vicinity of Ta-yu-kou. The uppermost part of the Taitzuho System in this coal field crops out on the eastern slope of Tzu-erh-shan and forms a dish-shaped structure. The average inclinations of both limbs of this synclinal structure are estimated to be 20°–30°. A great fault runs north-south at the center of this dish-shaped basin, where denudation is vigorous at present, and alluvium is thick. Therefore, the remaining quantity of fire-clay is very small.

b. Pen-hsi-hu coal field

The Taitzuho System in this coal field forms a truncated isosceles triangle; its upper and lower rim and diagonal lines are estimated respectively to be 3.6, 6.1 and 4.8 km long; its upper rim trends southwestward. The system is also distributed in a narrow belt along the western diagonal line, which stretches about 4.2 km to Lin-chia-wei-tzu at the south end. This coal field is the best area of distribution and development of the Taitzuho System in South Manchuria. Good semi-anthracite and high-grade bituminous coals are yielded.

The Penhsi Series crops out monoclinally along the north foot of a ridge which stretches from Ming-shan-kou on the east to Hsin-tung-kou on the west. It strikes almost east-west or NW-SE and dips 20°–30° toward the south. The total thickness is estimated to be about 120 m. It consists essentially of shale, sandstone and limestone. Two workable fire-clay beds are found in some areas in the lower part.

Limestone occurs mainly in the upper part of this series and is mostly lenticular.

The Huangchi Series consists of sandstone, shale, and coal; fire-clay bed D is intercalated in the lower part. The total thickness is estimated to be about 70 m. There are eight beds of coal belonging to the so-called lower coal group, which swell and pinch in places. The following five coal beds are workable.

I-chieh bed	0.6–1.8 m thick
Erh-chieh bed	2.4–2.7 ,,
San-chieh bed	0.6–1.0 ,,
Ssu-chieh bed	0.6–1.0 ,,
Wu-chieh bed	1.0–1.2 ,,

The thickness of the Liutang Series is estimated to be about 170 m. The series consists mainly of sandstone, shale and coal. There are about ten coal beds that are especially well developed in the lower part. The following three beds are workable and constitute the so-called upper coal group (in descending order):

Pao-cha bed	0.6–2.4 m thick
Hsiang-tuan bed	0.6–2.7 ,,
Chou-cha bed	0 –1.0 ,,

The coal is, in general, short flame, with a heating value of approximately 7,300 cal. and a strong caking capacity. This coal is therefore most suitable for manufacturing coke for iron smelting. The Pao-cha and Chou-cha beds are especially low in phosphorus and are mostly used for manufacturing low phosphorus cokes. Shales of the lower part of this series are black or dark brown; in the upper part they often become ochre colored, and fire-clay bed Ao is developed in the uppermost part.

The Tsaichia Series crops out typically on the southern slope of a ridge which stretches from south of the electric power house via Okura Shan to Ma-i-tsun-kou and on the northern slope of a hill south of Pao-chia-wa-tzu. Part of this series is rather extensively distributed between San-chia-tzu and Ho-tou-kou along the western rim of this district.

Let us now glance at the geologic structure of this coal field.

In the vicinity of Pen-hsi-hu and Miyanohara, the land forms a hilly basin surrounded by higher ridges. The Taitzuho System, the Miyanohara Group and the Kabutoyama andesite group are the principal formations exposed in this basin. The Tai-tzu Ho river runs from the northeastern corner to the southwestern corner across the basin. The hills surrounding the basin are composed of older Paleozoic strata. The Taitzuho System and the Miyanohara Group in the basin are in fault contact with these older Paleozoic strata, except for the northern side. Therefore this is a large structural basin.

c. Niu-hsin-tai coal field

The Niu-hsin-tai coal field is about 15 km upstream from Pen-hsi-hu (see Fig. 7). The Penhsi Series crops out extensively along the outer margin of this coal field, except in the alluvial plain to the northwest, and serves as the basement of the Permian coal measures. Limestone conglomerate of unknown age is developed between the Penhsi and Ssuyen Series in this coal field. Its development is especially remarkable in the south and southeastern parts, and its thickness is estimated at about 20 m in the vicinity of Hung-lien-kou.

The Penhsi Series is a complex of shale, sandstone and limestone, and is about 20 m thick. Thick development of ochre shales in the lower part and the presence of more limestone beds within this series are the outstanding features as compared with the Yen-tai and Pen-hsi-hu coal fields. Nodular limonite ore is contained in the basal part and was formerly mined east of Wang-kuang-kou. Fire-clay bed G occurs approximately in the same horizon as this limonite ore and sporadically contains very good aluminous shales.

The Huangchi Series is distributed in a relatively low hilly zone from Lao-kung-la-tzu via Wan-kuang-kou to Hung-lien-kou, and dips 20°–30° towards the southwest. It crops out at the foot of steep hills which consist of Ordovician Ssuyen limestone in the vicinities of Hsia-niu-hsin-tai and Hsiao-nan-kou, where it rests in parallel unconformity on the Penhsi Series and dips steeply towards the north. The upper part shows a gentle inclination of 15°–30° interrupted at one point by a strike fault. The Huangchi Series crops out three times from two north-south

faults on a hill south of Hung-lien-kou. The coal in this series was formerly mined at random throughout the area, but the coal seams are thinner, in general, than those of the Liutang Series.

The Liutang Series is well exposed on the eastern slopes of Lang-tung Shan and Wu-hsing-pai-tzu Shan, in the eastern part of Hsia-niu-hsin-tai as well as in the vicinities of Hsiao-nan-kou and Lao-mei-tung. The coal seams in the lower part of this series are the most important resources in the Niu-hsin-tai coal field. A somewhat generalized profile of bed A at Wu-hsing-pai-tzu Shan is as follows:

Hanging wall, sandstone

Coal and coaly shale	0.05–0.15	m thick
Black clay	2.00	,,
Coal and coaly shale	0.20–0.40	,,
Aluminous shale	2.00	,,
Gray clay	1.50	,,
Ochre and gray coarse clay	2.00	,,

Foot wall, sandstone

The Tsaicha Series is well distributed on the western slopes of Lang-tung Shan and Wu-hsing-pai-tzu Shan as well as at Sung-shu-pai; it always dips 20°–30° towards Hsia-niu-hsin-tai.

The geologic structure of this coal field, including the surrounding hills of the older Paleozoic and Sinian Systems, is characterized by a great synclinal structure whose axis runs from northwest to southeast. A divide south of Hung-lien-kou approximately corresponds to the synclinal axis. The dip of the strata is very gentle and stratification near this axis is nearly horizontal; the dip is gentler in the northeastern limb than in the southwestern. A great fault which is traceable from Pen-hsi-hu extends along the course of the Tai-tzu Ho; this fault line not only bounds the northwestern rim of this coal field under the alluvial plain but also cuts the synclinal structure. Thus the geology on the left side of the Tai-tzu Ho is contrasted with more complicated Paleozoic geology on its right side.

d. Hsiao-shih coal field

The Hsiao-shih coal field is located 46 km east of Miyanohara on the Hsi-kan line. The Penhsi Series is distributed extensively in the vicinity of Miao-kou, west of Hsiao-shih Station, east of Chang-chia-pu-tzu, Kan-chang-kou, Yuan-chia-pu-tzu, Li-chia-pu-tzu, Ma-chia-chuang-tzu and others. Six limestone beds are contained in this series in the neighborhood of Miao-kou. Though two or three coal beds are intercalated, they are too thin to be workable. Aluminous shales are sometimes contained within fire-clay bed G.

The area of distribution of the Permian System is divided approximately into the north and south districts. The Permian System west and east of Hsiao-shih is included in the north district while that in the south between Kan-chang-kou and Yuan-chia-wo-peng belongs to the south district. In both districts, the middle part of the Tsaichia System approximately bounds the upper limit of the Taitzuho System in the Hsiao-shih coal field. A synclinal structure in the north district has

its axis trending approximately from west-northwest to east-southeast, while in the south district the structure is monoclinal, striking approximately east-west and dipping towards the south. The southernmost boundary of this area contacts granitic porphyry of a later intrusion.

An isolated exposure of the Taitzuho System is found in the neighborhood of Chuan-shui Station, where the system forms a synclinal structure whose axis runs approximately east-west. Since the Tai-tzu Ho flows through the central part, most of this area is covered by alluvial deposits. However, the lower parts of the Penhsi Series crop out in both the north and south limbs and fire-clay bed G is traceable.

e. Tien-shih-fu coal field

The Tien-shih-fu coal field is located 38 km east of Hsiao-shih along the Hsi-kan line. Permian and Triassic coal measures are developed in this coal field. Since it has many hills, and the faults are remarkably developed, its structure is complicated. However, the Penhsi Series of the Taitzuho System crops out in the vicinities of Chuan-chia-pu-tzu and Kung-chia-pu-tzu as well as north of Chang-chia-pu-tzu. It consists of ochre-colored formations generally intercalated with one to three beds of grayish-white limestone.

The Permian coal measures are distributed mainly in the vicinities of Kung-chia-pu-tzu and Chuan-chia-pu-tzu, west of Ta-pu, as well as in a north-south belt along the eastern foot of the Pa-pan-ling range, north of Wang-chia-pu-tzu; part of it is also developed sporadically at the eastern foot of Tieh-cha Shan and in Ying-wu-pei.

The stratigraphic sequence and thickness of each series approximately coincide with those of the Pen-hsi-hu field. The sandstone in the middle part of the Tsai-chia Series is developed as the uppermost stratum of this coal field. Good coal seams are intercalated within the Huangchi and Liutang Series.

B. Southern district of Liao-tung Peninsula

a. Fu-chou (Wu-hu-tsui) coal field

The Fu-chou coal field is in Fu Hsien, Liao-ning Province. It is located along Fu-chou Bay at the mouth of Ya-tang Bay, about 50 km southwest of Wa-fang-tien station (see Fig. 8). This coal field is the type locality of the southern Liao-tung type of the Taitzuho system, and is well known for its good anthracite and fire-clay. A stratigraphic sequence ranging from the base of the Taitzuho System upwards to the middle part of the Liutang Series is developed.

The Penhsi Series is well distributed in the marginal parts of this coal field as the basement of the Permian coal measures; its total thickness is estimated to be about 90 m. The lower and upper parts of this series are characterized by ochre shale and ochre sandstone, the color becoming darker in the lower part. There is often also a splendid deep blue color due to the presence of ferric shale. Fire-clay corresponding to bed G of the Tai-tzu-ho district is always intercalated in this ochre shale, and is worked at San-ling-shan and Tao-shan as good, hard stone

clay. A thin bed of powdery coal associated with this clay bed as its hanging wall is sometimes developed.

Throughout the coal field, good fire-clay beds are distributed at the base of the Yatang Series and are subdivided into the upper, middle and lower beds from the standpoint of mining. Pyritiferous limestone pebbles which may have been derived from the Penhsi Series are abundant in the basal part of the Yatang Series, resting on the erosion surface of the Penhsi Series.

The Liutang Series is developed in a syncline with axis trending WNW–ESE, south of Fei-chia-tun. Since almost all of this series is concealed under a saline marshy plain its complete sequence is unknown. The north limb of this synclinal structure and the basal part of the Liutang Series are barely traceable at Hsi-piao, Fei-chia-tun and in a valley east of the old office of the former colliery. However, judging from observations of a mine interior and the boring data, it is probable that almost the whole sequence of this series is preserved except for the upper part which was more or less eroded out. A good anthracite bed, called the upper coal seam, is developed in this series and has been mined for many years.

The Fu-chou coal field is surrounded by Ordovician limestone and forms a great structural basin. Investigating the structure of this coal field in detail, one can recognize two synclines and one anticline. The axis of one syncline stretches from WNW to ESE between Lo-chia-shan and Ting-chia-tun and the other, running NW-SE, is found near Hsiao-li-chia-tun, the northernmost village in this coal field, and Kang-yao. One anticline is located south of Li-chia-tun between these two synclines. These structures control the distribution of the Taitzuho System of this coal field. The Hsiao-li-chia-tun—Kang-yao synclinal axis coincides with the Lo-chia-tun—Ting-chia-tun axis north of Pai-chia-tun, and forms a Y-shaped synclinal structure in the coal field, which has many faults and strong denudation. Saline marshes and low rolling hills are scattered throughout the district. Black chert in the middle part of the Yatang Series constitutes the tops of almost all these rolling hills. Since the faults and folds are quite remarkable, as at San-ling-shan and Tao-shan, the strata are usually steeply inclined.

b. Tiao-hu-chu

The Tiao-hu-chu clay quarry is located on the south coast of Ya-tang Bay, opposite the Fu-chou coal field on the north coast, about 15 km west of Erh-shih-li-tai Station in Liao-ning Province. Fire-clay in the ochre shale in the lower part of the Penhsi Series crops out in a small area commonly called the Chi-ting-shan Mine, on the coast which is covered at high tide. In view of its geological structure the area seems to be the southwestern limb of a great syncline which runs towards NW—SE. The Taitzuho System rests in parallel unconformity on the Ordovician limestone, and is covered unconformably by loess deposits. The stratigraphic sequence of the Taitzuho System in this area is as follows, in ascending order:

Ochre shale	about 30 m thick
Fire clay bed G	,, 1 m
Ochre shale	,, 8 m

Alternation of yellowish-gray sandstone and shale	more than 30 m

This succession constitutes the lower part of the Pen-hsi Series.

c. Chien-shih-hui-yao-tun area

The Taitzuho System crops out in a small area in the Ordovician limestone, on hilly land north of Chien-shih-hui-yao-tun and Yao-chia-tao, about 10 km northwest from Chin-chou Station along Chin-chou Bay. Though the outcrops in this area are generally poor and the geological structure is relatively complicated by many faults, the stratigraphic sequences coincide with those of the Fu-chou coal field. Hence, a geological survey of this area is relatively simple. The formations have a monoclinal structure dipping towards the north. The east-west strike prolongation is about 3 km. Here the Taitzuho System consists of the Penhsi Series associated with the lower part of the Ya-tang Series.

d. Tung-chia-kou

Tung-chia-kou is situated along a small bay, about 16 km east of Chin-chou, facing the Yellow Sea. Since small quantities of coal and aluminous shale have been yielded for many years, it is a well-known place. The Taitzuho system is distributed in a northwest-southeast long narrow belt of low rolling hills and at the foot of hills surrounded by older Paleozoic strata. The area is divided in two by the alluvial deposits of the Tung-ta Ho. Natives call the coal field west of the Tung-ta Ho, Hsi-yao and the coal field on the east Tung-yao.

The Taitzuho System, ranging from its base upwards to the upper part of the Yatang Series is exposed.

C. Hun-Chiang district

The Taitzuho System in the so-called Tung-pien-tao area is extensively distributed along the Hun-chiang, in the Sung-shu-chen and Wan-kou area (the Sung-wan coal field), and yields much good coal, especially caking coal, and fire-clay. Though the formations are very important and interesting from both the scientific and economic standpoint, the stratigraphical and paleontological reports of this district are relatively scanty. The writer surveyed the Taitzuho System in Tieh-chang-tzu, Wu-tao-chiang, Ta-tung-kou and Lao-huan-tzu-kou along the Hun Chiang river with the following results.

The Penhsi Series is generally about 100 m thick, but attains 270 m in Ta-tung-kou and thins out completely north of Tieh-chang-tzu. Though several thin seams of coal are intercalated throughout, usually none are workable.

It is especially noticeable that a basal conglomerate, 1–2.5 m thick, is developed at the basal part in the vicinities of Lao-huan-tzu-kou, Ta-tung-kou and in a valley of the Wu-tao-chiang, Mo-ku-yuan-tzu. The pebbles are water-worn quartzite ranging in size from a fingertip to a hen's egg, rarely to a man's head. However, these pebbles are compressed by later strong crustal movements.

One or two, or sometimes three, workable coal seams are found in the middle part of the Takang Series. However, they show swelling and pinching and form

so-called pockets. The thickest coal seam at the open mine in Li-shu-kou, Wu-tao-chiang is estimated to be more than 20 m. The coals are generally high-grade bituminous or semi-anthracite and most of them are powdery and highly caking. Therefore, the coals are suitable for manufacturing coke.

D. Chinchou-Jeho district

a. Hung-lo-hsien coal field

Hung-lo-hsien is a town located about 25 km west of Chin-chou. The Permian System is distributed in an area, 6 km east-west and 1.5–2 km north-south, and west of this town (see Fig. 9). Though some sporadic disturbances are noticed, the formations strike generally east-west and dip 20°–40° towards the north. The formations, showing a monoclinal structure, rest on the Ordovician limestone and are overlain unconformably by Mesozoic strata. In the vicinity of Tung-ta-ling, the western end of this coal field, the Permian System forms a syncline, its axis striking north-south and dipping about 30° towards the east.

Several seams of workable coal are interbedded in the Hunglohsien Series and were formerly worked at random.

Coal seams and fire-clay beds are especially well-developed in the eastern part of this coal field, but they, together with the Hunglohsien Series, become very thin westward from Chien-pan-chuang.

The Hamashan Series is characterized by cross-bedded, ochre sandstone; its lower part is often associated with the same colored shale and also includes cross-bedded, gray to white, coarse-grained sandstone and conglomerate. These rocks are resistant to erosion and form a continuous line of hills which stretch east-west in this coal field.

The Mesozoic formation, resting unconformably on the Hamashan Series, is distributed extensively along the northern margin of this coal field, and consists mainly of so-called volcanic strata; consequently, it has no fossils.

All the formations are sporadically disturbed somewhat by several faults in some places of this district. Of these faults, one that runs north-south, passing through Kao-shan-tun, is particularly noticeable. The Hunglohsien Series and the underlying Ordovician limestone, cut by this fault at approximately right angles are seen to extend from the southern foot of Ha-ma Shan, and disappear at the eastern foot of Nan Shan.

b. Yang-chia-chang-tzu coal field

Yang-chia-chang-tzu coal field (Fig. 10) is located about 35 km northwest of Chin-hsi where the well-known Yang-chia-chang-tzu Mine Office of the former Manchuria Mining Co. is situated.

Two imperfect large synclinal structures are recognizable in this area. One of them passes the vicinity of Fu-erh-kou with an east-west axis, while the other, with northeast-southwest axis, passes Pai-miao-tzu and Ssu-ssu Shan on the western margin of this area. The north limb of the former dips about 40°–70° to the south. Due to the intrusion of the Tapeiling granite, ore deposits of galena, zincblende,

molybdenite, magnetite, etc., are developed mainly in the Cambrian limestone.

Sandstone at the upper part of the Hamashan Series strikes east-west dips about 20° to the south in the vicinity of Pi-chia Shan. The south limb dips 20°–40° to the north. Strata ranging upward from the Sinian to the Hamashan Series, southwest of Ping-ting Shan are intruded by granite. Intrusion of monzonite is extensively noticed in an area between Shang-pein and Sung-shu-mao west of Pi-chia Shan. The synclinal structure of this area is remarkably deformed by the monzonite intrustion.

The Hunglohsien Series is developed best in an area between Pai-yang-mu-kou and Shang-pien to the west. The thickness of this series is estimated to be about 80 m in the vicinity of Hsia-hei-yu-kou, but it becomes much greater near Sung-shu-mao, locally exceeding 300 m.

Coal seams are intercalated in the middle and upper part of this series in the neighborhood of Hsia-hei-yu-kou. They range from 50 cm to almost 1 m in thickness, the thickest seams being in the upper layer. Only two of these 60–70 cm thick, have been developed.

Four beds of fire-clay are found in this series on a hill east of Yang-chia-chang-tzu, but all except the lowermost grade into shale or sandy shale.

The Hamashan Series of this area consists essentially of thick sandstone, and its upper limit is truncated by an east-west fault in the central part of a synclinal structure. The thickness of the series is estimated at about 1,200 m.

c. Nan-piao coal field

A village called Sha-kuo-tun 31 km northwest of Nu-erh-ho Station, is the center of the Nan-piao coal field. The northeast extension of the coal field reached Kao-li-ching-tzu via Ta-yao-kou and Chao-chia-tun, and as far as Erh-fo-miao in Chin-hsi Hsien and Kang-yao-kou in I Hsien; its southwest prolongation reaches west of Kang-yao-ling via Fu-lung-shan in Chin-hsi Hsien, Wei-tzu-kou and Tang-chin-kou in Chao-yang Hsien. Thus, this is a narrow Permian coal field, about 33 km in its total extension. In general, it shows a monoclinal structure, dipping to the northwest, and its extension along a strike is sometimes interrupted by the intrusion of andesite. This coal field is also disturbed by many faults and intruded by volcanic rocks. One to six workable coal seams are intercalated in the lower part of the Hunglohsien Series, while one to four thin seams, less than 1 m each, are found in the upper part. These coal seams always swell and pinch, often easily thinning out.

About three beds of fire-clay are interbedded in the Hunglohsien Series, the upper and lower one being relatively continuous and of good quality. Each bed is conformable with its hanging and foot walls. The correlation of these beds with those of the Tai-tzu-ho district has not yet been completely studied.

The Hamashan Series consists mainly of ochre, nonfossiliferous, coarse- grained sandstone with white, coarse-grained sandstone at its base where conglomerate is found occasionally.

The Mesozoic conglomerate and sandstone which contain large quantities of

sand and gravel of volcanic rocks are developed extensively throughout this coal field, and the Mesozoic formation rests unconformably on the Hamashan Series.

d. Yang-shu-kou coal field

The Yang-shu-kou coal field is situated about midway between Pei-piao and Chao-yang; it is about 10 km north of Nung-chia station on the Chin-ku line, and about 4 km directly south from the southwestern end of the Pei-piao coal field. Chao-chi LIN[16] divided the stratigraphic sequence in this area as shown in Table 8. According to his report, the formations ranging from the Sinian limestone to the Mengkuyingtzu shale were overturned, on the Tuchengtzu conglomerate to form a *klippe*. This klippe strikes N 40°–60° E and, since the Paleozoic strata consist of plastic shales, they are remarkably disturbed by extensive lateral pressure and have variable inclinations, being sometimes, even vertical, and pinch and swell extraordinarily.

Table 8. Geological Stratigraphic Sequence in the Vicinity of Yang-shu-kou (after LIN).

Mesozoic	Tuchengtzu conglomerate Mengkuyingtzu shale Hachihhai agglomerate Hochiakou tuff
Paleozoic	Permian coal seam Mantou shale
Pre-Cambrian	Basic intrusive sheet (olivine gabbro) Sinian limestone

Hiroshi OZAKI[40] collected *Cordaites* sp., *Sphenophyllum oblongifolium* (G. et K.), *Sph. emarginatum* BR., *Sph.* sp., *Sphenopteris* sp., and *Samaropsis* sp. from the debris near the entrance of the Tungyao mine in this coal field.

e. Vicinity of Pao-kuo-tu

The Permian System(?) is extensively distributed south of Pao-kuo-tu, about 80 km north of Pei-piao. According to MORITA and SAKAGUCHI[23], the geological setting of this area is as follows:

The formation strikes generally N 60° E, and its prolongation attains about 24 km. The following features are notable. (1) The formation seems to rest directly on the gneiss group, in between, lacking the fossiliferous Ssu-yen limestone of the Ordovician. (2) Five lenticular beds of limestone are found in the lower part, while the upper part consists of conglomerate, sandstone, shale and fire-clay in which three coal seams are intercalated. (3) Though the development of lenticular limestone is remarkable, fossils are rarely found; only one species each of coral and bryozoa, and a fragment of crinoid stem were collected. (4) More than thirteen limestone beds are counted, which is ascribed to the repeated appearance of the same strata due to disturbance.

f. Wu-tao-ling coal field

The Wu-tao-ling coal field is located 37 km directly southwest from Ling-Yuang, Jeho Province. This coal field is also midway along the road from Ling-yuan, via Cha-peng, Ta-chang-tzu and Chien-chang-ying-tzu, to the Kai-luan coal field in North China.

The Permian System is divided into two blocks by an approximately east-west fault which passes near Pei-ta-ling, and these blocks are displaced by about 400 m. The strike is roughly N-S and the dip is about 50° E. The north block sometimes shows a strike N 70° W and dip 20° NE. In the east, both the north and south blocks contact the Ordovician limestone which was thrust upon these blocks from the east. The Permian System of the south block consists chiefly of yellow sandstone, in association with brown shale, coal, coaly shale and conglomerate. This formation is distributed in a north-south trending narrow belt, 50–200 m in width, and disconformably covers the underlying Ordovician limestone.

Formerly, R. KONDO collected several plant fossils from the black to dark gray shale in this coal field, and of them *Lepidodendron oculis-felis* (ABB.) and *Neuropteris wutaotingensis* MATSUZAWA were described by MATSUZAWA[17].

g. Sung-shu-tai area

Sung-shu-tai is a town 16 km southeast of Ping-chuan, Jeho Province. The Permian System is distributed in an area from the north foot of Nan-ta-wa Shan to the north of Sung-shu-tai. The strike is NW or N 60° W and the dip is 30°–45° NE. The formation is divided into the upper, middle and lower groups by KAWADA.[9]

The lower group consists of conglomerate, sandstone and sandy shale. Hard fire-clay is interbedded at its base. The total thickness is 30–100 m.

The middle group consists of siliceous sandstone and conglomerate, intercalated with two coal seams. The total thickness is about 90 m.

The upper group is composed of an alternation of sandy shale and sandstone. Since the upper part of this group is covered by alluvial deposits, its total thickness is not estimated. However, the thickness of the exposed part is about 120 m.

h. Hsing-lung coal field

The Hsing-lung coal field is situated about 90 km south-southeast of Jeho. This coal field, with Ying-shou-ying-tzu as its center, is about 28 km east-west and 1–2 km north-south. The so-called Pei-ma-chuan-tzu, Lao-yeh-miao and Huo-shen-miao coal fields are included in this coal field.

The area is generally occupied by steep hills and the strata are remarkably disturbed, but the Permian System strikes generally east-west and dips towards the south. Along the southern margin of this coal field, the Ordovician limestone was thrust upon the Permian System, whereas along the northern margin, the Permian System rests in parallel unconformity on the Ordovician limestone and is overlain by the Lower Cretaceous System. Granite, porphyry and basalt intrude the Permian System.

Toshio KIHARA gave the name Liuho System to the Permian formations in this coal field and subdivided the stratigraphical sequence as in Table 9.

Table 9. Stratigraphic Sequence of the Liuho System in the Hsing-lung Coal Field.

Liuho System	Maoshan formation	Maoshan sandstone	more than 60 m thick
		Upper coal-bearing shale	5–15
		Fushan sandstone	15–30
		Middle coal-bearing shale	15–30
	Huangshenshan formation		80–120
	Lamakou formation		20–30
	Peishan formation	Lower coal-bearing shale	10–30
		Peishan conglomerate	10–40
	Chuanshihkou formation	Lowermost coal-bearing sandstone	15–50
		Basal conglomerate	15–30

A coal seam about 1 m thick is interbedded in the lower coal-bearing shale which is conformably overlain by a black shale of the Lamakou formation. The lowermost part of this black shale is calcareous, about 0.2–5.0 m thick, and has abundant marine fossil animals. KIHARA collected the following animal fossils which were identified by the present writer.

Bryozoa

Fenestella sp.

Brachiopods

Squamularia asiatica CHAO
Spiriferina cristata SCHELLW.
Orthotichia derbyi (WAAGEN)
Schellwienella sp.
Orthothetina sp.
Chonetes molleri TSCHERNYSCHEW
Ch. carbonifera KEYSERING
Waagenoconcha cf. *abichi* WAAGEN
Marginifera pusilla SCHLLW.
Productus taiyuanfuensis GRABAU
P. gruenewaldti KROTOW
P. cf. *volgensis* STUCK.
Linoproductus koninchianus (VERNEUIL)
Striatifera sp.

Cephalopods

Orthoceras sp.
Pleuronautilus sp.
Remeleoceras grabaui YIN

Gastropods

Bellerophon compressus GRABAU

B. cf. *jonerianus* DE KONINCK
Euphemus sp.
Euomphalus sp. (n. sp. ?)
Holopella trimorpha WAAGEN
Sphaerodoma avellanoides (DE KONINCK)
Soleniscus sp.

Pelecypods

Nuculopsis anthraconeiloides CHAO
Schizodus shansiensis CHAO
Sch. subquadratus GRABAU
Sanguinotites olseni GRABAU
Astartella adenticulata JAKOWLEN
Lima striatoplicata CHAO
Aviculopecten alternatoplicatus CHAO
Entolium aviculatum SWOLLOW
E. cf. *obtusum* GRABAU

From these fossils, it is clear that the Lamakou formation is correlated with the Taiyuan Series of North China. If this is true, it is problematical whether the Penhsi Series is developed in this coal field or not. Not only in this area but also in other areas throughout Chin-chou and Jeho districts, it was thought that the Penhsi Series is not developed. As mentioned above, no data to verify the presence of the Penhsi Series were available in this coal field. However, considering the fine development of the Penhsi Series, about 120 m thick, in the Kai-luan coal field not far from this coal field, the presence of the Chuanshihkou formation is very noticeable, as it is separated by an unconformity at the base of the Peishan formation according to KIHARA. The Huangshenshan formation yields *Lepidodendron,* while the Maoshan formation contains many plant fossils, identified by the writer as follows:

Calamites Suckowi (BRONGN.)
Annularia stellata (SCHLOTH.)
Sphenophyllum oblongifolium (GERM. et KAULF.)
Sph. Thonii MAHR
Sph. Thonii var. *minor* STERZEL
Pecopteris spp.
Cladophlebis Nystroemii HALLE
Alethopteris ascendens HALLE
Neuropteris flexuosa BRONGN.
Odontopteris subcrenulata (ROST)
Emplectopteris triangularis HALLE
Emplectopteridium alatum KAWASAKI
Protoblechrum Wongii HALLE
Taeniopteris sp.
Lepidodendron oculis-felis (ABB.)

Stigmaria ficoides (STERNB.)
Cordaites principalis (GERM.)
C. Schenkii HALLE
Tingia Hamaguchii KONNO

These plant fossils suggest an age equivalent to the Shanhsi Series of North China and the Liutang Series of South Manchuria.

III. The Carboniferous and Permian Systems in North Manchuria

1. General description

Neither the stratigraphic nor the paleontologic studies of North Manchuria are much advanced. It is noticeable that in lithology and palentology North Manchuria differs from South Manchuria and is rather similar to Siberia and Mongolia. The formations are mainly of marine deposits.

An apparent eastern prolongation of the Jisu Honguer formation of Mongolia described by A. W. GRABAU[5] is extensively distributed in the west of Ta-pan-shang in Jeho Province, in the vicinities of Lin-hsi and Tarim Nor, as well as in the Cha-ha-erh Province of Inner Mongolia.

LICENT and CHARDIN[15] gave the name Linhsi formation to a complex of green clayslate and conglomerate which is distributed in the vicinity of Lin-hsi, and they reported the presence of Permian fossils in a thin bed of limestone which is interbedded in this Linhsi formation. A description of these fossils has not yet been published, however.

Shigemitsu OKADA studied the geology of a hilly land north of the Dabus Nor basin, and collected many animal fossils there. He gave the name of Dabus Nor formation to the Upper Paleozoic rocks of this area.

According to OKADA, a north-south fault system predominates in the hilly land, and one fault divides the area into two blocks, east and west. However, both blocks generally strike N 80° E and dip 50°–60° to the south, and form a monoclinal structure. The western block lacks a basal part due to the intrusion of granite along the northern margin. Since the southern margin of the eastern block contacts the Pre-Cambrian formation(?) by a fault, the upper limit cannot be recognized. The formations constituting the eastern and western blocks are tentatively called the East and West formations. The stratigraphic relation between these formations needs more detailed studies in the future, but OKADA inferred from the lithology, fossils, and geologic structure, that the East formation is younger than the West formation. The stratigraphic sequence of each formation is given in Table 10 (X means fossiliferous).

Except for bed C_1, the conglomerate, sandstone and clayslate of each bed alternate and grade lithologically into one another. Consequently, the boundaries of each bed in Table 10 are not always distinct, especially in the East formation. The writer identified the following fossils from these two formations. Consequently,

Table 10. Stratigraphic Sequence of the Permian System in the Vicinity of Dabus Nor (after OKADA).

East formation		
f.	Graywacke, sandy clayslate	2,000 m+ thick
e.	Conglomerate, conglomeratic sandstone, clayslate(?), limestone (X)	1,200
d.	Graywacke, arkose sandstone, clayslate, limestone (X)	800
c.	Conglomerate, graywacke (X), arkose sandstone, sandy clayslate	1,000
b.	Graywacke, black clayslate	1,200
a.	Dark sandstone, sandy clayslate	1,000
West formation		
E_2.	Conglomerate, graywacke, arkose sandstone	2,000
E_1.	Conglomerate (X), graywacke (X), arkose sandstone, clayslate (X), limestone (X)	800
D.	Agglomerate	600
C_2.	Conglomerate, arkose sandstone, clayslate (X), limestone	100
C_1.	Conglomerate, conglomeratic sandstone	2,500
B.	Andesite	100
A_2.	Conglomerate, arkose sandstone, sandy clayslate (X), clayslate (X)	100
A_1.	Conglomerate, breccia, graywacke, clayslate (with a thin bed of limestone?)	1,500

there is no doubt that these formations correspond to the Jisu Honguer formation of Mongolia.

Arthropoda

Trilobita. Genus and species undetermined.

Bryozoa

Geinitzella collumnaris var. *tuberosa-sparsigemmata* GRABAU

Fenestella sp.

Brachiopods

Diellasma millepunctatum var. *mongolicum* GR.

D. jisuense GR.

Hustedia remota (EICHWALD)

Spiriferella kailhaviiformis FREDRICKS

S. salteri TCHERNYSCHEW

Neospirifer moosakhailensis DAVIDSON

N. fasciger (KEYSERLING)

Choristites trautscholdi (STUCKENBERG)

Martinia mongolica GR.

M. orbicularis GEMMELLARO

Uncinulus sp. (n. sp.)

Camalophoria superstes (VERNEUIL)

C. pordoniformis GR.

Orthotychia cf. *derbyi* (WAAGEN)

Enteletes obesa GR.

Chonetes sp. (n. sp.)
Schuchertella frechi HUANG
Schellwienella regina GR.
Derbya dupliciseptata GR.
D. cf. *hemisphaerica* WAAGEN
Meekella sp.
Cf. *Geyerella mongolica* GR.
Derbyella bureri GR.
Linoproductus lineatus (WAAG.)
L. cora (D'ORBIGNY)
Striatifera sp.
Echinochonchus fasciatus KUTORGA
Produceus cf. *porrectus* KUT.
Proboscidella cf. *leta* TSCHERN.
Thomasia sp.
Marginifera morrisi CHAO

Pelecypods
Schizodus sp.
Sanguinolites olseni GR.
Pseudomonotis (*Aviculomonotis*) *kazanensis* (VERNEUIL)
P. furcoplicatus GR.

Gastropods
Bellerophon jonesianus DE KONINCK
Luciella planoconvexa GR.
Naticopsis khoovensis WAAG.

Corals
Tetrapora syringoporoides YOU
Wentzelella sp.

Echinodermata
Crinoids

In North Manchuria, KOBAYASHI's[11,12] Solun formation (its age between post-Devonian and Permian) and the Hahai fauna (latter half of the Permian) are distributed.

According to Hajime YOSHIZAWA[44] and Hikoji MORITA,[22] metamorphosed sedimentary formations are sporadically distributed also throughout the Ta-hsing-an-ling area.

At this time, the problems of the Chilin and Touman formations are of special interest to us. As far as the present inferences are concerned, the Chilin formation is composed mainly of the Carboniferous System in association with a part of the Devonian System, while the Touman formation which is extensively distributed in Eastern Manchuria consists almost wholly of the Permian System. Therefore, it is reasonable to infer that these two systems were deposited in different marine basins. However, as will be mentioned in the following paragraph, if the same

strata or fossils as the Touman formation are found from the Chilin formation, that part would be inferred to be the westward transgressed sediment of the Touman formation and may need to be separated from the Chilin formation. Again, if the Permian System, which is related to the Mongolian geosyncline, e.g. the Permian System in the vicinity of Yu-chuan, were found from the Chilin formation in the future, it would be explained as the deposition of the eastern end of the latest transgression in the same geosyncline, and it would also have to be separated from the Chilin formation.

2. Special description

A. Chilin formation

The Chilin formation was named by Michio KAWADA[8] for a complex of hornfels, breccia and limestone which is extensively distributed in the vicinity of Chi-lin; its thickness is estimated to be 1,000–3,000 m. Though KAWADA grouped it under the so-called Permo-Carboniferous Period, he added that the Devonian or Silurian Periods may be associated with this formation.

As was expected, Devonian fossils and strata were found recently from a part of the Chilin formation in the vicinity of Erh-tao-kou in the suburbs of Chi-lin. It is anticipated that this stratigraphical relation will be investigated in the future.

Until the present time, the Chilin formation, which is distributed in the vicinity of Ming-cheng on the Shen-chi Line, was studied in the greatest detail. Shigemitsu OKADA[3] divided the Chilin formation in this locality into upper, middle and lower parts and each part was again subdivided into upper and lower subdivisions. The lower part of the lower formation (bed a) consists essentially of gray to black shale and clayslate with occasional thin beds of limestone containing corals and brachiopods.

The upper part of the lower formation (bed b) is composed of large lenticular limestone containing corals and crinoids, and is about 500 m thick. This formation often grades into saccharoidal limestone under the influence of granite.

The lower part of the middle formation (bed c) is composed mainly of dark gray clayslate which contains plant fossils and pelecypods (*Pecten* and others). Thin beds of limestone predominate as one moves upwards and are at last gradually transformed into the following bed d.

The upper part of the middle formation (bed d) is a thick limestone group, 2,000 m thick; it is generally gray to white and extensively distributed with a south-eastward prolongation from the vicinity of Ming-cheng station. Thin beds of black to ochre shale, pale greenish tuff and brecciated sandstone are interbedded in some parts of it. Corals and crinoids are yielded from the limestone.

The lower part of the upper formation (bed e) is black shale, and crops out only in the vicinity of Ma-tai-kou.

The upper part of the upper formation (bed f) is volcanic rocks and consists of agglomeratic porphyrite to plagio-liparite with a thin bed of white tuff. It grades sporadically into agglomerate and agglomeratic conglomerate.

Subsequently, Masao MINATO[19] recognized the five following fossil zones in both beds b and c of OKADA at a place between Lu-chuan-tzu and Lao-tao-kou.

1. *Dibunophyllum* zone. *Dibunophyllum* spp., *Clisaxophyllum* spp., *Palaeosmilia*? sp., *Carcinophyllum* sp., *Diphyphyllum* sp.

2. *Gigantella* cf. *latissimus* zone. *Gigantella* cf. *lattissimus* (SOWERBY), *G.* sp., *Endothyra* sp., *Siphonodendron irregulare asiatica* (YABE and HAYASAKA).

3. *Siphonodendron* zone. *Siphonodendron irregulare asiatica* (Y. et H.), *S.* sp.

4. *Auloclisia* zone. *Auloclisia* sp., *Caninia* sp., *Clisaxophyllum* sp., *Thysanophyllum*? sp.

5. *Lonsdaleia floriformis floriformis* zone. *Lonsdaleia floriformis floriformis* MARTIN, *Siphonodendron irregulare asiatica* (Y. et H.), *S.* sp.

He described these fossils and concluded that its age is the uppermost part of the Lower Carboniferous and is to be correlated with the Visean in Western Europe (*Dibunophyllum* zone), *Yuanophyllum* zone at the upper part of the Fengnin System in South China and the Onimaru series in Japan.

Hiroshi OZAKI[41] collected fossils of foraminifera from a limestone boulder in the vicinity of Nan-ti-tzu, north of Ming-cheng. From this boulder, the writer identified *Fusulinella* sp., *Ozawainella* sp., *Tetrataxis* cf. *conica* EHRENBERG and bryozoa and concluded that the age is Moscovian, i.e. that it can be correlated to the Penhsi series. According to OZAKI, the diameter of this boulder is about 1 m, and limestone similar to the boulder crops out on the slope of a northern hill near by. Therefore, it is clear that the boulder fell from this limestone outcrop.

OZAKI also collected fusulinids and crinoids from a limestone boulder which may have been derived from the limestone in dark-grayish hornfels, in the district northeast of Hsi-hsiao-ho-yen, Erh-tao-ho-tzu, Yung-chi Hsien, about 30 km north of the former locality. The writer identified *Schubertella obscure* LEE et CHEN from the boulder. Since the present species was first reported, from the Huanglung limestone in Central China, this boulder may be Moscovian in age, like the limestone at Nan-ti-tzu.

Thus, the Middle Carboniferous System may be developed sporadically in a rather extensive area in the vicinity of Yen-tung-shan. However, the detailed stratigraphic sequence of this system and the mutual stratigraphic relations between the system and the above-mentioned formation near Ming-cheng are not yet well understood.

As was seen from the above description, the group which was formerly treated as the Chi-lin formation consists essentially of the Carboniferous System in association with a part of the Devonian System. There is evidence for the presence of the Permian System, however, in *Pseudoschwagerina* sp. found by MINATO[21] in the vicinity of Ming-cheng. Thus, though the exact stratigraphic position is not yet recognized even to-day, the existence of the Permian System in the Chi-lin formation is gradually being confirmed at the present time. Hence, the so-called Chi-lin formation may range from the Devonian to the Permian and must be subdivided through further study. Only after this can the correlation and precise paleogeography be discussed in detail.

B. Touman formation

The Touman formation was named by Keiji HARIO for the Permian System in the vicinity of the Tou-man River. Later, M. MINATO[20] identified the following fossils, which were collected by Takumi NAGAO from clayslate-like chert at Shang-tsai-hsiu-tung, southwest of Kai-shan-tun, Ho-lung Hsien, Sung-chiang Province. MINATO concluded that the age of this formation is the upper part of the Middle Permian (Artinskian).

Fenestella spp.
Polypora manchoukuoensis MINATO
Acanthocladia (?) sp.
Batostomella (?) sp.
Waagenophyllum indicum (WAAGEN et WENTZEL)
Linoproductus lineatus (WAAG.)
Echinochonchus sp. nov. (?)
Spiriferina cristata SCHLOTHEIM
S. nasuta WAAG.
Spirifer sp.
Hustedia (?) sp.
Marginifera sp.
Aviculopecten sp.

Subsequently, the writer[33] surveyed the Touman formation, which is distributed in the vicinities of Kai-shan-tun and Sang-sam-bong, Hamgyeong bukdo on the bank opposite Manchuria and divided it into upper, middle and lower parts according to the lithic character. Of these, the lower and middle parts gradually intergrade.

The boundary was tentatively established as a line between the limestone and ochre rocks; the limestones of the lower part become relatively fewer and the ochre rocks of the middle part become more conspicuous near the boundary line, while the boundary between the middle and upper parts is comparatively distinct. The middle part is composed of many ochre rocks while the upper completely lacks ochre rocks and consists mainly of dark black rocks with a moderately thick conglomerate at its base. It is inferred that there is an unconformity between them, but this has not yet been confirmed.

The lower part of the Touman formation is extensively developed at Nei-yen-chih, Tsai-hsiu-ling, Nan-ta-feng and in the area east of Sang-sam-bong. Though its base is unknown, the thickness is estimated at more than 1,000 m. It consists essentially of clayslate, shale, sandstone and sandy hornfels with more than two beds of limestone. The limestone is dark gray in most cases and is sometimes altered white by metamorphism.

In the vicinity of Sekido, east of Sang-sam-bong, the general strike is north-south and the dip is steeply westward. Fossils listed in Table 11, especially the more advanced fusulinids, are abundant in the gray limestone, about 50 m thick, in the relatively lower part of the Lower Touman formation on a cliff in a valley

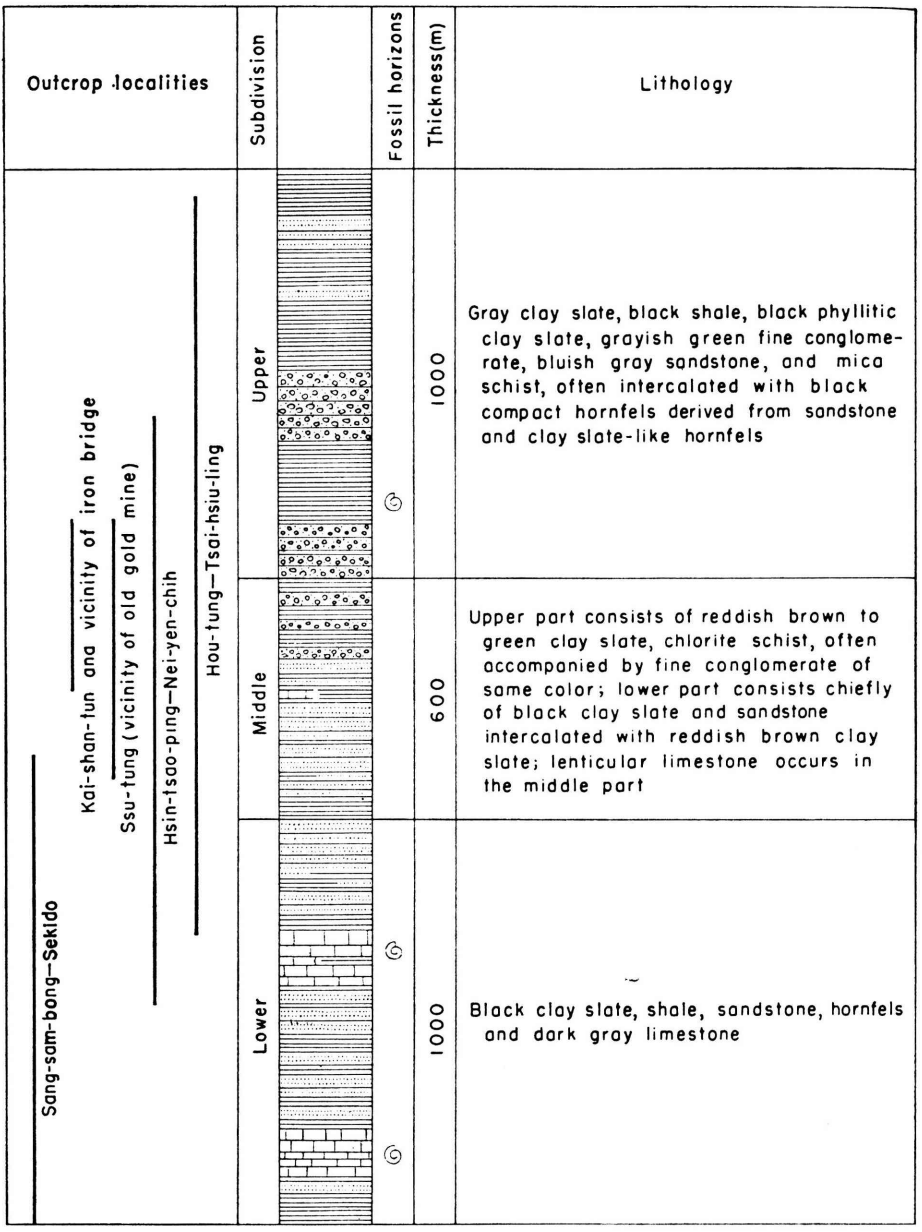

Fig. 4. Geologic Columnar Section of the Kai-shan-tun District.

about 4 km east of Sang-sam-bong Station.

The middle part of the Touman formation crops out most extensively in an area from Kai-shan-tun to the vicinity of the former office of the Ssu-tung mine and on the northern slope of Tsai-hsiu-ling; its thickness is estimated at about 600 m. Its lower part is composed mainly of black clayslate, green conglomerate and

sandstone, with one or two beds of ochre clayslate. Upwards, ochre clayslate and ochre conglomerate predominate and gray to grayish-green clayslate, conglomerate, and sandstone or green marl are associated with the ochre rocks.

Table 11. List of Fossils in the Touman Formation.

Fossils \ Locality		Lower			Upper
		Sekidō	Yao-shui-ssu	Tsai-hsiu-ling	Shang-tsai-hsiu-tung
Green algae	1. *Mizzia velebitana* SCHUBERT	×			
Foraminifera	2. *Tetrataxis* spp.	×			
	3. *Lunucammina? conica* LANGE	×			
	4. *Pachyphloia pediculus* LANGE	×			
	5. *P.* sp. (n. sp.)	×			
	6. *Lagena* sp.	×			
	7. *Staffella* sp. (n. sp.)	×			
	8. *Triticites* sp.	×	•	×	
	9. *Parafusulina imlayi* DUNBAR	×			
	10. *P. subextensa* CHEN	×			
	11. *P. lungtanensis* CHEN	×			
	12. *P.* cf. *constricta* CHEN	×			
	13. *P.* sp.	×			
	14. *Misellina* spp.	×			
	15. *Neoschwagerina* cf. *margarite* DEPRAT	×			
	16. *Yabeina hayasakai* OZAWA	×	×		
	17. *Y. shiraiwensis* OZAWA	×			
	18. *Sumatrina gemellaroi* SIRVESTRI	×			
	19. *Lepidolina* sp.	×			
Tetracoralla	20. *Wentzelella timorica* (GERTH)	•	•	×	
	21. *Waagenophyllum?* sp.	•	×		
Bryozoa	22. *Fenestella* sp.	•	•	•	×
	23. *Polypora?* sp.	•	•	•	×
Brachiopoda	24. *Chonetes* cf. *chonetoides* (CHAO)	•	•	•	×
	25. *Neospirifer* cf. *moosakhailensis* DAVIDSON	•	•	•	×
	26. *Spiriferella persarnae* GRABAU	•	•	•	×
	27. *Spiriferina* (*Tylotoma*) *cristata* SCHLOTH.	•	•	•	×
Pelecypoda	28. *Pseudomonotis* (*Aviculomonotis*) *kazanensis* (VERN.)	•	•	•	×
Crinoidea	29. Genus and species indet.	×	•	×	×

The upper part of the Touman formation is extensively distributed at Kai-shan-tun, Ssu-tung, Shang-tsai-hsiu-tung, Hou-tung, Shih-po-tung, Hsin-tsao-ping and in the western part of Hui-ching-chieh and its thickness is estimated to be more than 1,000 m. It consists mainly of gray clayslate, black phyllitic clayslate, grayish green small-grained conglomerate, bluish gray sandstone, and mica schist with occasional intercalating black hard compact sandy hornfels or clayslate-like hornfels.

At the base of the upper part, grayish green conglomerate, 50 m thick, is usually developed and is often intercalated with sandstone of the same color. Many of the marine fossils listed in Table 11, especially brachiopods and bryozoa, are yielded from the sandy hornfels just beyond this conglomerate at Shang-tsai-hsiu-tung. The fossils collected by the writer at Shang-tsai-hsiu-tung are approximately the same as those formerly reported by MINATO.[104]

The writer concluded that the total Touman formation in the vicinity represents the upper part of the Lower Permian on the basis of the fossils listed in Table 11, and that this formation is equivalent to the Leonald formation in the U.S.A., the upper part of the Artinskian in the U.S.S.R., the uppermost part of the Chihsia limestone in China and a part of the Maokou limestone. To settle the problem of what part of the Touman formation is exposed in this vicinity in relation to the Touman formation that is extensively distributed in Eastern Manchuria, northern Manchuria, and the U.S.S.R. will require further investigation of all formations.

Yenzo KONNO[13] collected many plant fossils from the conglomerate (containing pebbles of granite and granitic gneiss), 170 m thick, in the vicinity of Kai-shan-tun and inferred that its horizon is approximately the same as the marine fossiliferous bed at Shang-tsai-hsiu-tung. The plant fossils clearly contain lower Gondwana elements and also yield many representatives of the younger Cathaysian elements such as *Gigantopteris Yabei, Lobatannularia heianensis, Neuropteridium* and others. It also contains Middle Cathaysian elements. Therefore he concluded that it is to be regarded as part the oldest stage of the Younger Cathaysian flora, and correlated it to the fossil flora of the Tsaichia series in the vicinity of Pen-hsi-hu in South Manchuria. The fossil flora collected by KONNO at Kai-shan-tun are as follows.

Phyllotheca deliquescens (GOEPP.)
Lobatannularia heianensis (KODAIRA)
Sphenophyllum verticillatum (SCHLOTH.)
Sph. Thonii MAHR
Pecopteris cf. *Anderssonii* HALL
P. unita BRONGN.
P. cf. *Yabei* KAWASAKI
P. sp. nov. a
P. sp. nov. ? b
Odontopteris subintegra KONNO

Gigantopteris Yabei KAWASAKI
Emplectopteris triangularis HALLE
Callipteridium rarinervium KONNO
Neuropteridium longifolium KONNO
Brongniartites Imaizumii KONNO
Taeniopteris spp.
Rhipidopsis densinervis FEISTMNPEL
Rh. cf. *lobata* HALLE
Rh. cf. *gondwanensis* SEWARD

A conglomerate whose pebbles are cemented by ochre, pale green to pale blue, sandy clay is situated in the upper division of the middle part of the Touman formation. KONNO pointed out that this conglomerate is the basal conglomerate of the district, and he correlated it with the basal conglomerate of the Tsaicha formation. He also regarded the unconformities at the base of these two formations as equivalent to a hiatus at the basal part of the Middle Productus Limestone in India, and suggested that the Lower Gondwana flora first invaded the Far East at this time.

C. Permian System in the vicinity of Yu-chuan

Yu-chuan, east of Harbin, is a station on the Pin-sui line, and was formerly called Erh-tseng-tien-tzu. A Paleozoic formation which consists of sandstone, clay-slate and limestone crops out in this vicinity. AHNERT[1] collected many animal fossils from the limestone in this locality and FREDERIK identified the following 14 species and attributed them to the Middle Permian.

Brachiopods
Productus cf. *boliviensis* D'ORB.
P. weyprechti TOUL.
P. mammatiformis FREDR.
P. aculeatus MARTIN
P. waageni POTHP.
P. purdoni DAVIDS.
Paramarginifera peregrina FREDR.
Spirifer striatus mut. *neostriatus* FREDR.
Spiriferella rajah (SALT.)
S. lytha FREDR.
S. cf. *vercherei* WAAGEN
Bryozoa
Polypora sykeri WAAG.
Pelecypods
Aviculopecten cf. *subclathratus* KEYS.
Gastropods
Berellophon sp.

Recently, the writer[36] received several specimens from Shigemitsu OKADA, who had collected them from the greenish gray sandstone in the vicinity of Hsieh-

hsiao, about 8 km south of Yu-chuan. The writer identified the following fossils among them.

Brachiopods

Neospirifer moosakhailensis (DAVIDSON)
Waagenoconcha cf. *purdoni* (DAVID.)
Linoproductus cora (D'ORBIGNY)

Pelecypods

Pseudomonotis (Aviculomonotis) kazanensis (DE VERNEUIL)

In addition to these, there was an indistinct crinoid specimen. Though the state of preservation of these fossils is generally very poor, the fossils apparently correspond with those of the Jisu Honguer limestone in the Far East. Therefore they are regarded as evidence of the Lower Permian. The Permian System in the vicinity of Yu-chuan appears as sediments of the last marine transgression in the Mongolian Geocyncline as indicated by the fossils present.

D. Solun formation

Torao HATTYO formerly collected several fossil specimens at So-lun (Hsi-cha-ka-erh-chi), on the eastern side of the middle part of the Ta-hsing-an-ling Mountain range, about 100 km northwest of Hsing-an (Wang-yeh-miao). Teiichi KOBAYASHI[11] identified these fossils and reported such pelecypods as *Aviculopecten khinganensis* KOBAYASHI, *A. (Deltopecten)* sp., *Crenipecten soronensis* KOB. and a gastropod *Pleurotomaria yabeshigerui* KOB.

He reported that the age of these fossils points to some age from the post-Devonian to the Permian, and that since all these fossils are new, the precise age cannot be determined. The fossils were yielded from tuffaceous sandy shale in the above-mentioned alternation, which was named the So-lun formation by KOBAYASHI.

Later Lihsu CHANG[2] collected fossil specimens of pelecypods from the relatively massive, yellowish, dark gray shale and the overlying yellowish gray fine-grained micaceous sandstone at the side of a road which passes from the bank of the Hahai River, north of So-lun to the hot spring. KOBAYASHI and HISAKOSHI identified *Carbonicola? khinganensis* KOBAYASHI and HISAKOSHI, *C? soronensis* K. and H., *Palaeomutela hahaiensis* K. and H., *P. chaoi* K. and H., *P. subrectangularis* K. and H., and an allied species of *Palaeonodenta longissima* HATSCHEF, collected by FEDOTON from the Upper Permian Kolchugino series in the Kuznetsk Basin. They concluded that the Hahai fauna may perhaps indicate the later half of the Permian and may be situated at a horizon above that of the above-mentioned *Aviculopecten* fauna. According to CHANG, the geology of this fossil locality consists essentially of an alternation of brownish yellow sandstone and black gray or dark blue clay-slate and the clayslate sometimes grades to phyllitic rock. The strike shifts from N 80° E to N 70° W and the dip is also very variable, but it is generally steep except for several cases. Thus, synclines and anticlines are developed on a small scale.

As will be seen from the above description, the exact relationship between the

Solun formation and the Hahai fauna is not yet distinct; however it is not unreasonable to infer that both are related to the Mongolian Geosyncline. One rather remarkable character is that no fusulinid specimens have been obtained from the Jisu Honguer formation and the Dabus Nor formation, and the same is true in the Yu-chuan and the Solun formations as well as the Hahai fauna. In a report on the Jisu Honguer formation, GRABAU[5] pointed out that this situation arises from the fact that no connection existed between the Mongolian Geosyncline and the waters of the Pacific Ocean at that time. Even the Permian System of the North Manchurian type, the Touman formation and the system in the vicinities of Vladivostok and Khabarovsk, which may be prolongations of the Touman formation, yield many fossil specimens of fusulinids. They are, therefore, to be regarded as having been deposited in the Pacific area, which differed and was separate from the Mongolian Geosyncline.

IV. Conclusions

1. The Manchurian Carboniferous and Permian Systems are composed of two different types of sedimentation. One is represented by the Taitzuho System of the South Manchurian type, i.e., the coal-measures, and the other is the marine formation of the North Manchurian type.

2. The Taitzuho System rests on the Ordovician Ssuyen formation and is overlain by the Lower Cretaceous Miyanohara complex. The stratigraphic relations between these three systems is always parallel unconformity. However, as in the case of the Niu-hsin-tai coal field, some formation of unknown age is sometimes interbedded in parallel unconformity between the Ssuyen formation and the lower formation (Penhsi series) of the Taitzuho System.

3. The Taitzuho System is subdivided into the Penhsi, Huangchi (Yatang), Liutang and Tzaichia series in ascending order. Parallel unconformities are found between the former two and the latter two series. However, the relation between the Huangchi and Liutang series is conformable.

4. The Penhsi series is equivalent to the so-called Penchi Series in North China and the Koten series in Korea, and the age can be regarded as Middle Carboniferous, namely Moscovian. The Huangchi series (Yatang series) corresponds to the lower part of the Yuehmnkou series (Taiyuan series) in Shan-hsi and the lower part of the Jido Series in Korea and is apparently lowermost Permian or Sakmarian in age. The Liutang series coincides with the upper part of the Yuehmengkou series (Shanhsi Series) in Shan-hsi and the upper part of the Jido series in Korea, and its geological age is to be recognized as Lower Permian, the lower part of the Lower Rotliegendes. Lastly, the Tsaichia series can be correlated with the Shihhotzu series in Shan-hsi and the Kōbōsan series in Korea and is to be regarded as approximately Upper Permian in age.

5. The coal-seams in the Penhsi, Huangchi (Yatang) and Liutang series are of brackish water deposition while the formations between coal seams are of

shallow sea water deposition, no matter whether limestone exists or not. However, upwards, the degree of transgression may become gradually less.

6. The Carboniferous and Permian Systems along the Hun Chiang River are the eastern prolongation of the Taitzuho system in the Taitzuho district. The Penhsi series of this district is well developed, as in the Taitzuho district. Though the Permian Takang series is apparently equivalent to the Liutang series in the Taitzuho district, it may also include the Huangchi series. The Techang series coincides with the Tsaichia series.

7. The Hunglohsien and Hamashan series rest on the Middle Ordovician limestone in the Chin-chou and Jeho districts, and these series are overlain by Mesozoic formations; the stratigraphic relations between these systems are always parallel unconformities. Though it is clear that the Hunglohsien series corresponds with the Huangchi and Liutang series in the Taitzuho district, it is as yet unknown whether the part that can be correlated with the Penhsi series develops or not. The Hamashan series is the equivalent of the Tsaichia series.

8. Some part of the boundary between the South Manchurian and North Manchurian types may have existed merely in a paleogeographical sense. However, the formations of the North Manchurian type which are not separated from the Penhsi series by fossils and sedimentary facies crop out in the vicinity of Yen-tung Shan, Pan-shih Hsien, Chi-lin Province and in a place about 200 km north of Chang-chia-kou, Inner Mongolia. Moreover, compressed and brecciated gneiss is extensively distributed near the boundary line between these two types in the vicinities of Ta-tien-tzu, An-t'u Hsien, Chi-lin Province and at the boundary line between An-tung and Chi-lin Province. Therefore the geological tectonic meaning must also considered.

9. The Carboniferous and Permian Systems of the North Manchurian type can be divided into three formation groups, namely the Chilin formation, the Touman formation and formation type near Yu-chuan. However, it is not possible at present to infer that the depositional basins of these three groups were connected with each other chronologically and geographically.

10. The Chilin formation consists essentially of the Middle Carboniferous including a part of the Devonian System. However, there is some possibility that older formations will be found after further investigation. This formation is sporadically distributed from the north of the type locality to Siberia in the far north.

11. The Touman formation belongs to the Permian, and extends to the vicinities of the Ussuri River and Vladivostok from the district of the Tou-man River. It is suspected that the Touman formation may overlap the Chilin formation at its western end.

12. The Permian System in the vicinity of Yu-chuan is the last deposition of transgression connected with the Mongolian Geosyncline. There is no indication that the present basin was connected with the depositional basin of the Touman formation. If the eastern margin of this transgression is at Yu-chuan, however,

Table 12. Correlation of the Carboniferous and Permian Systems of Manchuria.

Area / Period		North China		Korea			South Manchuria			North Manchuria		
							Taitzuho district	Hunchiang district	Chinchou-Jeho district	Chilin district	Touman R. district	Yuchuan district
Permian	Upper	Shihhotzu series		Heian system	Kobosan series	Taitzuho system	Tsaichia series	Techang series	Hamashan series	?	Touman formation	?
	Lower	Yuehmenkou series	Upper (Shanshi series)		Jido series Upper		Liutang series	Takang series	Hunglohsien series		?	
	Lowermost		Lower (Taiyuan series)		Lower		Huangchi series (Yatang series)	?		(Permian)		Yuchan Permian
Carboniferous	Middle	Penchi series			Koten series		Penhsi series	Penhsi series	?	Chilin formation		
	Lower	Laiwu formation (undated)					Niuhsintai Conglomerate (undated)					
Devonian												
Silurian										?		
Pre-Silurian		Middle Ordovician Limestone								Older Rocks		

there is a great possibility that the same formation will be found in the western part of North Manchuria, west of Yu-chuan.

13. To sum up and clarify the discussion in the preceeding pages, Table 12 presents a generalized correlation of the Carboniferous and Permian Systems in Manchuria.

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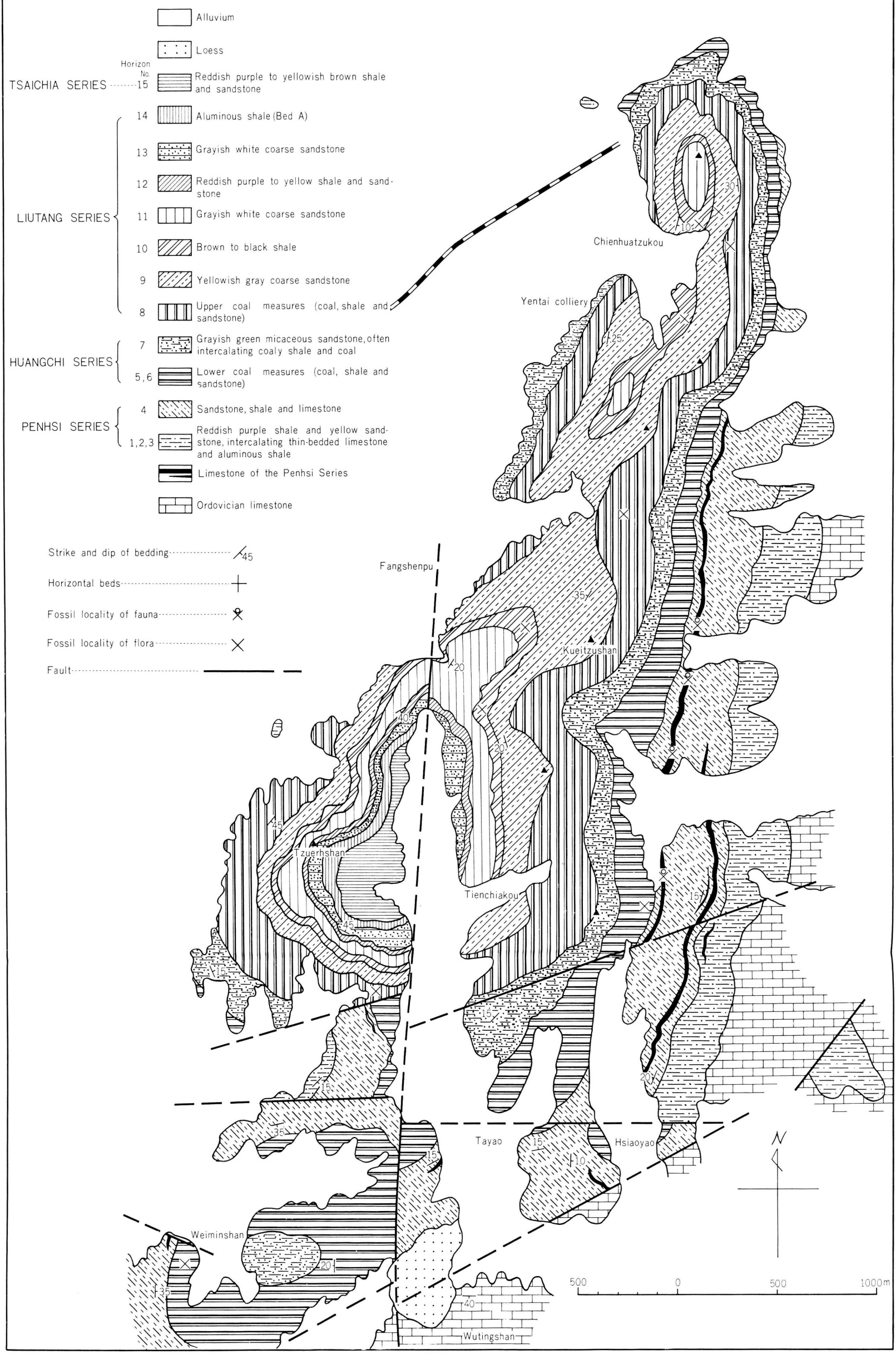

Fig.5. Geologic Map of the Yen-tai Coal Field

N

500 0 500 1000m

Huangchikou

Liutang

Ssuyenkou

PENHSIHU

Tsaichiatun

Miyanohara Station

Taitzuho

I II III

Alluvium

MIYANOHARA SYSTEM
- Grayish white coarse sandstone and variegated shale
- Conglomerate with large pebbles of quartzite
- Reddish purple, cross-bedded coarse sandstone
- Conglomerate, cementing with reddish purple sandstone

TSAICHIA SERIES (Horizon No.)
- 18 Variegated shale, sandy shale and sandstone
- 17 Reddish purple shale and grayish white sandstone
- 16 Grayish white coarse sandstone, with some layers of abundant small quartz pebbles
- 15 Reddish purple to yellowish brown shale and sandstone, intercalating a layer of aluminous shale (Bed Ao) in the upper part

LIUTANG SERIES
- 14 Aluminous shale (Bed A)
- 13 Grayish white coarse sandstone
- 12 Reddish purple to yellow shale and sandstone
- 11 Grayish white coarse sandstone
- 10 Brown to black shale
- 9 Yellowish gray coarse sandstone
- 8 Upper coal measures (coal, shale and sandstone)

HUANGCHI SERIES
- 7 Grayish green micaceous sandstone, often intercalating coaly shale and coal
- 6 Lower coal measures (coal, shale and sandstone)
- 5 Grayish white coarse sandstone and grayish black sandy shale

PENHSI SERIES (Horizon No.)
- 4 Sandstone, shale and limestone
- 3 Reddish purple to black shale and yellow sandstone, occasionally intercalating a layer of lenticular limestone
- 2 Yellow coarse sandstone and sandy shale
- 1 Reddish purple sandy shale, intercalating layers of aluminous shale (Beds G and F)

Limestone of the Penhsi Series

Pre-Carboniferous rocks

Andesite

Fossil locality of fauna

Fossil locality of flora

Fault

Strike and dip of bedding

Strike of vertical strata

Horizontal beds

Location of drill hole

Fig.6. Geologic Map of the Pen-hsi-hu Coal Field

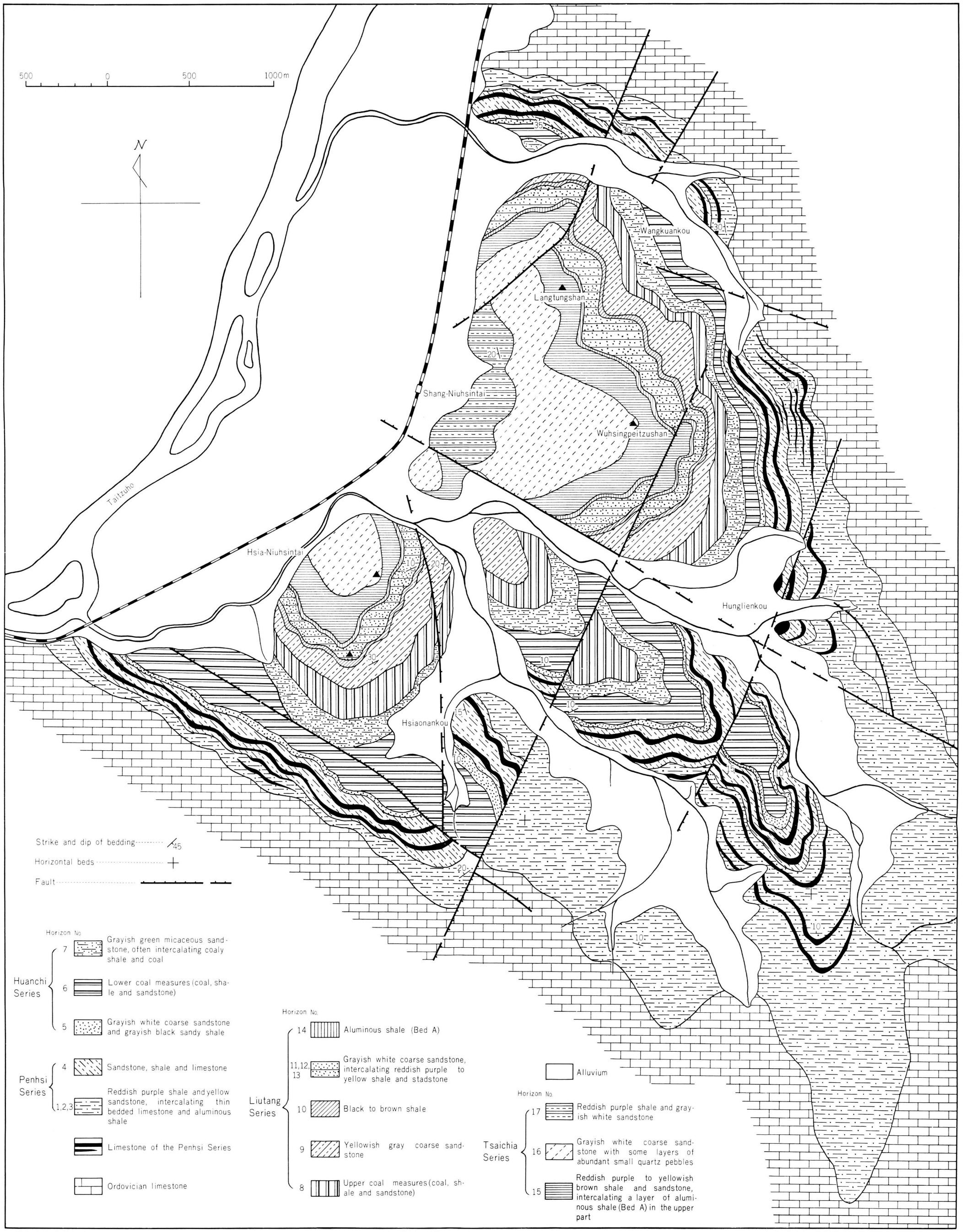

Fig.7. Geologic Map of the Niu-hsin-tai Coal Field

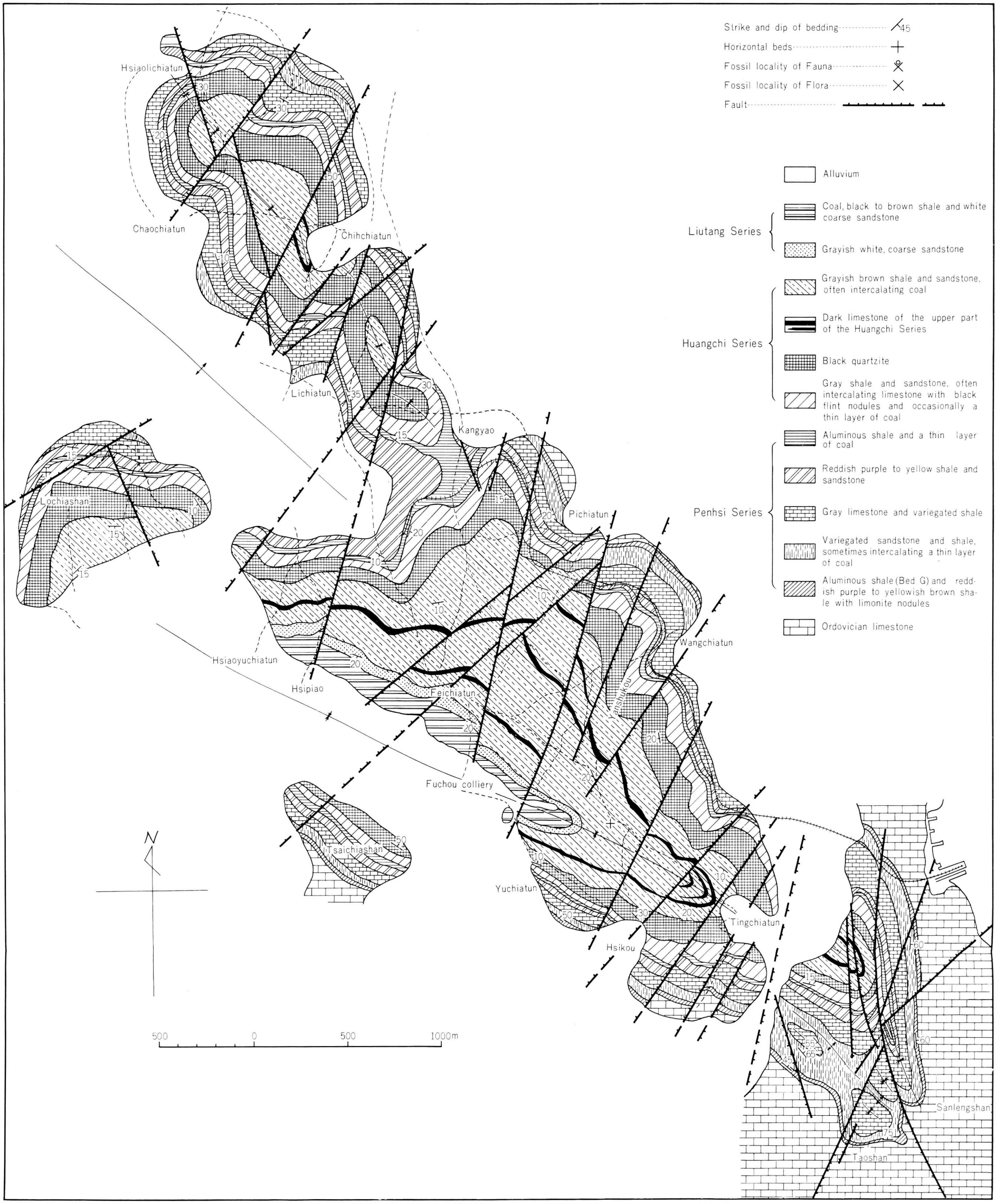

Fig.8. Geologic Map of the Fu-chou (Wu-hu-tsui) Coal Field

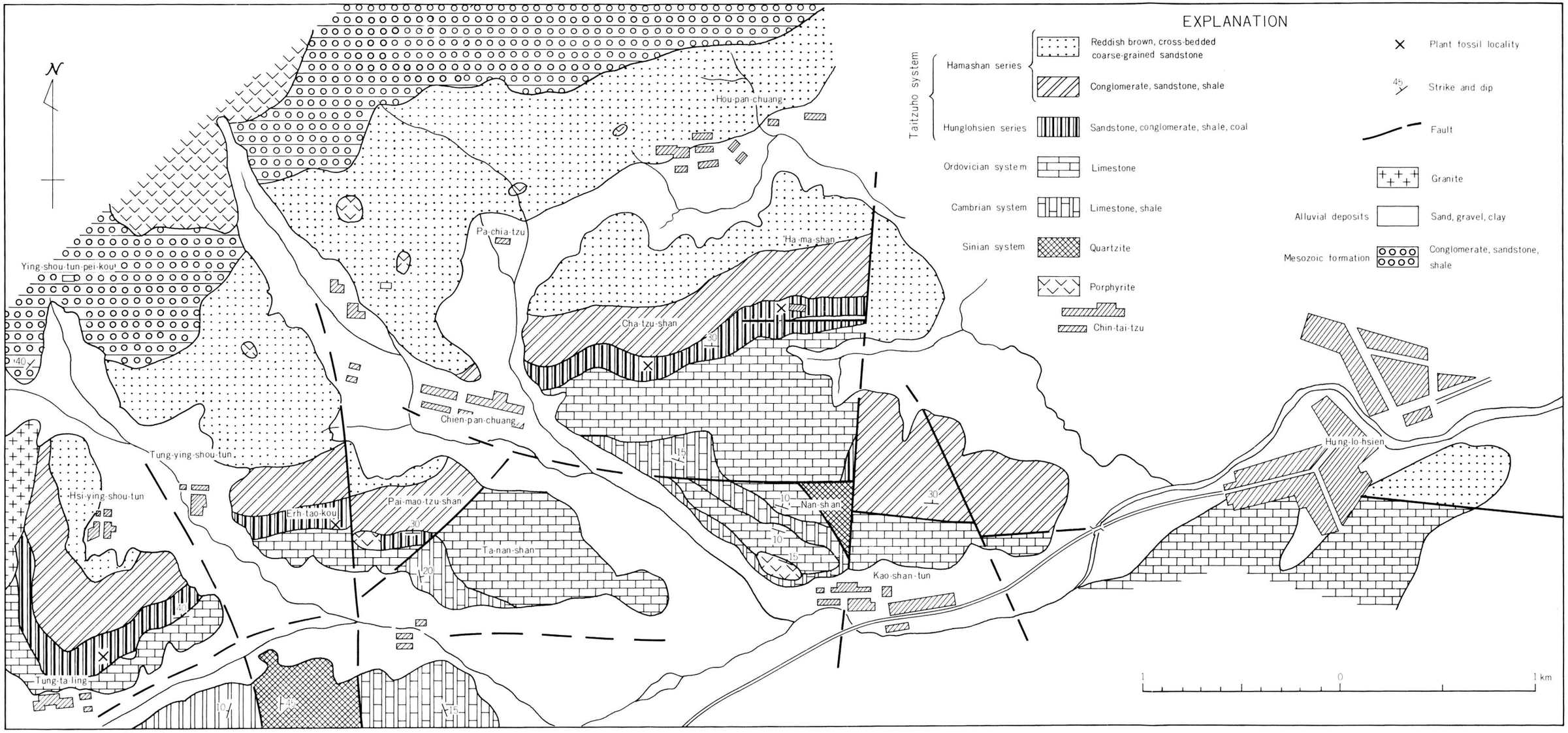

Fig.9. Geologic Map of the Hung-lo-hsien Coal Field

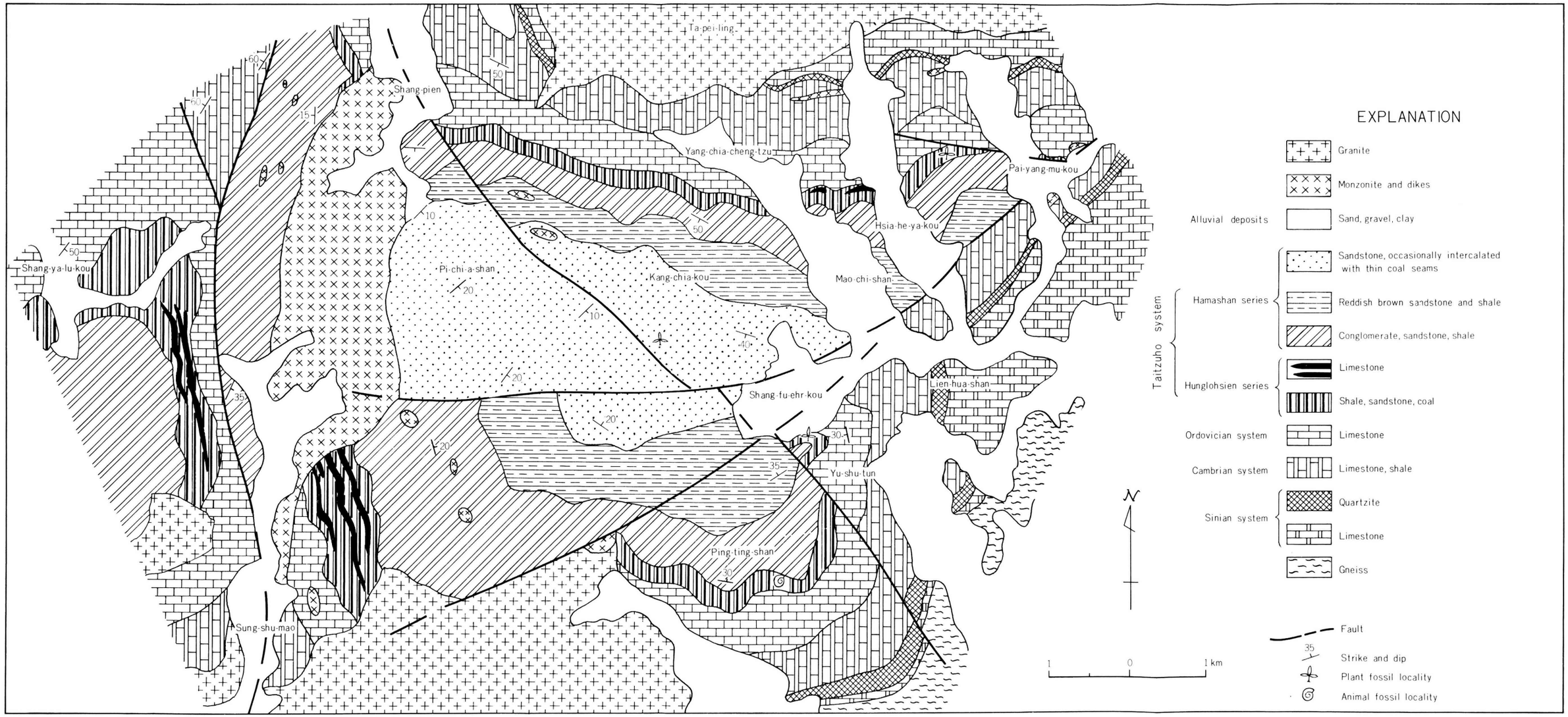

Fig.10. Geologic Map of the Yang-chia-cheng-tzu Coal Field

Volcanoes in Manchuria

Tsutomu OGURA

I. GENERAL REMARKS

1. Introduction

The earliest description of a Manchurian volcano was made by a Chinese governor in the year following the eruption of Uyunhordongi in north Manchuria (1720). Since the middle of the 19th century, survey reports on the same volcano have been issued by many Russians. Hakutosan (Chang-pai-shan) in southeastern Manchuria was famous for many centuries as a holy place in Manchuria-Korea. Scientific research on the volcano began in 1920; the geological works by YAMANARI of the Geological Survey of Korea and WATANABE of Hokkaido University are notable. In 1919 and 1922, SOWERBY, an English naturalist, published a note on the crater lakes of Lung-wan volcano in eastern Manchuria. TANAKA (1924) and NIINOMI (1930) described the volcanoes of Manchuria, but their observations seem rather incorrect. Since the establishment of Manchoukuo (1932), the Harhintun volcano in western Manchuria was studied by KIYONO and the Dalinor volcano in western Manchuria by SASAKURA. In 1935, a geological and volcanological survey of Manchurian volcanoes was undertaken by members of the College of Engineering in Port Arthur under the leadership of OGURA. Five volcanic districts were studied: the Wu-ta-lien-chi volcano of northern Manchuria in 1935, the Erh-ko-shan volcano of northern Manchuria in 1936, the Chi-hsing-shan volcano of central Manchuria in 1938, the Lung-wan volcano of eastern Manchuria in 1940 and 1942, and the Chang-pai-shan volcano of southeastern Manchuria in 1942 and 1943.

For the former three volcanoes, survey reports were published in 1936, 1937 and 1939 as Nos. 1, 2 and 3 of "Survey Reports of Volcanoes in Manchuria." For the latter two, however, maps, notes, rock specimens and other research materials were all unfortunately lost at the end of the war.

2. Regional Distribution of Volcanoes

Some 16 volcanic groups are found in Manchuria, as described in many reports and unpublished papers. They are distributed in the central, southeastern, southwestern and northern provinces (see Fig. 1).

In the central provinces, including the Chi-lin, Ssu-ping and Mukden districts, the (1) Ta-tun, (2) I-tung and (3) Chi-hsing-shan groups are found in the hilly country of Kung-chu-ling. In the southeastern provinces, including An-tung, Tung-hua and Chien-tao districts, three groups of volcanoes occur, (4) Kuan-tien, (5) Lung-wan and (6) Chang-pai-shan. The latter, situated on the Manchuria-Korea border, rise 2,751 m above sea level. Another volcanic group, (7) Da-li-no-erh, is situated on the Manchuria-Mongolia border.

In the northern provinces, six volcanic groups are distributed in Pei-an, Lung-chiang and Hsing-an-ling districts. They are found within a 150 km radius. They are the (8) Erh-ko-shan, (9) Wu-ta-lien-chi, (10) Ko-lo, (11) Ka-tsung, (12) Kan-kuei and (13) Sha-tu volcanoes. The cones of these volcanic groups stand like islets in the hilly country in the east and on mountainous land of moderate relief in the west. In addition, there are two volcanic groups, (14) Ha-r-hin-tun and (15) O-ne-nor, in the Great Hsing-an-ling Mountains, and four cones are found along the Sungari (Sung-hua-chiang) River, east of Harbin.

Each volcanic group consists of more than two cones. In some cases, the boundary between two groups is not clear because of their close proximity, in other cases a single cone represents one volcanic group. The numbers and names of cones in each volcanic group are listed below (Fig. 1).

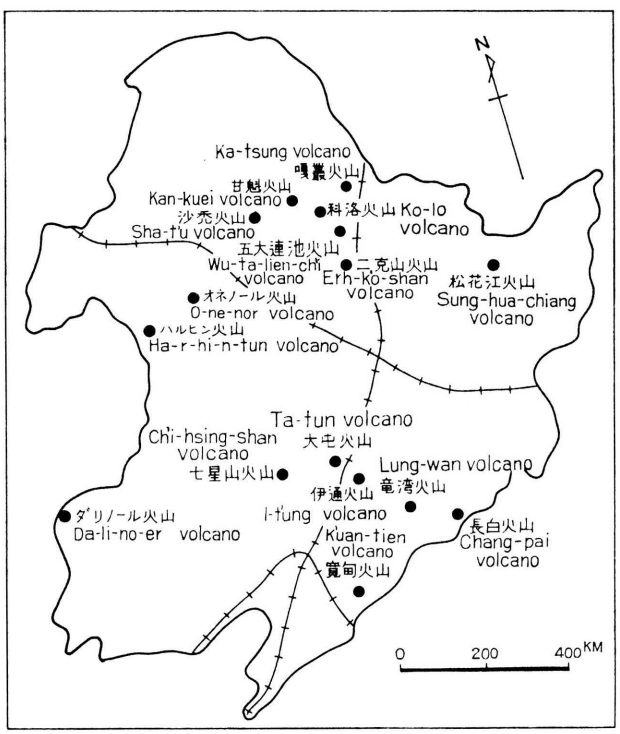

Fig. 1. Map Showing the Distribution of Volcanoes in Manchuria.

Volcanic group (number of cones)	*Main cones*
1. Ta-tun (4)	Ping-lin-shan
	Tung-shan
	Ping-ting-shan
	Chien-shan
2. I-tung (6)	Tung-chien-shan
	Hsi-chien-shan
	Ma-an-shan
	Mo-li-ching-shan
	Ta-ku-shan
	Hsiao-ku-shan
3. Chi-hsing-shan (7)	Tung-ha-la-pa-shan
	Hsi-ha-la-pa-shan
	Po-li-shan
	Po-po-tu-shan
	Nao-pao-shan
	Hsiao-tu-ko-erh-chi-shan
	Ta-tu-ko-erh-chi-shan
4. Kuan-tien (4)	Huang-i-shan
	Ching-i-shan
5. Lung-wan (35)	Hsing-an-nan-shan
	Ta-ting-tzu
	Hsi-heng-tao-shan
	Tung-heng-tao-shan
	Ta-i-shan
	Teng-chia-wang
	Chien-shui-ting-tzu
	Ta-ku-shan
	Hsiao-ku-shan
	Weng-chuan
	Hsiao-weng-chuan
	Ya-pa-kang
	Kuan-tzo-ling
	Shih-men-tzu-shan
	Hsiao-lung-wan
	Erh-lung-wan
	Ta-lung-wan
	Hu-lu-lung-wan
	Tung-lung-wan
	Nan-lung-wan
	Pan-pan-lung-wan
Another group near Lung-wan (20)	Hsi-pai-tzu-lung-wan
Another group near Chang-pai-shan (40)	

6. Chang-pai-shan (1)	(With parasitic cones)
7. Da-li-no-erh (10)	
8. Erh-ko-shan (3)	Tung-shan
	Hsi-shan
	Hsiao-ko-shan
9. Wu-ta-lien-chi (14)	Wei-shan
	Mo-la-pu-shan
	Tung-lung-men-shan
	Hsi-lung-men-shan
	Yen-pei-shan
	Tung-chiao-te-pu-shan
	Hsi-chiao-te-pu-shan
	Nan-ko-la-chiu-shan
	Pei-ko-la-chiu-shan
	Huo-shao-shan
	Lao-hei-shan
	Pi-chia-shan
	Wo-hu-shan
	Yao-chuan-shan
West of Wu-ta-lien-chi (1)	Chien-shan
East of Wu-ta-lien-chi (2)	
10. Ko-lo (7)	Tuan-tzu-shan
	Ko-lo-nan-shan
	Ta-i-shan
	Hsiao-i-shan
	Ta-hei-shan
	Hsi-shan
11. Ka-tsung (4)	
12. Kan-kuei (4)	
13. Sha-tu (8)	Sha-ti-erh-shan
	Tu-hu-lu-shan
14. Ha-r-hin-tun (1)	
15. O-ne-nor (1)	
16. Sung-hua-chang (4)	Ma-ku-li

The total number of cones is 176, 17 in the center, over 106 in the southeast, 10 in the southwest, 43 in the north and the remaining 6 in other regions; consequently most of the volcanoes are found in southeastern and northern Manchuria.

3. Arrangement of Volcanoes

Volcanoes are widely distributed over all Manchuria as stated above, but they do not seem to be arranged in any systematical or regular state. They rather have the appearance of being irregularly distributed, each volcano being independent.

The volcanic groups do not run parallel to the direction of the mountain ranges or stratigraphical foldings, but some parts seem to have some relation to the geological structure of the regions.

There is a tendency for the cones to be aligned NE–SW or NW–SE in some groups. For instance, in the Wu-ta-lien-chi volcano in northern Manchuria, 14 cones are separately situated on lines or their intersections which are indicated by NE or NW fissures. In the Lung-wan volcano in eastern Manchuria, over 37 cones are arranged on fissure lines running E–W.

In a region 150 km long connecting the Lung-wan and Chang-pai-shan volcanoes, there are over 90 cones in the midst of dense forests.

There are several groups within a 150 km radius, with Mo-erh-ken at the center. This region lies between the Great Hsing-an-ling Mts. and Little Hsing-an-ling Mts.; here the volcanoes are arranged NNE–SSW along the southeastern foot of the Great Hsing-an-ling Mts. This fact is seen to be closely related to the geological structure of the Mo-erh-ken district near the intersection of two mountain ranges. Next, three volcanic groups, the Chi-hsing-shan, I-tung and Ta-tun volcanoes, are found at the periphery of the Hei-liao Divide which extends from Kung-chu-ling northwest. It is believed to be related to the geological structure based on upheaval of the divide. Thus, the volcanoes in Manchuria scatter irregularly without showing any zonal arrangement as in Japan; in some cases, the arrangement of volcanoes seems to be related to geological structure.

4. Morphology of Volcanoes

According to the state of volcanic activity in Manchuria, volcanoes are classified into three types, those of lava flow, mamelon, and ejecta (such as ash and lapilli). In detail, the volcanoes are classified as follows:

(1) Volcanoes consisting of massive lava.
  (a) Shield volcanoes, such as the Wu-ta-lien-chi and Erh-ko-shan volcanoes, and others in northern Manchuria.
  (b) Lava flows, such as the Wu-ta-lien-chi and Lung-wan volcanoes.
  (c) Mamelon, such as the Chi-hsing-shan, Ta-tun and I-tung volcanoes.

(2) Volcanoes consisting of scoria.
  (d) Cinder cones, such as the Kuan-tien, Da-li-nor, Lung-wan, Wu-ta-lien-chi and Erh-ko-shan volcanoes, and others in northern Manchuria.
  (e) Volcanoes having crater lakes, such as the Lung-wan, Wu-ta-lien-chi and Chang-pai-shan volcanoes.

(3) Volcanoes consisting of massive lava and scoria.
  (f) Stratovolcanoes, such as the Chang-pai-shan volcano.

In the classification, shield volcanoes (a) are characterized by gentle hills on basalt plateaus which lie as the foundation of cinder cones in northern Manchuria. Thus, beautiful landscapes have been formed on the skirts of volcanoes. In the

Wu-ta-lien-chi volcano, the area of such shield volcano is 10–20 km² and the lava flows, called "shih-tang," "stone barrier," are often observed on the gentle slope. Shih-tang consists of an aggregate of block lavas 1 m in diameter and the length of lava flow exceeds 4 km in the larger ones. The shield volcano forming the foundation of the Chang-pai-shan volcano is over 100 km in diameter and its uppermost limit is 2,000 m above sea level.

(b) Lava flow is especially prominent in the *shih-lung* lava field of the Wu-ta-lien-chi volcano and in the *ha-la-tzu* lava flows of the Lung-wan volcano. The *shih-lung* lava forms a lava field of jet-black obsidianic basalt which occupies an area of 68 km² like a kind of racket in the central part of the district. This lava poured from the central part of the field in all directions along the slope and ran over an area 8 km long and 1 km wide to the south along a valley corresponding to the racket handle. This lava field has a very gentle slope and is nearly horizontal away from the center. The microtopography of the surface is very conspicous: pahoehoe, ropy and spiny lavas are found; trunk-like, ripple-like, wavy, tabular and reptile-like features are also sculptured on the lava surface. In addition, strange features such as hornito, lava tunnels and depressions are found here and there in the lava field.

There are four basalt lava flows in the Lung-wan volcanic district. These flows ran down through the lower levels or along the valley courses and consist of large and small volcanic blocks; such flows are called *ha-la-tzu,* "waste land of black blocks." In the southern part, the flows, 8 km long and 500 m wide, ran down along the Liang-shui-ho east to west. The second flow issued from the Ta-i-shan crater to the west, and has a length of 6 km and a width of 2.2 km. The third lava flow poured from the Ta-ku-shan crater, ran down the northern mountain slope and turned west along a valley over an area 9 km long and 2 km wide. The fourth flow, the largest in the district, originated in the Chin-lung-ting-tzu cone of the eastern part and ran down along the Hsiang-shui-ho toward the west, 35 km long and 5 km in maximum width. It is also known that several lava flows ran down from the craters of Hu-lu-lung-wan and Nan-lung-wan along the valleys toward the northwest.

(c) Mamelon volcanoes are found around the Hei-liao upwarping zone, as in Ta-tun and I-tung districts in the eastern edge and in Chi-hsing-shan district in the south. They are composed of black, massive basalt. They are mostly mammillary or dome-shaped with a steep slope except for some low humps in the Ta-tun volcano; the basal section is circular or elliptical. The average relative height of the 7 domes in the Chi-hsing-shan volcano is 67 m, the 4 domes in the Ta-tun 28 m, the 6 domes in the I-tung 87 m and the diameter of the basal section is 600–850 m.

(d) Cinder cones are widely and abundantly distributed throughout Manchuria, especially in the northern and southern parts. The structure of cinder cones is simple; they are formed from a mixture of ejecta such as block, lapilli, bomb and ash, sometimes intercalated by lava flow. Such mixed strata measure

over 20 m thick and incline toward the outside of the crater at an angle of about 25°. Scoria is porous basaltic rock, irregular in form and size, black or brown in color. Volcanic bombs are abundant and many specimens were collected easily, especially in Lao-shan in Wu-ta-lien-chi, Ta-i-shan, and Shih-men-tzu-shan in Lung-wan and Da-li-nor districts. Small volcanic bombs are 3 cm in size and large ones over 30 cm, mostly fusiform or amygdaloid in form. Basement rocks ejected from the crater consist of granite, sandstone or olivine nodules. Olivine nodules in the Weng-chuan crater of Lung-wan district are over 30 cm in size and abundantly scattered within the crater.

Cinder cones have a similar aspect, the general form being a truncated cone, like an overturned boat seen from the side. The basal section is roughly circular and the angle of the slope does not exceed 30°. In most cases there is one crater on the summit, but there are 4 craters in Wo-hu-shan in Wu-ta-lien-chi district. The crater is circular to elliptical with a diameter of 300–400 m, but the craters of Weng-chuan and Ya-pa-kang in Lung-wan district are over 1,300 m in diameter. The inner wall of the crater inclines steeply, and its bottom has become shallow due to the accumulation of detritus from the wall. The bottom of the crater is sometimes flat, resembling an amphitheater. On the flat bottom of the crater of Yao-chuan-shan in Wu-ta-lien-chi and Tung-shan in the Erh-ko-shan volcanoes, several wooden temples have been built. The depth of the craters varies, being about 50 m on the average. The crater of Lao-hei-shan in Wu-ta-lien-chi district is funnel shaped and 136 m deep, being the deepest in this district. Thus, the truncated cone has a rather large basement compared to its height. The summit is surrounded by a crater ring of similar height, and a part of the crater ring is almost broken. Since this feature of a cinder cone with a broken crater wall resembles an arm chair, there are many cones, such as Ta-i-shan or Huang-i-shan, where the name includes "i" meaning arm chair. The average relative height of the cones, the diameter of the basement, the diameter and depth of the crater in 3 volcanic groups are given in the following table (Table 1).

Table 1

Name of volcano	Number of cones	Relative height (m)	Diameter of base (m)	Diameter of crater (m)	Depth of crater (m)
Wu-ta-lien-chi	14	101.9	828	333	54
Erh-ko-shan	3	68	487	173	30
Lung-wan	27	113	1039	599	90

These cones were not built over a long period of times, but by temporary igneous activity.

(e) Crater lakes exist in Wu-ta-lien-chi, O-ne-nor, Lung-wan, and Chang-pai-shan volcanic districts. In Wu-ta-lien-chi district two cones of Mo-la-pu-shan

and Nan-ko-la-chu-shan have crater lakes, but these appear in the crater only in the rainy season and usually swampy. There are no records for the O-ne-nor crater lake, but it was very probably formed by an eruption of the crater.

Eight crater lakes are known in Lung-wan district and its environs, all called lung-wan, "dragon's pit." These lakes have not been known for a long time, because of dense forests in the environs of Hui-nan and Meng-chiang Prefectures.

Table 2

Measurement / Name of crater lake	Lake surface above sea level (m)	Longer dia. (m)	Shorter dia. (m)	Circumference (m)	Area (km^2)	Deepest point (m)	Transparency (m)	Water temp.		
								Surface (°C)	Lowest (°C)	Bottom (°C)
Hsiao-lung-wan	645	310	250	900	0.064	27	4.0	23.5	—	4.6
Erh-lung-wan	725	750	500	2000	0.28	41.1	10.5	22.5	—	—
Ta-lung-wan	629	1150	800	4175	0.81	88.5	11.45	23	5.0	7.5
Hu-lu-lung-wan	722	1050	300	2900	0.465	76	5.65	24	—	—
Nan-lung-wan	567	750	470	2100	0.20	71.8	4.5	25.5	4.5	5.3
Tung-lung-wan	563	750	730	2300	0.41	123	5.5	23.5	4.4	5.8
Pan-pan-lung-wan	605	1050	750	3200	0.60	117.5	5.5	25	4.25	4.6
Hsi-pai-tzu-lung-wan	745	800	750	2550	0.47	—	—	—	—	—

Their features were obtained by surveys in 1940 and 1942. These crater lakes were formed by water precipitation into the crater or pit on the granite foundation, and they are unusual in depth and temperature distribution compared with other lake waters in Manchuria. Measurement on eight lakes are given in the following table (measured in August, 1940 and 1942): (Table 2).

The crater lakes are circular, elliptical, gourd-like, purse-like or rhombic in shape. The deepest lake is Tung-lung-wan, 123 m deep, followed by Pan-pan-lung-wan, Ta-lung-wan, Hu-lu-lung-wan and Nan-lung-wan, all deeper than 50 m. In depth, these lakes are surpassed only by Tien-chih, a crater lake on the Chang-pai-shan mountain.

The temperature of the lake water, according to measurements in Ta-lung-wan, Tung-lung-wan, Nan-lung-wan and Pan-pan-lung-wan, quickly decreases to a minimum of 4–5°C, 30–35 m below the surface. Below this depth, the tempera-

Table 3. Water Temperature Change of the Lung-wan Lakes.

Name / Depth (m)	Hsiao-lung-wan	Ta-lung-wan	Tung-lung-wan	Nan-lung-wan	Pan-pan-lung-wan
0	23.5° C	23.5° C	23.5° C	25.5° C	25.8° C
5		22.5			
10		13.1	8.2	8.7	11.8
20		6.0	4.7	5.2	5.7
25			4.4		
27	4.6				
30		5.0	4.7	4.7	
35			4.8	4.5	
40		5.7	4.9	5.0	4.7
50		6.5		4.5	
60			5.3		4.3
68		7.0		5.3	
80			5.5		4.25
88		7.5			
100			5.7		4.25
116					4.6
121			5.8		

ture gradually increases at a rate of 0.3°–0.5°C per 20 m (see Table 3). In Ta-lung-wan, for example, the temperature reaches a minimum of 5°C 30 m below the surface, and gradually increases toward the bottom (7.5°C at the bottom, 88 m down). Water temperatures of this sort have never been observed in crater lakes in Japan, except in the Okama crater lake of Zao volcano in Miyagi Prefecture, where such a phenomenon had been observed temporarily.

Inside the crater of Hu-lu-lung-wan, granite cliffs stand high on the southern side, the lava flows appear on the other side, and a granite islet rises above the lake. These features are characteristic of craters of the maar type; that is, a violent explosion occurred in the granite region, resulting in a great pit and new lava flowed out from the pit southwest along a valley. In Erh-lung-wan, granite is exposed in the cliff wall of the crater, and also at the bottom of the Weng-chuan crater.

The lake water of Erh-lung-wan flows out from the southwest corner through a barranco; there is no exit in other lakes. The water level of Ta-lung-wan is the same as the groundwater table in Hsiao-chin-chuan, a small village near Ta-lung-wan. It is believed that the water in both places is connected through volcanic lapilli beds. These eight crater lakes exist in dense forests and provide a combination of mountains, waters and trees, presenting one of the finest landscapes in Manchuria.

Tien-chih, or Lung-wang-tan, on the summit of the Chang-pai-shan volcano, is a caldera lake. The surface of the lake is 2,257 m above seal level, the highest peak of the crater wall is 2,751 m above sea level, and the maximum depth of water was measured at 375 m; therefore, the depth of the crater is 869 m, the deepest in Manchuria-Korea. The crater has a swollen pear shape in the northwestern section, is 3 km in length east–west, 4 km north–south, 9.2 km^2 in area and 13.7 km in circumference. Water flows out from Ta-men in the northern part of the lake and runs north through a barranco, forming 60 m high waterfall called the Chang-pai. The lower course is called the Erh-tao-pai-ho, which is the origin of the Sung-hua-chiang River.

(f) Volcanoes composed of volcanic scoria and lava flow consist of cinder cones occasionally intercalated with lava flow as mentioned above, but these do not occur on a large scale. Representative of this type is Chang-pai-shan, composed of an alternation of volcanic ejecta and lava flows. Chang-pai-shan is situated on the border between Manchuria and Korea; and had been known as the highest point Ta-cheng-fen (2,745 m), but in 1943 the highest point was observed to be 2,751.48 m, 95 m west of a triangular survey mark at Ta-cheng-fen. The crater at the summit is nearly circular, 5 km in diameter, and the crater wall is surrounded by peaks over 2,600 m above sea level; the northern section is broken, running through a barranco.

The inner crater wall is steep and a cliff formed by lava flow rises several hundred meters. At the bottom of the crater lies the caldera lake of Tien-chih. Lake water runs out to the north, forming the Chang-pai waterfall.

In the river bed 2 km below the fall (1,800 m above sea level), there are several hot springs called the Chang-pai hot springs. These springs are mostly simple, weakly alkaline springs 80°C in maximum temperature; others are carburetted and weak sulphur springs. Here, the width of the valley is 2 km; both sides, east and west, have steep cliffs rising over 400 m, and the south is bounded by the crater wall of Chang-pai-shan, giving the crater the appearance of like a kettle bottom. The remnants of a lacustrine deposit were found midway up the eastern cliff. The above observations support the existence of an old eruption-type crater lake. At one time, the Tien-chih crater and this eruption-type crater stood side by side in a north-south direction. The outer crater wall is mostly covered with pumice ejecta, and has a gentle slope. Under the pumice cover, pantellerite and alkaline trachyte lava flows intercalated with layers of tuff and agglomerate make up the main body of Chang-pai-shan, and measure several hundred meters in thickness.

The upper limit of tree growth on Chang-pai-shan is 1,800 m above sea level in the east and 2,200 m in the west; a thick forest region exists below these limits.

In this great volcanic mass, the part above 2,200–2,300 m is steeply inclined at 20°–30°; the section below this level down to 1,000 m consists of shield basalt. On the gentle slope at about 2,000 m, there were several parasitic cones 100 m high; the mud lava of the last eruption covers a great area in the lower section.

On the whole, Chang-pai-shan volcano consists of a gentle basalt plateau between 1,000 and 2,000 m above sea level, the major part of alkaline trachyte occupies an area 30–40 km in diameter and the uppermost part of alkaline ryolite has a steeper inclination (10 km in diameter); thus a stratovolcano was formed.

5. Modes of Eruption

In Manchuria, there is no volcano active at present, and except for the two dormant Chang-pai-shan and Wu-ta-lien-chi volcanoes, most are extinct; thus, the mode of eruption can be seen from the structural features of the volcanoes.

In the two volcano types (a) and (b), massive basalt lavas ran slowly and smoothly from the crater. From the great amounts of issuing lava, plateaus or shield volcanoes were formed on the hilly land, and lava flowed (several to 30 km) along the valleys. Type (c) also consists of basalt, but dome-shaped mountains were formed around the crater, with no flow. Such differences seem due to the chemical composition of the lava and the quantity of issuing lava. Type (d), the cinder cone type, has two forms: one has a shield volcano at its base (often seen in north Manchuria), and the other stands directly on the old formation (seen in southeast Manchuria) without any shield basalt. In both cases, these cones are composed essentially of volcanic scoria mixed with some basement blocks. The truncated shape of the cones is not destroyed and the original form has been fairly well preserved.

Lao-hei-shan and Huo-shao-shan, which stand on the Shih-lung lava field in

Wu-ta-lien-chi district, are the product of an eruption in the 59th year of Kanhsi (1720) (ascertained from a reliable document); thus the Wu-ta-lien-chi volcano is only a dormant volcano. In the Ning-ku-ta journal edited in 1721 by Chenchan Wu, it is written that: "There is a lake measuring 30 ri around, northeast of Chichihar City. Great fires and smoke suddenly began to rise high in the sky in the vicinity of the lake in June and July of 1720 and the clap of thunder did not cease day and night for several days, and could be heard 50 ri away. At last the ejected stones, blocks and sulphur formed a mountain, but because of the severe heat spread for at least 30 ri around, it could only be observed from remote highlands. Then the heat became less and less, but still we could approach no closer than several ri." This is a description of the eruption of Lao-hei-shan and Huo-shao-shan. Due to the explosive type of eruption, the lava was ejected as scoria or bombs, and these materials accumulated around the crater to form hills. Stratifcation is more or less observable and even lava flow is intercalated with volcanic scoriaceous layers.

The structure of the cone is rather simple, the feature and structure resemble the island newly formed in the South Sulphur Islands in 1904. The volume of erupted material is greater in Lao-hei-shan, (0.1 km/) than in 13 other cones. Thus the formation of two cones took place in a relatively short time, but the continuation of eruption after birth was deduced to form the accumulation of lapilli measuring over 1 m thick on the lava field near the Lao-hei-shan and Huo-shao-shan craters, and fusiform bombs spread far out.

In other scoria cones, ejecta accumulated and formed cones immediately around the craters, but in the case of Ta-i-shan in Lung-wan district, small bombs were thrown 2 km away from the crater.

There are many examples of scoriaceous truncated cones from the last eruption of lava from the craters. In Huo-shao-shan in Wu-ta-lien-chi, Ta-i-shan, Chin-lung-ting-tzu, Ta-ku-shan, Hu-lu-lung-wan, Nan-lung-wan in Lung-wan district, lava issued from the craters and ran from several to 30 km down the valleys. From the craters of parasitic cinder cones in the northwestern section of Chang-pai-shan, lava flowed out at the last eruption.

On the top of scoriaceous cones (e), there are one or more craters, but because of the loose material and breaking of part of the crater walls, the accumulation of rain water and hence the formation of crater lakes was difficult, this is the reason for the lack of crater lakes in this type of cone. In the eight Lung-wan crater lakes, the compactness of building material the great depths and intactness of the crater walls were favorable for holding precipitation for the formation of lakes. On the whole, the formation of such craters took place during short-term eruptions just as for other cones. The Hu-lu-lung-wan crater is a maar type formed in the granite region.

The above cones were formed one by one in a relatively short time and on a small scale, and the form and structure are simple and similar. The Chang-pai-shan volcano is, however, a much larger volcanic body, unmatched in Manchuria

and Korea; its duration, formation and complex structure are characteristic. Volcanic activity occurred in the central part of wide basalt basement, and alkaline trachyte issued forth; lava, tuff and agglomerate accumulated to a thickness of over 300 m, forming the foundation of the volcano. Next, a great quantity of pantellerite lava issued forth attaining over 400 m in thickness. Thus, the main body of Chang-pai-shan was formed.

After formation of the volcanic body, parasitic cones of scoria erupted on the slope and a great quantity of pumice, blown out from the summit, covered wide areas of the slope above 2,000 m; at the same time, a great caldera was formed on the summit. In the last stage, mud-lava flowed from the caldera in all directions, going some 20 km along valleys. Then activity came to an end. To the north of the great caldera an explosion-type crater was produced and a crater lake also formed, but afterwards the lake was destroyed, and the present location of the Chang-pai-shan hot spring is thought to be the bottom of the old explosion crater.

6. Time of Eruption

There is no reliable evidence concerning the time of eruption of Manchurian volcanoes, except for a record of the eruption of Lao-hei-shan and Huo-shao-shan in the Wu-ta-lien-chi volcano in 1720. But judging from the features and geological relations of the volcanoes, the eruption of other cones must have occurred not too long ago, mostly in the Quaternary or a later age. Scoria cones of the Wu-ta-lien-chi volcano lie on a gravel bed, massive cones of the Chi-hsing-shan volcano intruded Diluvial sediments, the ha-la-tzu lava flows of the Lung-wan volcano flowed out along the recent river bed and some scoria cones stand on those lava flows.

At the present time, post volcanic activity is seen only in the Chang-pai-shan volcano. The Chang-pai hot springs of 80°C spout from a spot 2,000 m above sea level north of the Tien-chih caldera. The Tang-chui-ping hot spring of 50°C gushes out at 1,700 m on the western slope, and a hot spring of 30°C has been found at the lake side of Tien-chih within the crater.

Some standing woods preserved under pumice layers as natural charcoal were found at a point 2,000 m above sea level, 3 km southeast of the summit, and the species of buried wood are identified to be the same as modern types. Such a phenomenon seems to indicate an eruption in the not too distant past. The upper limit of tree growth on Chang-pai-shan is 2,200 m above sea level on the west and 1,800 m on the east slope. This may be explained as follows: in the eruption which occurred in the recent past, the falling of pumice was more severe on the east than on the west slope, and trees were burned out on the east side. A recent eruption is also supported by the existence of natural charcoal under the pumice bed. According to tradition, Chang-pai-shan erupted twice, in 1597 and 1702, but it is not clear whether there is any relation between these eruptions and the facts mentioned above.

The Wu-tai-lien-chi volcano, which consists of 14 cones, was called Uyun-hordongi which means 9 mounts in former times. It is thought that the remaining 5 cones were formed in the eruption which occurred after the old mountains were named, but this is not necessarily so. The eruption of 1720 refers to the formation of Lao-hei-shan and Huo-shao-shan and the shih-lung lava field of that district is believed to have already existed at that time; that is, in the Wu-tai-lien-chi volcano 12 cones erupted first, next the shih-lung lava issued forth forming 5 dammed lakes, and then in 1720, Lao-hei-shan and Huo-shao-shan appeared. At the present time no post-volcanic activity is observed in this district. In Lung-wan district, long wide basalt lavas issured from craters of cinder cones and flowed along recently formed river courses.

Basalt flows are dated from two periods in southeast Manchuria; in the former case, the basalt is situated on a high level and covers the high, often dissected, land surface forming a table land. This is seen in the basal lava of Chang-pai-shan and on the top of the high land along the Mu-tan-chiang River. The basalt of the later period lies on a lower level and usually occupies river courses; Ha-la-tzu basalt flows of the Lung-wan volcano and the wide basalt field between the Tiao-shui-lou waterfall hanging on the edge of Ching-po-hu Lake and the old town of Tung-ching-cheng in the course of the Mu-tan-chiang River are outstanding examples.

Hot spring directly related to these volcanoes are rare in Manchuria except for the Chang-pai-shan volcano; other famous hot springs are not concerned with these volcanoes.

7. Characteristics of Volcanic Rocks

Volcanic rocks constituting the volcanoes of Manchuria are wholly basaltic in character except for the alkaline trachyte and pantellerite of Chang-pai-shan and quartz-trachyte of O-ne-nor and Ha-r-hin-tun volcanoes.

Massive rocks of shields in the Wu-ta-lien-chi and Erh-ko-shan volcanoes are black to blackish-gray compact trachybasalt. The constituent minerals are plagioclase, anorthoclase, augite, olivine, magnetite, ilmenite, glass, etc. The shih-lung lava is jet-black obsideanic glassy rock with microphenocrysts of olivine and augite in a glassy groundmass, and sometimes with leucite microphenocrysts, less than 0.1 mm, in size as well as xenoliths of granite pieces and quartz grains. Volcanic cones of the Wu-ta-lien-chi volcano consist of porous black or brown scoria containing microphenocrysts of augite, olivine and leucite, and resembling the above shih-lung lava. Thus these rocks were named "shihlunite" by the author and assigned to alkaline basalt. Other cones in the vicinity of Mo-erh-ken are thought to have the same composition as the above.

Cones of the Chi-hsing-shan volcano consist of black massive microcrystalline to phanerocrystalline rock, both being trachybasaltic varieties. Components are plagioclase, augite, titanaugite, aegirine-augite, olivine, picotite and glass. In

Nao-pao-shan, leucite basalt crops out. The same rocks are found in cones of the Ta-tun and I-tung volcanoes.

In the Lung-wan volcano, the lava flow is massive. In some cases it is black to grayish-black basalt, consisting of oligoclase, augite, olivine, magnetite, biotite and glass, with xenocrysts of olivine. The scoria is black or brown porous rock, resembling the former in mineral composition. It sometimes contains a large quantity of big olivine nodules.

In the Chang-pai-shan volcano, many kinds of rocks are found. The order of eruption is as follows: first came basic basalt, next intermediate alkaline trachyte and last a great quantity of pantellerite issued forth contributing on a large scale to the formation of the volcano. This is the normal order of differential eruption for basaltic magma. In the next stage a small scale eruption of basalt occurred, forming several scoriaceous parasitic cones, succeeded by a pumice explosion from the summit. The nature of the pumice is not clear, but it seems to correspond to alkaline liparite; its chemical composition was described by Dr. Rault as pantellerite. The mud flow, the last period of activity, was of alkaline trachyte.

The mineral components of the volcanic rocks of Chang-pai-shan are as follows: labradorite-olivine-basalt basement has large phenocrysts of plagioclase, and the groundmass consists of plagioclase, augite, iron ore, olivine and glass. Next, the alkaline trachyte is classified into three kinds according to its components: yellow augite-alkaline trachyte, fayalite-yellow augite-anorthoclase-trachyte and fayalite-yellow augite-anorthoclase glassy trachyte. Pantellerite trachyte grades into proper pantellerite and finally into glassy pantellerite. Components of pantelleritic rocks are abundant phenocrysts of anorthoclase and augite, and the groundmass is generally of aegirine-augite or aegirine, cossyrite, riebeckite and glass, sometimes with magnetite, barkevikite and arfvedosonite. The pumice is white, fibrous, silky lustrous and alkaline rhyolitic in character, having abundant phenocrysts of anorthoclase in a colorless groundmass. Xenoliths exploded with pumice forms blocks of basalt, alkaline trachyte, alkaline syenite, kali-granite, etc. Mud lava is brown to black, loose alkaline trachytic rock, containing phenocrysts of anorthoclase with soda pyroxene in a grayish-brown glassy groundmass. In this mud lava several kinds of xenoliths are found of pre-existing rocks. Thus, the volcanic rocks of Chang-pai-shan are alkalic and different from those of other volcanoes in Manchuria.

The chemical compositions of volcanic rocks of Manchuria are shown in the following table (values are the average for each volcano): (Table 4).

In general chemical composition, the percent alkali is comparatively high in every case; in comparison with percent alumina, the trachyte and quartz-trachyte of Chang-pai-shan properly belong to alkaline rock, the leucite-basanite of the Wu-ta-lien-chi and Erh-ko-shan volcanoes is sub-alkaline and the basalt of the Chi-hsing-shan and Lung-wan volcanoes belongs to calc-alkaline rock. But from the mineral composition, these rocks are said to be alkaline in nature. A characteristic difference between rocks of volcanic districts is that the percent K_2O is always

Table 4. Average Chemical Composition (%) of Volcanic Rocks.

	Wu-ta-lien-chi	Erh-ko-shan	Lung-wan	Chi-hsing-shan	Chang-pai-shan		
					Basalt	Trachyte	Pantellerite
SiO_2	50.76	50.99	48.15	45.10	49.96	63.61	67.89
TiO_2	2.38	2.48	2.15	2.04	2.70	0.54	0.35
Al_2O_3	14.37	14.19	17.49	14.65	15.95	16.35	14.91
Fe_2O_3	2.96	4.53	4.14	2.30	3.15	2.66	2.13
FeO	6.10	4.20	7.08	10.07	8.89	3.31	3.40
MnO	0.11	0.10	0.23	0.18	0.21	0.11	0.09
MgO	7.02	5.95	7.47	9.16	4.51	0.25	0.07
CaO	6.60	6.15	7.21	9.30	8.32	1.40	0.84
Na_2O	3.72	4.28	3.23	3.55	3.18	5.28	5.41
K_2O	4.76	5.23	2.16	1.77	1.41	5.18	4.79
P_2O_5	1.04	1.08	0.46	0.58	0.56	0.07	—
$-H_2O$	0.51	0.98	0.15	1.30	0.33	0.33	0.10
$+H_2O$			0.45		0.47	0.31	—
Total	100.33	100.16	100.37	100.00	99.64	99.40	100.98
Number of samples	19	3	13	8	2	9	3

greater than the percent Na_2O in northern Manchuria, but the reverse in the central and southeastern districts. There are many possible explanation of why $K_2O > Na_2O$. Some say it is the result of the assimilation of foundation granite in the northern district, but the foundation is also granite in the Lung-wan district and the volcanic rock often captures granite blocks; the volcanic rock in this district is not rich in K_2O, but is sodic. Therefore it is not likely that the source of the large amount of K_2O in volcanic rocks is the K_2O of granite. Alkaline rocks in the Chang-pai-shan district are also rich in Na_2O. From this point of view, it is assumed that the underground magma was differentiated into kalic and sodic parts which then erupted locally. Where then is the boundary of the kalic and sodic districts? The chemical composition of the ignerous or volcanic rocks in the districts between Erh-ko-shan and Chi-hsing-shan (300 km apart) has not been known, and their boundary probably lies in the intermediate districts.

II. Description of Volcanoes

1. Ta-tun Volcano

There are four domes in the Ta-tun and Han-chia-tun district between Kung-chu-ling and Chang-chun along the Ta-lien-Harbin Railway line. On the east side of the railway, there are Chien-shan (266 m above sea level), Ping-ting-shan (266 m) and Ta-tun-tung-shan (225 m), and on the west, Ta-tun-ping-ling-shan (283 m). The relative height of the domes is under 40 m. They are small aspite types with gentle slopes, and are arranged in two parallel lines NE-SW. The rock is black compact basalt and has columnar joints. It is quarried for railway construction.

2. I-tung Volcano

Six domes of basalt are distributed over an area of 5–15 km, stretching E-W near I-tung, Chilin Province. These are Tung-chien-shan (371 m above sea level) south of I-tung, Hsi-chien-shan (353 m), Ma-an-shan (272 m) and Mo-li-ching-shan (321 m) to the northwest, and Ta-ku-shan (389 m) and Hsiao-ku-shan (270 m) to the south.

They are of mamelon type 50 m high, and stand out above the hilly land. Tung-chien-shan, Hsi-chien-shan, Ta-ku-shan and Hsiao-ku-shan are arranged in a NE-SW line, and Ma-an-shan and Mo-li-ching-shan are on another line parallel. These cones are thought to be composed of black, compact basalt.

3. Chi-hsing-shan Volcano

The Chi-hsing-shan volcano consists of seven domes scattered around the hilly land of Cheng-chia-tun district, Feng-tien Province. The name probably comes

from the arrangement which is similar to that of the seven stars of the *Ursa Major* constellation. Po-li-shan, one of the seven domes, is famous for a grand view from the window of trains passing through the environs of Cheng-chia-tun station (Fig. 2).

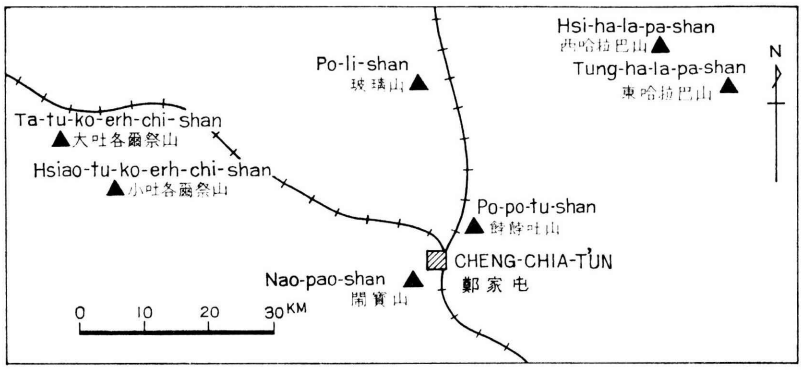

Fig. 2. Map Showing the Distribution of Cones in the Chi-hsing-shan Volcanic District.

Topography

The centre of the district lies at Long. 123°30′E and Lat. 43°30′N, and the seven domes are scattered over an area of 100 km E-W and 30 km N-S. Three of them stand on the east side of the Hsin-kai-ho River running parallel to the railway line, and four on the west. The district spreads over the central part of the Manchurian Plain, 150–200 m above sea level. The eastern part of the district is a wide, hilly plain, the central part (the environs of Cheng-chia-tun), often forms a flood plain, because of the intersection of the Hsi-liao-ho and Hsin-hai-ho. The western part is distinguished by irregularly arranged groups of sand dunes, 240 m above sea level in the southwest.

The Chi-shing-shan volcanic group consists of seven domes. Their height, base diameters and height above sea level are shown in the following table, going east to west (Table 5.)

Tung-ha-la-pa-shan: The dome is situated 12 km ENE from the town of Shuang-shan. The base is elliptical, being elongated to WNW; the summit forms a ridge in the same direction. While the slope near the summit is nearly 30°, it gradually decreases below 20° towards the foot. On the eastern edge of the summit, columnar joints of basalt stand precipitously.

Hsi-ha-la-pa-shan: Located 12 km N-W of Tung-ha-la-pa-shan, it is a mamelon type with a gentle slope. A great rift runs straight through the summit in a N-W direction, which corresponds to the direction of a line connecting Tung-ha-la-pa-shan and Hsi-ha-la-pa-shan.

Po-li-shan: Located 8 km west of the railway and can be seen from the train. The dome is typically mamelon-shaped, very much resembling Hsi-ha-la-pa-shan. The relative height is 110 m, the highest of the seven domes; the lower part is

Table 5

Name of cone	Height above sea level (m)	Relative height (m)	Diameter of base (m)
Tung-ha-la-pa-shan	293	90	550
Hsi-ha-la-pa-shan	318	70	650
Po-li-shan	278	110	770
Po-po-tu-shan	220	70	900
Nao-pao-shan	170	30	320
Hsiao-tu-ko-erh-chi-shan	267	50	490
Ta-tu-ko-erh-chi-shan	238	44	700
Average	255	67	626

covered with aeolian sand. There are several stone piles called obo on the summit, which are folk symbols of worship.

Po-po-tu-shan: Northeast of Cheng-chia-tun, just opposite the town on the Hsin-kai-ho River. In the western part, there is a basalt quarry. It resembles a sea cucumber in shape and the greater part is covered with aeolian sand except for the summit, on which basalt is exposed east to west.

Nao-pao-shan: A small dome, 30 m high on the plain, situated 3.5 km SW of Cheng-chia-tun. Although the dome is completely covered with thick aeolian sand, it seems to be formed of somma and a central cone.

Hiao-tu-ko-erh-chi-shan: A butte dome in the sand dune region, 45 km WNW of Cheng-chia-tun. The basement is elliptical, going NW-SE; the relative height is 50 m and the summit forms a 50 m long ridge in the same direction.

Ta-tu-ko-erh-chi-shan: Located 11 km NW of Hsiao-tu-ko-erh-chi-shan and situated in the western extremity of the district. The mount stands on a rhombic basement; the foot is covered with sand and the slope becomes gradually steeper toward the summit 44 m high. The summit is elongated E-W, bending slightly towards the south. There is a big obo on the summit.

These seven domes are arranged like the seven stars of *Ursa Major*; the three domes of Ta-tu-ko-erh-chi-shan, Hsiao-tu-ko-erh-chi-shan and Nao-pao-shan correspond to the handle, and the other four to the ladle. With respect to the fissure system, there seems to be no regular arrangement of domes, but a line S 47° W connecting Hsi-ha-la-pa-shan, Po-po-tu-shan and Nao-pao-shan, a line S 82° W connecting Hsi-ha-la-pa-shan, Po-li-shan, Ta-tu-ko-erh-shan, a line S 63° E connecting Hsi-ha-la-pa-shan and Tung-ha-la-pa-shan and a line S 12° W connecting Hsi-ha-la-pa-shan and Shih-tou-shan, a very low hill, are considered these four directions radiate from Hsi-ha-la-pa-shan as a center, but it cannot be

concluded that a radial fissure system is present. From the petrological character of these domes, Po-po-tu-shan and Nao-pao-shan form a center, and the others are arranged concentrically. But, it still is not certain whether a concentric fissure system exists.

Geology

The foundation of this volcanic group consists of a Quaternary system; hilly land east of the Hsi-liao-ho is essentially composed of sand and clay and west of the river the sand dunes consist of aeolian sand; the low plain is chiefly of clay-like sand. The sand dunes are 20–25 m in height and the aeolian sand over 25 m in thickness. The fluvial plain is 3–4 km in width and consists of fine grayish-black sand and clay.

Volcanic rocks forming the seven domes and Shih-tou-shan belong to black compact and massive basalt or trachy-basalt which is fine-grained in Nao-pao-shan and Po-po-tu-shan in the inner zone, medium-grained and phanerocrystalline in Hsi-ha-la-pa-shan, Shih-tou-shan, Po-li-shan and Hsiao-tu-ko-erh-chi-shan in the middle zone and coarse-grained in Tung-ha-la-pa-shan and Ta-tu-ko-erh-chi-shan in the outer zone. Mineral constituents are generally similar in each rock type, and essential components are oligoclase, olivine, titanaugite and augite with additional alkali feldspar, aegirine-augite, biotite, apatite, picotite and leucite, which is an essential component of Nao-pao-shan lava. This occurrence of leucite was the first record in central and eastern Manchuria. The average chemical composition of the seven domes and one hill is shown on Table 6.

Table 6

SiO_2	45.10 %	CaO	9.30 %
TiO_2	2.04	Na_2O	3.55
Al_2O_3	14.65	K_2O	1.77
Fe_2O_3	2.30	P_2O_5	0.58
FeO	10.07	H_2O	1.30
MnO	0.18		
MgO	9.16	Total	100.00 %

This volcano situated in the center of the Manchurian Plain, lies on the southern edge of the upheaved Hei-liao divide (a hilly highland 250 m above sea level stretching SE to NW between Kung-chu-ling and Tao-nan). In the northeastern edge of this divide lies the Ta-tun volcano and in the east the I-tung volcanic group; the domes of these volcanoes consist of black basaltic rocks and are mamelon shaped. Eruption of these domes is thought to be connected with the upheaval of the Hei-liao divide.

4. Kuan-tien Volcano

The Kuan-tien volcano consists of several cones west of Kuan-tien Town, Tung-hua Province. Huang-i-shan in the western suburbs of Kuan-tien is a truncated cone 513 m above sea level and the crater wall is broken on the south side. The rock is mostly reddish-brown porous scoria of a basaltic character. Ching-i-shan is also a truncated cone, several km west of Huang-i-shan, but no details are available. There is also a cone north of Ching-i-shan.

5. Lung-wan Volcano

The Lung-wan volcano belongs to Hui-nan Prefecture, Tung-hua Province, and is situated 130 km WNW of Chang-pai-shan, standing on the west side of the Lung-kang Mts. The central part of the district is located at Long. 126°15′ E and Lat. 42°30′ N, and the volcanic district is limited to 25 km E-W and 20 km N-S (see Fig. 3). There are many volcanic cones in the eastern neighboring thickly forested zone but little is known about them. The district is a dissected mountainous land 400 m high in the west and 800 m in the east. The foundation of the district consists essentially of granite and granite-gneiss, the former distributed in the north and the latter in the south. In the west, Cambro-Ordovician shale and limestone occasionally crop out.

Topography

The volcano consists of basalt, divided into cone-basalt and flow-basalt according to the mode of occurrence.

There are over 35 cones in the district, the most important of which are listed here, going from west to east:

Hsing-an-nan-shan, Hsi-heng-tao-shan, Tung-heng-tao-shan, Hsiao-i-shan (455 m), Ta-i-shan (524 m), Teng-chia-wang, Chien-shui-ting-tzu, Ta-ku-shan-tzu, Hsiao-ku-shan, Shih-men-tzu-shan, Weng-chuan, Hsiao-weng-chuan, Ya-pa-kang, and Kuan-tso-ling. These are homatic truncated cones.

In the eastern part there are eight cones with crater lakes on their summits: Hsiao-lung-wan, Erh-lung-wan, Ta-lung-wan, Hu-lu-lung-wan, Nan-lung-wan, Tung-lung-wan, Pan-pan-lung-wan and Hsi-pai-tzu-lung-wan.

A topographical survey had been carried out on these cones and the size, depth and other crater measurements were obtained in detail. Part of these data, however, was lost at the end of the war. The general features of the volcanoes will be described in the following pages, although there may be gaps due to the lost of information (Fig. 3).

First, the cones are generally isolated and low truncated in form. The basement is mostly round with a diameter of 1,000 m on the average, 1,500 m being maximum (Weng-chuan and Ya-pa-kang). They are low, usually less than 100 m, the highest being 179 m above its base in Ta-i-shan.

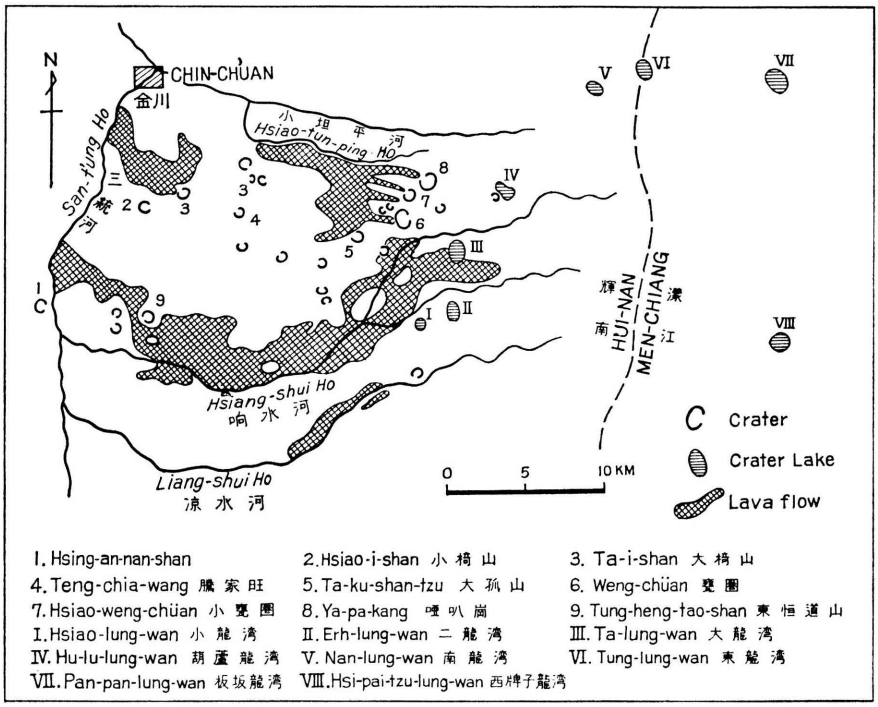

Fig. 3. Map Showing the Distribution of Principal Cones in the Lung-wan Volcanic District.

There are craters on the summits, mostly less than 500 m in diameter, but greater than 1,000 m in Weng-chuan, Ya-pa-kang, Ta-lung-wan and Hu-lu-lung-wan. In Weng-chuan crater, a prefectural road has been built along the inner wall. On the top of Hsiao-ku-shan, there is a small conical crater. The crater of Ya-pa-kang is round and 1,500 m in diameter, the largest in the volcanic district, and the western part is broken. The cone consists of alternate layers of volcanic scoria and ash, occasionally with lava flow; the layers incline about 25° toward the outside of the crater. Volcanic bombs are characteristic of this district; many fusiform or round bombs have been collected, especially near Ta-i-shan, Shih-men-tzu-shan and Chien-shui-ting-tzu. The basal rock of the district is chiefly granitic, and crops out at the bottom of the crater of Weng-chuan. Granite blocks are found among the efecta of Ta-i-shan, Hsiao-i-shan, Heng-tao-shan.

Eight crater lakes are found in the eastern part of a pseudo-trapezoidal area 20 km E-W and 15 km N-S. These lakes lie in a dense forest area, only 3 or 4 being known previously. All eight lakes were investigated for the first time in 1940. About eight crater lakes in Lung-wan district, there has been described on pages 378–380 of this Volume 2.

There are 4 principal lava flows in the district, and several other flows are said to be found in the northern craters from where lava flowed out to the northwest

along valley floors. These lava flow zones consist of an accumulation of various sized block-lavas forming a stony river bed; they are thickly covered with forests or consist of damp ground. Such waste land is called *"ha-la-tzu"* by the natives, meaning a black stony place. The greatest lava flow is situated in the central southern region, running east to west. The lava erupted from near the Chin-lung-ting-tzu cone, east of Ta-lung-wan crater, flowed along the crater rim of Ta-lung-wan, ran west along the Ha-ma-tang-ho, then the Hsiang-shui-ho and down to the San-tung-ho rivers, the total length of flow being over 35 km. The course of flow generally followed the valley floor, but not always; there are several areas without lava near low hills within the flow zone. The flow is variable in width, being 3 km on the average. In the west central region, the flow became over 5 km wide; then it flowed northwest, deflecting from the Hsiang-shui-ho, narrowed to 200 m at the foot of Tung-heng-tao-shan and then reached the San-tung-ho 5 km from there. Along the San-tung-ho River, the lava is distributed over a distance of 3 km with a thickness of over 20 m at the cliffs. The surface of the flow has an accumulation of block-lava and is covered with thick forests which are not utilized, but places free of lava flow are sometimes cultivated, as seen in Ha-ma-tang and Li-tai-fang Villages.

The second lava flow erupted from the Ta-i-shan crater in the northwest, and ran down about 6 km WNW to the San-tung-ho. It is 2.5 km wide and has two step terraces consisting of upper and lower lava flows, 7 and 13 m thick, respectively. Several "hornito-like" puff cones are found on the flow. There are also many volcanic bombs ejected in a later eruption scattered on the flow surface at the western foot of Ta-i-shan. On the cliff of the Shuang-yang-tung-ho, east of Ta-i-shan, there is a thick lava flow beneath the volcanic lapilli layer.

The third flow erupted from the top of Ta-ku-shan-tzu, 9 km ESE of Ta-i-shan, and ran down the slope north to the Hsiao-tan-ping-ho leaving several small islets of granite, turned west and stopped east of Jen-ho-pu Village. The length of flow was 9 km with a 1 km width. Small flows from Weng-chuan, Hsiao-weng-chuan and Ya-pa-kang craters, northeast of Ta-ku-shan-tzu, formed part of the third flow.

The fourth flow developed along the upper course of the Liang-shui-ho in the south and ran southwest for 8 km. The lava remains only on one side of the eroded valley cliff and is 17 m thick.

As mentioned above, the lava flowed westward from the craters, due to the topography of the district—higher in the east and lower in the west—and the flows made their way according to the topography of the valleys. The areas encompassed by these lava flows are 66 km^2 in the Hsiang-shui-ho and 11.5 km^2 in both Ta-i-shan and Ta-ku-shan-tzu; the whole area is estimated at over 90 km^2. This area is more than 3 times larger than that of the 35 volcanic cones which occupy about 30 km^2 of this volcanic district.

Petrology

Volcanic cones consist of alternate layers of volcanic scoria, lapilli and ash. Scoria is fist- to head-sized, round porous block, reddish-brown in color. The component minerals are not visible to the naked eye, but plagioclase, olivine and glass can be detected under the microscope. The rock is basaltic. Volcanic bombs are plentiful, being mostly fusiform and less than 20 cm in length. Many olivine nodules over 30 cm long are scattered among the ejecta, being especially abundant in the crater of Weng-chuan. The nodules are formed essentially of olivine aggregate with some pyroxene and picotite. The flow lava is grayish-black and porous, with a microporphyritic structure, and consists of olivine, plagioclase, pyroxene and magnetite, showing a basaltic texture. Occasionally olivine nodules are found. Scoria and flow lava are different in appearance, but not in chemical composition, as seen in the following table (Table 7).

Table 7

	Scoria (%)	Lava (%)
SiO_2	48.75	47.52
TiO_2	2.04	2.01
Al_2O_3	17.69	17.11
Fe_2O_3	5.40	1.81
FeO	5.71	9.48
MnO	0.24	0.22
MgO	6.85	7.97
CaO	6.86	7.84
Na_2O	3.18	3.45
K_2O	2.40	2.08
P_2O_5	0.44	0.38
H_2O	0.81	0.48
Total	100.37	100.35

Scenery

Little has been known of the Lung-wan volcano except for 2 or 3 crater lakes reported 30 years ago. The study in 1940 and 1942, just 10 years after the founding of Manchoukuo, revealed the main features of the volcanic district: (i) the existence of over 35 well-preserved cones with craters in a narrow region (ii) the

existence of 4 long lava flows and 8 deep crater lakes of Lung-wan, and (iii) the limnological characteristics of the crater lakes.

Thus, the district furnishes not only valuable material for volcanology, but also one of the most scenic landscapes in Manchuria.

6. Chang-pai-shan Volcano

Chang-pai-shan, called Pai-tou-shan in Korea, is the biggest mountain on the boundary of Manchuria and Korea. The highest peak, Ta-cheng-feng is situated at Long. 128°05′ E and Lat. 41°59′ N.

The volcano has been surveyed by many scientists, but the study carried out in 1942 and 1943 by the Chang-pai-shan Scientific Expedition under the auspices of the Science and Technical League of Manchoukuo was one of the most complete and successful. The members of the expedition were specialists in zoology, botany, forestry, physics, meteorology, geology, land survey, wireless telegraphy and photography.

Drs. Riuji ENDO, Goro ASANO, and Tsutomu OGURA took part in the geological research. The results were not previously published, however, because the manuscripts of the reports were lost at the end of the war. This report is therefore based on memory and on the description provided by Dr. ASANO.

Topography

A triangulation point on Ta-cheng-feng at 2,745 m above sea level was previously considered the highest peak, but it became clear in this expedition that the highest point is at 2,751.48 m, 95 m west of the 2,745 m point.

The base of Chang-pai-shan is a basalt plateau 120–150 km in diameter. The plateau has a gentle slope at the foot, but becomes gradually steeper as it rises presenting an aspite-shield aspect. Plateau basalt is found in the upper region roughly 2,000 m above sea level. The upper part of this aspite is the main body of Chang-pai-shan, and is formed by alkaline trachyte from the first eruption. The lava is nearly 300 m thick and its surface has an inclination of less than 10°. The lava area is 30–40 km in diameter but the greater part is covered by an accumulation of pumice or mud lava. Pantallerite from the last eruption forms the uppermost dome of Chang-pai-shan; it has an inclination of 20°–30° and is over 400 m thick. The base of the pantellerite dome is 10 km in diameter.

On the summit, a crater wall 2,600 m high surrounds the crater lake Tien-chih. The main peaks on the crater wall are Pai-yen to the north, Wang-tieh-hou to the east, Ta-cheng-feng (Ping-shih-yen) to the south, and Mo-tien-yu and Tseng-yen to the south and northwest. The outer wall of the crater slopes gently, especially on the Korean side, but the inner wall is quite steep and lava flows crop out strongly on the inner cliff. The crater wall has a pseudo-octahedral form, 5 km long east-west and north-south. The crater lake at the bottom is shaped like a pear with the large end to the north. It has a diameter of 3 km in east-west and 4 km north-south, with an area of 9.2 km^2 and a circumference of 13.75 km. The depth of the

lake was not measured by this particular expedition, but according to an expedition by Kyoto University some ten years ago it is 375 m at the deepest point. The surface of the lake is 2,257 m above sea level and the distance from the highest point of the crater wall to the surface of the lake is 494 m; therefore the depth of the crater is estimated at 869 m, making it the deepest crater in Manchuria. The lake water breaks through the crater wall between Pai-yen and Tseng-yen and flows out to the north from Tamen through a barranco, forming a waterfall 66 m high. This fall is called Chang-pai Fall, and is the highest in Manchuria. The valley widens suddenly in the lower course of the fall and it flows north as the source of the Erh-tao-pai-ho River. The flow of water was measured in August 1943 and estimated at 200,000 t per day at this point.

In the lower course 2 km from Chang-pai Fall, at 1,800–1,850 m above sea level, there are several hot springs in a 100 m square area with maximum temperatures of 70°–80°C, and weak alkaline simple springs with a slight odor of hydrogen sulfide. Some carburetted springs of lower temperature are found in the neighborhood. The total amount of water provided by the hot springs in this vicinity has been estimated at 10,000 t per day.

With respect to the topography near Chang-pai hot springs, the valley is 2 km wide, is flanked by steep cliffs over 400 m high to the east and west, and looks like the bottom of a kettle. In the middle wall of the eastern cliff there is a deposit of alternate layers of sand and gravel, 50 m thick, which is assumed to be the remnant of a lake. On the basis of the points mentioned earlier, this spring area is thought to be the bottom of an old explosion crater; in other words, this explosion crater and Tien-chih were originally connected north-south at the time of their formation.

In addition to these hot springs of Chang-pai-shan, there is a hot spring of 30°C near the shore of Tien-chi lake at the foot of Pai-yen; the rocks in its vicinity have turned brown. In summer the water temperature of Tien-chi at the foot of Ta-cheng-feng was 2–3°C, while the water temperature of the river in the lower course of Chang-pai Fall was 7–8°C, probably due to another hot spring in the lake, as in the case of Pai-yen. There are carburetted springs in the western outer wall of Mo-tien-yu and there is the Tang-shui-chang hot spring (58°C) in the upper course of the Man-chiang in the southwestern part.

There are several cinder cones of basalt on the slope of Chang-pai-shan. Ta-yen-chih-feng to the southeast of Ta-cheng-feng and Hsiao-yen-chih-feng 4 km southeast of Ta-yen-chih-feng are cinder cones with brown peaks standing out from the white pumice layers. There are also three parasitic cones on the northwest slope of the Tseng-yen crater wall, 30–40 meters high and 1 km in basal diameter. Farther west there are several other parasitic cones, two of which are found near Tang-shui-chang hot spring. Although they are relatively low, they break the monotony of the landscape at 2,000 m above sea level.

One characteristic of Chang-pai-shan is the pumice which covers a large circular area of 40 km radius with the caldera of the summit as its center. It forms a

surface on the slope, and has an attractive white color. It is 10–20 m thick on the average and 40 m at maximum. A wide distribution of mud lava is also characteristic west and north of the caldera. Highly fluid mud lava poured out from the caldera to a distrance of 40 km, resulting in a gentle topography. Vertical erosion by river water is strong in this rock, and there is a long narrow gorge over several km along the Erh-tao-pai-ho, forming deep grooves or natural bridges. As mentioned earlier, Chang-pai-shan holds first place in Manchuria on the following points: it has the deepest caldera and Tien-chih on the summit, the highest Chang-pai waterfall and hottest Chang-pai spring, remarkable change in distribution of characteristic trees and animals according to the altitude, and a rare occurrence of alkaline rocks that built the main body.

Little is known about the history of the eruptions of Chang-pai-shan. Traditional accounts of eruptions in 1597 and 1702 are not altogether reliable. This mountain has the highest hot spring, Chang-pai spring, and several other springs are known, but no other post-volcanic action such as solfatara has been observed. At a point 2,000 m above sea level and 3 km southeast of the summit, natural charcoal was found buried in the volcanic ash, and the types of trees are similar to recent flora such as *Picea koraiensis* NAKAI and *Larix dahurica* TURCZ. The fact that the upper tree limit on Chang-pai-shan is 2,200 m on west side and 1,800 m on the east side can be explained by the great forest fire caused by the greater fall of ash on the east side than on the west in the past. If the ejection and accumulation of pumice is older in time than the issue of mud lava, the eruption which produced the pumice cannot have occurred 400 years ago as tradition holds.

Geology and structure

As revealed by the foregoing descriptions, the topography of the Chang-pai-shan Volcano coincides well with the geology, and can be divided into four stages. The oldest formation, constituting the foundation of the volcano, occupies the lowest horizon, but is now exposed at a level of 600–1,000 m. Above this, the plateau basalt accumulated in an area 120–150 km across and 2,000 m above sea level at the highest point, forming the gentle slopes of the volcano, and resulting in an aspite-type of mountain. The third stage is represented by alkaline trachyte, consisting of alternating lava flows and agglomerates, which formed the base of the main body of the volcano. The surface of the trachyte is inclined about 10° and joins the plateau basalt below. The fourth stage is the formation of the main body of the volcano, which has a 20–30° inclination. The main body consists of pantelleritic lava flows, 30–40 m to 300–400 m thick. A dome, 1.1 km in diameter, was formed on the top by the accumulation of these lava flows, and rises over 2,750 m above sea level.

The older formation which makes up the foundation is mostly pre-Mesozoic. Near Nai-tou-shan, 30 km north of the summit, a hill of pre-Cambrian quartzite and dolomite stands like an island on a basalt plateau. In Man-chiang village in the west, the Mesozoic sedimentary and igneous rocks are distributed under the

plateau basalt in the capital city of Chang-pai Prefecture. Cambro-Ordovician rocks are present in the south. On the gentle, eroded surface of these older rocks the plateau basalt accumulated in large quantity after the central eruption, and made the entire surface flat. This basalt is not homogeneous in character but is generally of the type called augite-olivine basalt. The next eruption is represented by alkaline trachyte which forms the lower part of Chang-pai-shan Volcano proper. The center of eruption gradually moved from south of the present caldera to the north and southwest side repeating the explosion and eruption of the lava. In the first phase alkaline trachyte erupted, and then the more acid sodic pantelleritic alkaline trachyte. The trachyte is not exposed on the summit, but in Ma-an-shan to the south where rock covers the basalt and is covered by agglomerate, tuff and lava flow. The rock comprises three varieties: (i) yellow augite-anorthoclase trachyte, (ii) fayalite-yellow augite-anorthoclase trachyte, and (iii) fayalite-yellow augite-anorthoclase glassy trachyte.

Another type, called pantelleritic trachyte, which differs from the above types and from pantellerite, is exposed in the lower part of the inner wall of the caldera along a deep valley below Mo-tien-yu and under the pantellerite flow near the eastern forest boundary of Pai-yen. In the valley bottom east of Mo-tieh-yu alternating layers of tuff and agglomerate, several to 30–40 meters thick, and thinner lava flows amount to 200–300 m in total thickness. This lava is dark grayish cryptocrystalline with a few phenocrysts.

The pantellerite is distributed around the caldera. It piled up after several eruptions without any mixing of agglomeratic substance, each lava flow being 30–40 m to 300 m thick and running down the slope to the lower limit of the tree line at 2,000 m. The inclination of the slope is 20–30° above the 2,000 m line and less than 10° below. The pantellerite lava erupted in great quantity. Marked with tabular and columnar joints, it forms prominent cliffs. The rock is grayish blue and contains abundant phenocrysts of anorthoclase and augite in compact groundmass. It is called fayalite-soda pyroxene-aegirine augite-anorthoclase pantellerite from its mineral composition. It corresponds to "hakutoite" reported from the northeastern part of Korea, and is not known in other parts of Manchuria. A glassy variety of pantellerite flowed out of the top of Pai-yen and Ta-cheng-feng, presenting a unique topographical feature. It has numerous white phenocrysts of anorthoclase in black glassy groundmass. The rock belongs to a later eruption than pantellerite proper, and is distributed as long narrow flows around the summit.

The main body of the mountain was formed, for the most part, by accumulation of alkaline trachyte and pantellerite, and the initial height is assumed to have been 3,500 m above sea level. Later, a number of parasitic cones were formed on the sides of Chang-pai-shan: Ta-yen-chih-feng and Hsiao-yen-chih-feng on the southeast side, three cones on the northwest side, and several on the west side. These are cinder cones of basaltic rock containing phenocrysts of olivine, monoclinic pyroxene and labradorite. Many crystal bombs of labradorite are found on the cones

northwest of Tseng-yen. In the final stage, lava flowed out of these cones.

After the eruption of lava, the volcano remained quiescent for some time; finally, it erupted again, ejecting a pumice and fragments of older lava, basalt, nordmarkite and similar plutonic or hypabyssal rocks which were especially abundant in the upper part of the accumulation. The size of the pumice stones ranges from that of a fist to that of a head, and it has a white silky luster. It is an alkaline rhyolitic rock and consists of colorless glass dotted with phenocrystic anorthoclase and less aegirie augite. It is excellent for polishing lithographic plates.

Formation of the caldera, which has a diameter of 5 km is assumed to have occurred at the same time as the eruption of pumice. Later mud lava issued from the caldera in all directions, especially from north to west. The Sung-te-ssu temple above the Ta-men barranco was built on this mud lava within the caldera. Half way to Tseng-yen the rest of the mud lava is seen stuck on the caldera wall. Rolling debris is also observed between Pai-yen and Ta-cheng-feng. Along the lower course of the Erh-tao-pai-ho the mud lava flow is prominent. The mud lava is dark brown to black and rather loose; and consists of glassy groundmass with phenocrysts of anorthoclase and soda pyroxene. Fragments of pre-existing lava and plagioclase crystals are also found in abundance. The thickness of the mud lava exceeds 150 m along the Erh-tao-pai-ho.

The properties of lava

The chemical composition of rocks collected during the geological survey in 1943 are given in the following table. They are classified into six groups according to the order of eruption and lithologic character: (I) basalt, (II) alkaline trachyte, (III) pantelleritic trachyte, (IV) pantellerite, (V) glassy pantellerite, and (VI) basalt of parasitic cones. It can be seen from the table that the composition of the rocks gradually changed from basaltic to acidic. (Table 8).

Conclusion

Chang-pai-shan is a strato-volcano standing on a wide plateau of basalt, and has a big caldera lake on the summit. The original eruption laid a foundation of alkaline trachyte; the greater part of the mountain was formed after a great eruption of pantellerite and glassy pantellerite; subsequently, several basaltic cinder cones were formed on the sides of the mountain. Later, a major eruption of pumice created a large caldera on the summit, and from the caldera numerous mud flows issued and flowed down the north and west slopes. With this, the first volcanic activity came to an end. At the same time as the formation of the Tien-chih caldera, an explosion crater half its size was formed in its northern part, and filled with water to make a crater lake. This lake collapsed, however, before long, and its remains can be seen in the crater bottom near Chang-pai hot spring. This volcano is not only the highest mountain in Manchuria and Korea, but it has the biggest crater lake, the hottest spring, the highest waterfall and in comparable scenery.

All these features would certainly qualify it as an outstanding national park for Manchuria.

Table 8

	I	II	III			IV		V	VI
	1	2	3	4	5	6	7	8	9
SiO_2	50.43	61.68	64.42	64.78	65.04	64.89	67.84	70.95	49.05
TiO_2	2.90	0.65	0.55	0.50	0.40	0.40	0.35	0.30	3.19
Al_2O_3	15.18	17.36	16.26	15.00	16.66	15.42	15.27	12.23	14.35
Fe_2O_3	2.77	1.79	2.26	3.73	2.36	2.94	2.22	1.22	3.02
FeO	8.92	4.03	3.77	2.55	2.93	3.68	2.38	4.13	10.57
MnO	0.21	0.13	0.12	0.07	0.09	0.12	0.05	0.09	0.27
MgO	4.98	0.37	0.17	0.13	0.02	0.12	0.04	0.05	4.25
CaO	8.96	1.53	1.24	1.21	0.99	1.23	0.82	0.47	8.66
Na_2O	3.13	4.68	5.44	6.28	6.08	5.46	5.32	5.46	3.23
K_2O	1.52	5.10	4.74	4.90	4.88	4.74	5.02	4.60	1.40
P_2O_5	0.49	0.03	0.02	tr.	tr.	tr.	0	tr.	0.57
$+H_2O$	0.01	0.27	0.10	0	0	0	0	0	0.34
$-H_2O$	0.11	0.39	0.22	0.20	0.14	0.12	0.14	0.04	0.20
CO_2	0.29	1.80	0.28	0.40	0.16	0.58	0.22	0.36	0.73
Total	99.90	99.81	99.59	99.75	99.75	99.70	99.67	99.90	99.83

I. 1. Olivine-augite basalt: Shih-erh-tao-kou, Chang-pai Pref.
II. 2. Yellow augite-anorthoclase trachyte: Ma-an-shan, Chang-pai Pref.
III. 3. Fayalite-soda diopside-anorthoclase trachyte: Mo-tien-yu, Chang-pai-shan.
4. Fayalite-soda diopside-anorthoclase trachyte: near Chang-pai spring.
5. Anorthoclase-soda augite trachyte: south of Tseng-yen, Chang-pai-shan.
IV. 6. Alkali amphybole-fayalite-soda diopside-anorthoclase pantellerite: Tseng-yen.
7. Aegirine augite-soda diopside-anorthoclase pantellerite: Mo-tien-yu.
V. 8. Quartz pantellerite: Pai-yen, Chang-pai-shan.
VI. 9. Olivine basalt: Ta-yen-chih-feng, Chang-pai-shan.

7. Da-li-no-erh Volcano

This volcano is situated west of Dalinor Lake near the boundary of Jehol and Chahar Provinces. It consists of about 10 cones, standing on a basalt plateau, and

arranged along NE-SW fissure lines. These cones are truncated, about 100 m high, with craters on their summits. They are formed from volcanic ejecta, and reddish-brown bombs are scattered on the slopes. This volcano is not actually within Manchuria, but is described here for the sake of convenience.

8. Erh-ko-shan Volcano

Erh-ko-shan volcano lies in Ko-tung Prefecture, Lung-chiang Province, at Long. 126°18′ E. and Lat. 48°05′ N., southwest of Pei-an station. The writer, accompanied by the staff of the Ryojun College of Engineering, carried out a geological survey in the district in early April of 1936.

Topography

A hilly land, 300–360 m high stretches from Hai-lung—Pai-chuan to Pei-an—Wu-ta-lien-chi in northern Manchuria. Erh-ko-shan stands on this highland and consists of three cones with an average height of 120 m. The highland is formed of basalt, and the gentle slopes of Erh-ko-shan with their 1–2° inclination, are characteristic of a shield volcano. On this highland stand three truncated cones, Tung-shan, Hsi-shan and Hsiao-ko-shan. Measurements of the cones are given below. (Table 9).

Table 9

	Height above sea (m)	Relative height (m)	Diam. of base (m)	Diam. of crater (m)	Depth of crater (m)
Tung-shan	450	110	700	230	35
Hsi-shan	425	75	550	250	50
Hsiao-ko-shan	358	18	210	80	5

Tung-shan, situated in the southeast, is the largest of the three. The crater bottom is flat, and several buildings of a temple called Shenghsienkung are found there. Hsi-shan is 650 m northwest of Tung-shan, is very similar to it in form. The horseshoe shaped crater wall is broken in the northeastern part of Tung-shan and in the northwestern part of Hsi-shan. Hsiao-ko-shan is a low cone, standing 1,200 m southwest of Hsi-shan. The form of its crater is very imperfect.

These three cones were formed by the accumulation of ejecta in a brief eruption. Erosion is not very advanced, but gullies are developed on the slopes. There is no record of any eruption.

Geology

The foundation of the volcano is the Diluvial gravel and clay bed exposed in the southwestern part. The highland consists of basalt and is covered by surface soil over 10 m thick. The basalt is exposed along the valleys. It is dark gray, fine-

grained and porous rock and consists of microphenocrysts of olivine and leucite. The groundmass is composed of feldspar, augite, micaceous ilmenite, magnetite and biotite with glass. The rock is of the leucite-basanite type. The lower part of this lava flow is often represented by jet black, compact glassy rock which has less feldspar and more glass than the other rock. The cones are formed from fist-sized, porous, scoriaceous rock and agglomerate. These rocks are gray-brown or black, porous, and consist of olivine and leucite microphenocrysts, the groundmass being composed of anorthoclase, augite and glass. The presence of leucite is a characteristic feature of this volcano, as in the case of Wu-ta-lien-chi volcano. The plateau basalt and cone basanite are nearly the same in mineralogical composition and the difference in appearance is caused only by the mode of eruption. The chemical composition of these two rocks is shown in the following Table 10.

Table 10. Chemical Composition (%) of the Erh-ko-shan Rocks.

	1	2
SiO_2	51.12	50.99
TiO_2	2.45	2.48
Al_2O_3	13.76	14.19
Fe_2O_3	1.28	4.53
FeO	6.70	4.20
MnO	0.12	0.10
MgO	6.95	5.95
CaO	6.44	6.15
Na_2O	4.22	4.28
K_2O	5.61	5.23
P_2O_5	1.06	1.08
H_2O	0.49	0.98
Total	100.20	100.16

I. Plateau basalt: Ho-chia-tun, west foot of Erh-ko-shan.
II. Average composition of 3 lavas of 3 cones.

Conclusion

Erh-ko-shan consists of three cones standing prominently on the northern great plain of the Sung-hua-chiang. The rock constituting the volcano is leucite basanite, which is very rare in Manchuria. In this and other respects, this volcano provides a good subject for volcanic research.

9. Wu-ta-lien-chi Volcano

For centuries this volcano was known as Uyunhordongi, but the name changed to Wu-ta-lien-chi volcano after a joint expedition by the Ryojun College of Engineering and the South Manchuria Railway Company in 1935. The center of the volcano is situated at Long. 126°07′ E and Lat. 48°43′ N in Pei-hsiang, Te-tu Prefecture, Lung-chiang Province. Volcanic activity in 1720 produced two cones, Lao-hei-shan and Huo-shao-shan. So unique an event naturally made the name of this volcano familiar to the people of northern Manchuria.

Topography

The land in the district is undulating and hilly and 300–400 m above sea level. There are fourteen volcanic cones, two of which occur on the shih-lung lava field in the central part. The land is covered with shield volcanoes, over 100 m high, and with gentle slopes having a 1–2° gradient. These shield volcanoes consist of trachybasaltic lava. The shih-lung lava field has a racket outline with the handle to the south, and covers an area of 68 km². In spite of its very gentle slope, the lava field presents remarkable microtopographic aspects. Pahoehoe lava occupies the greater part, and block and spiny lavas are piled up on each other.

The shih-lung lava is a jet black obsidian-like glassy rock. The surface of the lava is variable in appearance, it may be smooth, striated, mounded reptilian, ropy, wavy, bark-like, etc. according to the state of consolidation. Puff cones, called hornitos have a conical shape and are 1–2 m high and 1 m in diameter,

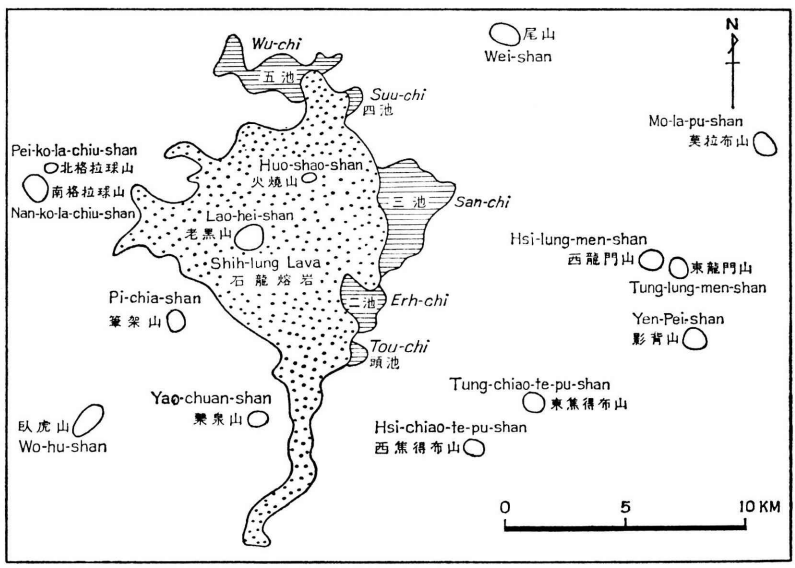

Fig. 4. Map Showing the Distribution of Cones in the Wu-ta-lien-chi Volcanic District.

with a hole on the top. These cones occur in two groups, and are a very unusual sight. There are also great crevices, depressions and lava tunnels in the shih-lung lava field (Fig. 4).

The shih-lung lava erupted from the central part of the lava field, flowed down in all directions, and dammed river waters, forming five connecting lakes along the north to east rim of the lava field. The lakes are Wu-chi, with an area of 6.5 km^2, Ssu-chi, 0.56 km^2 San-chi, 8.4 km^2 Erh-chi 2.8 km^2 and Tou-chi, 0.18 km^2 from north to south; the deepest is Erh-chi, with a maximum depth of 8 m.

At present, 14 volcanic cones are distributed throughout the volcanic region; seven are situated east of the Wu-ta-lien-chi lakes and the others west. Their measurements are given in the following table (Table 11).

The volcanoes stand mostly on the shield plateau. They are truncated cones, with a base diameter of 828 m and a relative height 100 m on the average. There

Table 11

Measurement / Name of cone	Height above sea (m)	Height of base (m)	Relat. height (m)	Volume (km^3)	Dia. of base (m)	Dia. of crater (m)	Depth of crater (m)
East side							
Wei-shan	518	415	103	0.021	800	320	41
Mo-la-pu-shan	524	417	107	0.026	900	240	44
Tung-lung-men-shan	578	440	138	0.046	950	445	108
Hsi-lung-men-shan	584	425	159	0.045	925	300	64
Yen-pei-shan	459	389	70	0.014	660	380	40
Tung-chiao-te-pu-shan	545	435	110	0.032	770	330	37
Hsi-chiao-te-pu-shan	482	387	95	0.012	670	230	27
West side							
Nan-ko-la-chiu-shan	602	487	115	0.056	100	470	50
Pei-ko-la-chiu-shan	543	506	37	0.001	500	230	—
Huo-shao-shan	393	320	73	0.015	670	415	63
Lao-hei-shan	516	350	166	0.100	1200	350	136
Pi-chia-shan	508	400	108	0.033	800	380	63
Wo-hu-shan	499	390	108	0.051	1200	350	36
Yao-chuan-shan	357	292	65	0.003	550	230	32

are 1–4 craters on the summit, with diameters of 330 m and a depth of 54 m on the average, and a slope of 28–32° on the sides. Parts of the crater walls are broken by explosion, except for Lao-hei-shan. In general, the craters keep their original forms without explosion or erosion.

The characteristic features of these 14 cones are given in detail in the following pages.

Wei-shan is situated in the northern part of the district. It stands on the shield plateau and has a typical homate form.

Mo-la-pu-shan is 11.7 km ESE of Wei-shan, and is similar to the former in shape. It has a crater on its summit 240 m in diameter. The bottom of the crater is flat and it turns into a lake in the rainy season.

Tung-lung-men-shan is 1 km away from Hsi-lung-men-shan. Both cones have elliptical craters and the mountains and neighboring district are covered with thick forest, favorite hideout for bandits in earlier days.

Yen-pei-shan is a comparatively small cone.

Tung-chiao-te-pu-shan is situated to the northeast of the district near Hsi-chiao-te-pu-shan. Both are typical cones. The craters are circular and flat on the bottom and that of the latter is shallow and flat, resembling an amphitheater.

Nan-ko-la-chiu-shan is in the northwest part of the district and is the highest cone in the area. Its crater, 470 m in diameter, is also the biggest; the bottom is flat, and forms a crater lake in the rainy season. A certain "reverse scaled" fish is said to inhabit the lake but we were unable to catch any on our expedition.

Pei-ko-la-chiu-shan is northeast of Nan-ko-la-chiu-shan. It is the smallest cone, in the distirct being 37 m in relative height.

Huo-shao-shan, together with another cone, Lao-hei-shan, is a relatively new cone on the shih-lung lava, but it is badly broken. The cone has an imperfect conical shape, 670 m in basal diameter, 73 m in relative height, and there is a great crater 415 m in diameter on the top. The top of the crater wall is uneven and several vertical crevices can be seen in the wall. Blocks of lava and scoria are piled against the inner and outer walls of the crater. The vegetation on this cone is less profuse than on other cones.

Lao-hei-shan is situated 4 km southwest of Huo-shao-shan and is often called Hsien-jen-shan. In the Ninguta Journal edited in 1721, the following description occurs: "There was a great eruption in the area 50 li northeast of Tsitsihar in June and July, 1720 and a mound was formed by ejected black rocks and sulphur. . . ." Judging from tradition, this statement corresponds to the eruption of Lao-hei-shan and Huo-shao-shan. Lao-hei-shan has the greatest relative height, depth of crater and volume of lava of the 14 cones. The diameter of its crater is half that of Mt. Fuji (600 m) but the volume of the mountain is 0.1 km^3 incomparably which is incomparably smaller than Mt. Fuji's. The crater wall is well preserved. There are three funnel-shaped craterlets about 10 m in diameter on the northern rim of the crater, and a round explosion crater, 80 m in diameter and 20 m in depth, on the ENE slope. On the northern slope, two great fissures can be seen, 300 m long

and 40 m wide. There seems to be a greater abundance of explosive phenomena in Lao-hei-shan and Huo-shao-shan than in other cones, and naturally the features of the mountains are more complicated. Volcanic lapillis and fusiform bombs are scattered around the slope near the foot.

Pi-chia-shan is 4 km southwest of Lao-hei-shan. The summit splits into three peaks. The bottom of the crater is triangular and flat, but the slope has been eroded and deep gulleys are present.

Wo-hu-shan is situated 4.5 km southwest of Pi-chia-shan. The basement is 1,400 m long, running northeast to southwest, and four cones with four craters unite to form this mountain. The southwest crater forms a shallow round amphitheater, 350 m in top diameter, the diameter of the bottom being 250 m and the depth 20 m. Three other craters lie together irregularly in the northeastern part.

Yao-chuan-shan is relatively near the town of Te-to, and many mountain climbers come here and stay at a small village called Chung-ling-ssu at its southern foot. The cone has a typical truncated shape and its crater is round and 230 m in diameter. On the flat bottom of the crater, five buddhist temple buildings were erected and a number of bronze statues were installed, but many of these statues were stolen in 1943.

The arrangement of these 14 cones is remarkably regular and oriented northeast-southwest and northwest-southeast. In the eastern district, Tung-lung-men-shan and Tung-chiao-te-pu-shan, and Mo-la-pu-shan, Hsi-lung-men-shan and Hsi-chiao-te-pu-shan sit on two parallel lines northeast to southwest, and Wei-shan, Hsi-lung-men-shan and Yen-pai-shan are on a straight line northwest to southeast. In the western district, Huo-shao-shan, Lao-hei-shan, Pi-chai-shan and Wo-hu-shan are arranged on a line northeast to southwest at 4 km intervals. Pei-ko-la-chiu-shan, Pi-chia-shan and Yao-chuan-shan lie on a line northwest to southeast. The tendency of volcanic cones to be arranged in such a manner can be observed in several places in Manchuria and is related to the tectonics of the district.

Geology

The basement of the volcanic district consists of granite sparingly cropping out in the northern and southern parts. Mesozoic clay, shale and sandstone are widely distributed in the northern central part, and Diluvial sand and gravel are developed in the northern, western and southern parts.

The greater part of the district is composed of basalt covering the basal rocks, the basalt is of two types, one forming hilly lands and the other shield volcanoes. The former basalt is gray to black anorthoclase-olivine trachybasalt and is generally fine-grained. The latter is reddish brown porous anorthoclase-olivine trachybasalt without macroscopic olivine.

The shih-lung lava in the central district is composed of black obsidian-like glassy rock, hard but very brittle. Components are mostly glass, over 80% in volume, and microphenocrystic and microlitic olivine and augite scattered in the

glass base. Quartz grains and granite blocks characteristically occur as xenolith in the rock. Anorthoclase and leucite microcrysts are also frequently observed. A chemical analysis of the shih-lung lava is shown below (Table 12-1). On the basis of its mineralogical and chemical composition the rock is a basic alkaline type called leucite-basanite, but the writer named it "shihlunite" for its unique characteristics. The leucite in this rock was first discovered in Manchuria. It is microphenocryst, 0.08 mm on the average and 0.15 mm in maximum size. Such leucite-bearing rock was found in other cones of the district as well as in other volcanoes such as the Erh-ko-shan volcano and other northern volcanoes.

Table 12. Chemical Composition (%) of the Wu-ta-lien-chi Rocks.

	1	2
SiO_2	52.7	50.76
TiO_2	1.9	2.38
Al_2O_3	14.5	14.37
Fe_2O_3	1.2	2.96
FeO	7.8	6.10
MnO	—	0.11
MgO	6.2	7.02
CaO	5.9	6.60
Na_2O	3.3	3.72
K_2O	5.2	4.76
P_2O_5	—	1.04
H_2O	—	0.51
Total	98.7	100.33

1. Shih-lung lava.
2. Average composition of 19 kinds of shield and cone rocks.

The lava of the twelve older cones, except for that of Lao-hei-shan and Huo-shao-shan, is generally reddish brown or black, compact or porous, and is represented by fist-sized scoria or lava flows. The lava is composed of olivine, augite and glass and sometimes leucite as well as anorthoclase. These rocks formed scoria cones in relatively small and brief eruptions.

The new cone lava which formed Lao-hei-shan and Huo-shao-shan is composed of black or brown porous scoria and lava flows. Many volcanic bombs are found.

The rock consists of a glass base in which olivine and augite microphenocrysts are scattered, it is similar to the older cone lava in character, but the new cones seem to be built by relatively severe eruptions and explosions.

The volcanic rock of the Wu-ta-lien-chi district is all alkaline basaltic. Depending on the time and mode of eruption, various topographical features—hilly highlands, shield volcanoes or cones and shihlung lava field—were formed, but from the point of view of mineralogical and chemical composition the lavas are very similar to each other, differing only in name according to the mode of eruption. The average chemical composition of 19 kinds of volcanics which formed shield volcanoes and cones in the district is shown on the Table 12-2.

Conclusion

The Wu-ta-lien-chi volcano is a dormant volcano which erupted in 1720 and which has characteristic leucite-containing rock. At present no post-volcanic activity can be seen in this district, but evidence of activity in the Kanhsi era remains at Lao-hei-shan and Huo-shao-shan. The many kinds of volcanic phenomena sculptured on the shih-lung lava field provide valuable natural monuments which cannot be observed even in so volcanic a country as Japan. Fourteen cones are arranged like stepping stones in the wilderness of the north Manchurian highland, clad in dense forest, and reflected in the waters of the Wu-ta-lien-chi lakes. Thus the district ranks high in terms both of natural beauty and scientific interest.

Chien-shan volcano

This volcano is situated on the southern side of the No-mo-erh-ho River, 35 km west of the prefectural town of Te-tu. It has a gentle conical shape and stands on the basalt shield volcano. Its height is 425 m above sea level and the relative height is about 100 m.

In the upper course of the No-mo-erh-ho River, east of Te-tu, is found the No-mo-erh volcano which consists of two cones, but no details about it are known.

10. Ko-lo Volcano

The Ko-lo volcanic group is situated near the village of Ko-lo-chan along the road from Nen-chiang (Mo-erh-ken) to Ai-hun on both sides of the Hsiao-hsing-an-ling Mts. and the cones are scattered over a distance of 30–50 km to the east of Mo-erh-ken. The cones are Tuan-tzu-shan, Ko-lo-nan-shan, Ta-i-shan, Hsiao-i-shan and Ta-hei-shan.

Tuan-tzu-shan is situated nearest to Mo-erh-ken, and is a big cone, 650 m above sea level and 200 m in relative height. Ko-lo-nan-shan is 6 km southeast of Ko-lo-chan, 550 m above sea level and 120 m in relative height. On the summit there is a crater and the crater wall is broken in the southern part. Ta-i-shan is 11.5 km northeast of Ko-lo-chan, 570 m above sea level. Hsiao-i-shan is 6 km northeast of Ta-i-shan, 610 m above sea level and 50 m in relative height, and the northeastern

part of its crater wall is broken. Ta-hei-shan is 9 km north of Ta-i-shan and 630 m above sea level. The depth of its crater is estimated at about 100 m. These cones can be clearly seen from the northern part of Wu-ta-lien-chi volcano.

Six km southeast of Ssu-chan, and 30 km northeast of the Ko-lo volcanic group, there is a rounded cone called Hsi-shan which is 750 m above sea level and 230 m in relative height. A cone is believed to exist in the upper course of the Tsao-lai-ho River, SSW of Ko-lo-chan.

All the cones mentioned above are arranged on a NE-SW line.

11. Ka-tsung Volcano

Along the road from Mo-erh-ken to Ai-hun, northeast of Ko-lo volcano, on the east side of the Hsiao-hsing-an-ling Mts. and 12 km north of Erh-chan, is the Ka-tsung volcano, consisting of 2 cones 150 m high. There is also a cinder cone west of San-chan, southwest of the Ka-tsung volcano. These 3 cones are arranged in NE-SW direction.

There is also a cone 100 m high on the right side of the Amur River, 40 km southeast of Ai-hun.

12. Kankuei Volcano

Kan-kuei volcano is 70 km northwest of Mo-erh-ken and 52 km northwest of Pa-yen-chieh, which is near the confluence point of the Kan-ho and the Kue-i-ho tributaries of the Nen-chiang River. There are four or five cones with relative heights of about 170 m. Details are not known.

13. Sha-tu Volcano

Sha-tu volcano is a collective name for eight cones situated 125 km northwest of Mo-erh-ken, and scattering for nearly 170 km along the far upper course of the No-min-ho, a tributary of the Nen-chiang. These cones are arranged in a NNW-SSE direction. Sha-ti-erh-shan and Tu-hu-lu-shan are the two principal cones. Sha-ti-erh-shan is in the northernmost part, on the left side of the No-min-ho, it is 686 m above sea level, and 100 m in relative height. On the summit there is a crater 400 m wide, the northwestern part of whose wall is broken. Tu-hu-lu-shan is 40 km south of Sha-ti-erh-shan, 10 km west of the No-min-ho, and 845 m above sea level; it is the highest cone of the 8. There are 3 cones on a line connecting Sha-ti-erh-shan and Tu-hu-lu-shan. The first cone is situated 15 km north of Tu-hu-lu-shan and is 300 m high; the second is 8 km north of the first and has a flat summit 300 m in diameter; and the third is north of the second, 250 m high, and has a flat elliptical summit. Two other cones stand on a line parallel to Sha-tu in the east. Its relative height is about 40–50 m. These 7 cones are truncated cinder cones. Another cone, 5 km west-north-west of Sha-ti-erh-shan, is 100 m in

relative height. It has a crater on the summit, 200 m in diameter and 50 m in depth, and there is a central cone within the crater. A double volcano of this sort is rarely seen in such a small cone.

14. Ha-r-hin-tun Volcano

This volcano was studied by Mr. Nobuo KIYONO. It is located on the east side of Ha-lun-erh-shan hot spring, in the central Ta-hsing-an-ling Mts. The volcano is a mountainous mass with a base 1,000 m in diameter and a summit consisting of several peaks. The summit is about 200 m above the river floor of Ha-lun-erh-shan plain. There are two central cones within the crater, to the north and south, and the southern one contacts the somma. The volcano is formed from quartz trachyte intercalated with tuff and obsidian, and thus differs from other volcanoes. It apparently has some genetic relation to the Ha-lun-erh-shan hot spring. This hot spring issues from 44 points within a distance of 700 m in a N-S direction. Its maximum temperature is 45° C, and there are 6 springs which maintain a temperature over 40° C. These springs are simple or carburetted types.

15. O-ne-nor Volcano

East of the Ta-hsing-an-ling Mts. and about 100 km north of So-lun along the upper course of the Cho-erh-ho, there is a lake called O-ne-nor, in a liparite area. Its diameter is 2 km, but the lake proper is crescent-shaped. The lake is surrounded by 250–300 m heights inclining at a 40° angle toward the lake. The lake water pours out through a break in the heights and originates the upper course of the Cho-erh-ho River. Judging from the topography of the environs this is a crater lake and the heights are the crater walls composed of liparite.

16. Along the Sung-hua-chiang

Along the right side of the Sung-hua-chiang from I-lan, in San-chiang Province to Fu-chin via Chia-mu-ssu, there are four basaltic domes, one of which reaches a height of 100 m. Two of the domes are in a NE-SW direction.

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Copper-bearing Contact Deposits of Hua-tung-kou, Fu Hsien, Feng-tien Province, Manchuria

Kamezo MATSUDA

1. Introduction

It is said that a gold placer mine at Hua-tung-kou was first worked about 700 years ago. However, there are no details on mining in this area until 1935. At this time, a Japanese textile manufacturer, Giheita HITOMI of Feng-tien tried to obtain low phosphorous pig iron from the ore of the Hua-tung-kou mine, using a small blast furnace and charcoal, after failing to operate a gold placer deposit there.

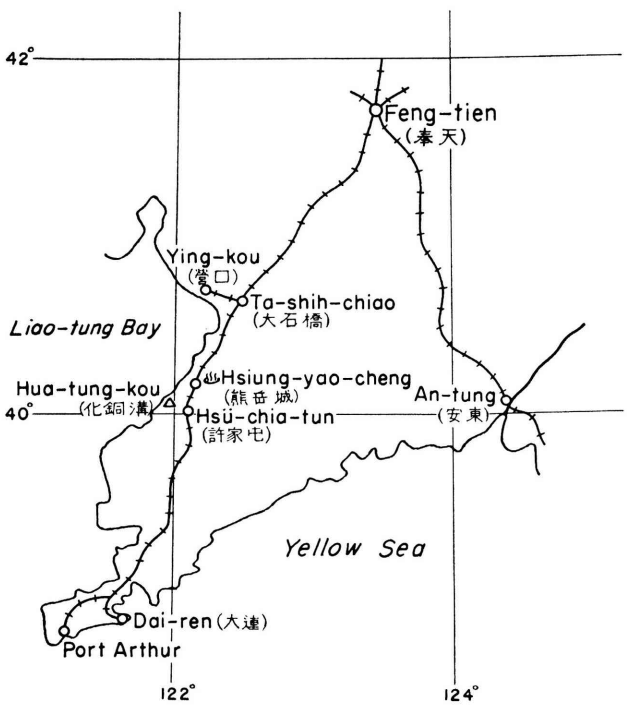

Fig. 1. Index Map of the Hua-tung-kou Deposit Fu-hsien, Feng-tien Prov.

In 1941 when HITOMI gave up the iron business and began exploration for copper ore, the present author surveyed the mine area and published a preliminary report[3] on the mode of occurrence of ludwigite. This borate mineral was found for the first time as one of the skarn minerals in the contact zone at this mine.

Based on this report, Masao ISHIBASHI carried out a detailed survey of the contact deposits in August 1942 and published two reports.[1,2] At the time of the investigation by the present author, the average grade of the copper ore of this mine was about 0.6% Cu, but as exploration proceeded it was found that the ore reserves were unexpectedly large, so that the Manchurian Mining Development Company decided to exploit the contact deposits under the name of the Hua-tung Mine in September 1942.

In 1944, the author carried out a more detailed investigation of the deposits. This paper is a report on that investigation, supplemented by ISHIBASHI's reports with his approval.

2. Location of the Mine

The Hua-tung Mine is located 15 km west of Hsu-chia-tun Station, which is 15 km south of Hsiung-yao-cheng Station on the railway between Dairen (Talien) and Feng-tien. The road between Hsu-chia-tun and the mine is good enough for trucks to transport concentrate and goods.

3. Geology

The basement of the mine area is composed of Pre-Cambrian sedimentary rocks intruded by granodiorite. Along the contact between the two, thermally metamorphosed rocks containing contact deposits accompanied by skarns are found. Gold placer deposits occur in alluvial sediment along the streams, and were worked in the past.

A. Sedimentary rock

Sedimentary rocks consist of dolomite and hornblende schist of pre-Sinian age, and Sinian quartzite unconformably covering the former.

Dolomite occupies the lowermost layer of the sedimentary rock, and grades upward into hornblende schist. Its lower limit can not be determined because of intruding granodiorite. An average of four analyses[4] shows that the dolomite contains 29 to 30% CaO and 18 to 21% MgO. The rock is partially altered to hornfels where the facies is sandy or argillaceous. The thickness of the dolomite is 380 m or more, and it is assigned to the Ta-shi-chiao series of the Liao-ho system according to Rinji SAITO.[5]

The hornblende schist occurs as a monoclinal formation dipping to the north. At Pei-tai-shan, it is covered by quartzite. Lithologically it is a green hornblende-oligoclase schist, locally intercalated with thin lenticular limestone. Although its

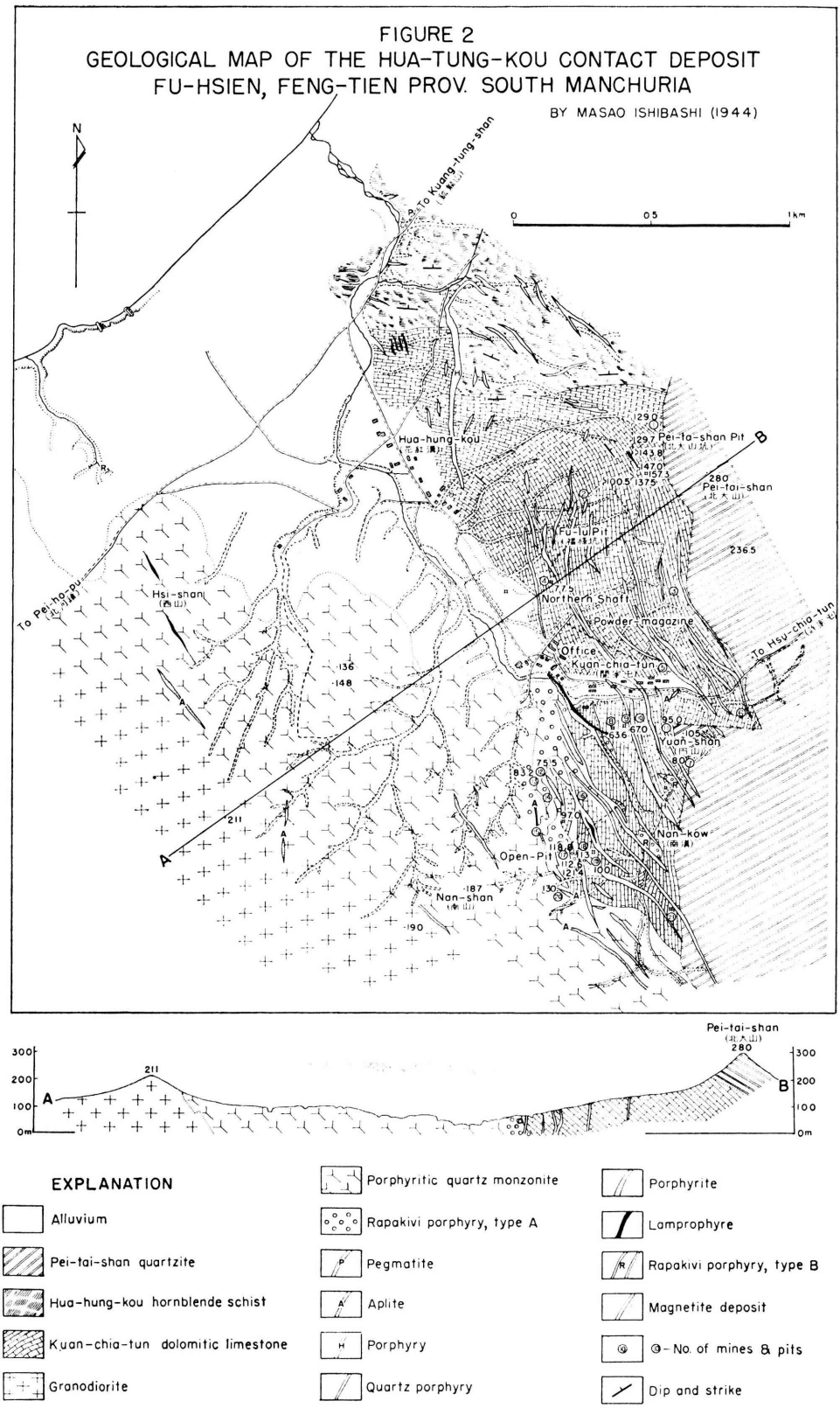
FIGURE 2
GEOLOGICAL MAP OF THE HUA-TUNG-KOU CONTACT DEPOSIT
FU-HSIEN, FENG-TIEN PROV. SOUTH MANCHURIA
BY MASAO ISHIBASHI (1944)
N
To Kuang-tung-shan
0 0.5 1km
Hua-hung-kou
Pei-ta-shan Pit
Pei-tai-shan
Fu-lu Pit
Hsi-shan
To Pei-ho-pu
Northern Shaft
Powder magazine
Office
Kuan-chia-tun
To Hsu-chia-tun
Kuan-shan
Nan-kow
Open-Pit
Nan-shan
A
B
Pei-tai-shan
EXPLANATION
Alluvium
Pei-tai-shan quartzite
Hua-hung-kou hornblende schist
Kuan-chia-tun dolomitic limestone
Granodiorite
Porphyritic quartz monzonite
Rapakivi porphyry, type A
Pegmatite
Aplite
Porphyry
Quartz porphyry
Porphyrite
Lamprophyre
Rapakivi porphyry, type B
Magnetite deposit
No. of mines & pits
Dip and strike

Fig. 2

upper limit cannot be determined, the thickness of the schist must exceed 400 m.

The Sinian quarzite consists of light brown to grey-white quartzite in the lower part, and reddish-purple sandstone, intercalated with fine-grained conglomerate, in the upper part. The Sinian quartzite is thought to correspond to the Yungning sandstone that is well developed in the vicinity of Fu-chou.[5] The thickness exceeds 600 m, and the age is Upper Sinian.

B. Igneous rocks[2]

The granodiorite constituting Mt. Nan-shan is a stock which intrudes the dolomite. From the stock, numerous small dikes branch off. The granodiorite,* where it comes in contact with the dolomite, has changed into porphyritic quartz monzonite, part of which forms lingulate dikes having a rapakivi texture. There is no conclusive evidence available on the age of the granodiorite, but it is certain at least that intrusion took place after the Sinian quartzite had been deposited. Since the rock is characteristically alkalic, similar to Chien-shan granite, and shows no cataclastic effects, it is most likely that intrusion occurred during the Mesozoic era. Many of the dikes are highly acidic, and are distributed roughly parallel to the edge of the stock.

a. Granodiorite

The rock has a dosemic microporphyritic texture. The principal constituents are plagioclase (An_{40} in the core and An_{10} around the edge), microperthite, quartz, biotite and hornblende, with such accessory minerals as apatite, zircon, allanite, titanite and iron ore. The chemical composition (%) is as follows (analyst, Hiroshi HAMAGUCHI):

SiO_2, 69.58; TiO, 0.43; Al_2O_3, 15.07; Fe_2O_3, 0.74; FeO, 2.49; MgO, 1.09; CaO, 2.20; Na_2O, 3.70; K_2O, 4.52; P_2O_5, 0.24; H_2O, 0.33; total 100.39.

b. Porphyritic quartz monzonite

The rock is characterized by thick tabular phenocrysts of microperthite, 1 to 2 cm in diameter, which amount to about 15 crystals per 10 cm^2. The part in contact with the dolomite and lingulate portions of dikes are found to grade into rapakivi porphyry having phenocrysts mantled with oligoclase. The texture of the monzonite is dopatic porphyritic and the principal constituents are orthoclase, plagioclase (An_{34} in the core, An_{16} around the edge), quartz, green hornblende and biotite; accessory minerals are titanite, apatite, allanite, augite, zircon, etc. The chemical composition (%) is as follows:

SiO_2, 68.19; TiO_2, 0.41; Al_2O_3, 16.02; Fe_2O_3, 1.34; FeO, 1.07; MgO, 1.11; CaO, 4.10; Na_2O, 3.85; K_2O, 4.67; P_2O_3, 0.22; H_2O, 0.22; total 101.20.

c. Rapakivi porphyry (type A)*

* The author found biotite granite at a quarry of Pei-ho-pu on the west slope of Nan-shan. However, due to the lack of microscopic data, the author refers to ISHIBASHI's reports for a description of the igneous rocks.

* A description of Type B of rapakivi porphyry is omitted in this paper. Type B refers to a rock containing rapakivi feldspars of a schlieren form. This type is usually found in dikes separate from the stock, but on rare occasions it occurs even in the stock.

In chemical composition, the rapakivi porphyry (type A) is similar to the rapakivi rock reported from Viborg by HACKMAN (1905). However, the rapakivi feldspars contained therein are rather small and have a thick tabular form, differing from the ovoid form of the North Europe specimen. Under the microscope, the orthoclase that previously crystallized out seems to have been gradually replaced by oligoclase as a mantle. The texture of the rock is sempatic porphyritic, and the groundmass contains myrmekite. The oligoclase mantle of megascopic phenocrysts of rapakivi feldspars shows a zonal structure with An_{40} in the core and An_{21} around the edge. Microscopic phenocrysts are plagioclase (An_{40} in the core, An_{21} around the edge), biotite, quartz and green hornblende. The chemical composition(%) is as follows:

SiO_2, 66.36; TiO_2, 0.94; Al_2O_3, 14.91; Fe_2O_3, 1.48; FeO, 2.64; MgO, 1.96; CaO, 3.40; Na_2O, 4.01; K_2O, 4.40; P_2O_5, 0.58; H_2O, 0.20; total 100.88.

d. Dike rocks

They are divided into five groups. Only the rock species will be given.

i. Pegmatite (tourmaline pegmatite)
ii. Aplites (quartz monzonitic, adamelitic, potash alaskitic, salite monzonosyenitic, augite syenitic, etc.)
iii. Rapakivi porphyry (Type B)
iv. Porphyry and quartz-bearing porphyrite
v. Porphyrites

C. Contact-metamorphosed rocks

There are two kinds of contact-metamorphosed rocks; one consists of hornfelses which were formed under thermal metamorphism without the introduction of any external material, and the other of skarns which are the product of replacement by various components supplied from magma to the thermally metamorphosed rocks.

a. Hornfels

Thermal metamorphism of dolomite gave rise to the formation of hornfels of various kinds according to the composition of the original rock. Contact minerals formed in the thermal metamorphism are tremolite, forsterite, diopside, etc. Of the ten standard minerals proposed by BOWEN* as products of thermal metamorphism, higher temperature types, such as periclase and wollastonite, are absent. From the composition and structure, the hornfels can be classified into the following five types:[2)]

(i) Massive calc-hornfels

The principal constituents of massive calc-hornfels are calcite and dolomite, with subordinate forsterite, phlogopite, diopside, titanite, apatite and iron ore. Part of the calcite was newly produced by dedolomitization.[2)]

* BOWEN, N. L. (1940): Progressive metamorphism of siliceous limestone and dolomite; *Jour. Geol.*

(ii) Banded calc-hornfels

Has a banded structure, with bands several millimeters to several centimeters wide, consisting of biotite, forsterite-calcite and dolomite-calcite-diopside. When affected by mineralizing solutions, these bands would change into leuchtenbergite band, humite and magnetite-sulphide bands.

(iii) Andalusite-cordierite hornfels*

Found in the hanging wall at the 118.8 m level in the northern corner of the Nan-shan pit. It is an grey-white compact rock with rose-colored spots. The main constituents are quartz, phlogopite, andalusite, cordierite and feldspar, with tourmaline, zircon and sillimanite as accessory minerals.

(iv) Diopside-anorthite hornfels

At the above 118.8 m level, this hornfels occurs in contact with porphyritic quartz monzonite, and forms the footwall of the andalusite-cordierite hornfels. This is a greenish-gray compact rock. Anorthite ($An_{85\sim90}$), one of the major constituents, is densely commingled with diopside. Subordinate constituents are hastingsite, garnet, epidote, zoistie and calcite.

(v) Hornblende-biotite-quartz hornfels

This hornfels is exposed in a cliff northwest of Nan-shan. Quartz, feldspar and biotite are the major constituents. Subordinate minerals are hornblende, apatite and sericite. Sometimes hornblende is found in a Garbenschiefer form.

b. Skarns

Thermally metamorphosed rocks are partially replaced by skarn minerals along the zone of contact with granodiorite.[2] There are the following kinds of skarn:

(i) Tremolite skarn. Found in the north shaft and certain other places. Small amounts of diopside and calcite accompany tremolite.

(ii) Actinolite skarn. Occurs as small lenses in the phlogoite-diopside skarn of the new adit of Nan-shan.

(iii) Diopside skarn. Widely exposed in the north shaft. Beside diopside, it contains small amounts of actionolite, calcite and quartz, occasionally accompanied by aggregates of small crystals of allanite.*

(iv) Phlogopite-diopside skarn. Found at Nan-kou and in the new adit of Nan-shan. It consists of green phlogopite and cream-yellow diopside.

(v) Garnet-diopside skarn. Found in the Nan-shan pit and the new Nan-shan adit.

(vi) Garnet-hornblende skarn. Found in the new Nan-shan adit. It is accom-

* Discovered by ISHIBASHI. According to him, the optical properties of the andalusite are as follows: Index of refraction $\alpha=1.629$, $\beta=1.635$, $\gamma=1.640$, $(-)2V=84°$; pleochroism X=light brownish-red, Y=Z=colorless, absorption X>Y=Z.

* Optical properties of allanite, according to ISHIBASHI, are as follows: $(-)$ $2V=70°$, $CZ=47°$, pleochroism X=greenish-brown, Y=brown, Z=reddish-brown. MATSUDA selected some allanite crystals and had them analyzed by Den-ichi NAITO; this revealed that the allanite contained 44.2% Ce_2O_3.

panied by green hornblende, and occasionally contains small lumps of hastingsite and epidote.

(vii) Scapolite-fels.* This is a loose, greenish-gray rock occurring in the hanging wall of the andalusite-cordierite hornfels mentioned previously. It contains small amounts of apatite and titanite.

(viii) Ludwigite-fels.[3] The ludwigite-fels, when weathered, looks like a limonite gossan. It was once mined as an iron ore for a blast furnace at Nan-shan. When fresh, the rock contains stringers of chondrodite, clinohumite and szaibelyite, in addition to a small amount of magnetite. It was found only in the new adit and the open pit of Nan-shan and the Seaside pit. MATSUDA picked up ludwigite crystals under a binocular magnifier and had them analyzed by D. NAITO; the result was as follows (%): SiO_2, 1.62; Al_2O_3, 2.36; Fe_2O_3, 32.02; FeO, 13.22; MnO, 0.11; MgO, 31.55; CaO, 0.31; B_2O_3, 15.52. Black acicular crystals showed a strong magnetism.

4. Ore Deposits

The ore deposits are typical contact deposits. The dolomite, after being thermally metamorphosed by intrusion of the granodiorite, was replaced by skarn zones along the intrusive contact zone, resulting in the formation of ore deposits. It is probable that the mineralization continued throughout, that is, starting with the pegmatite intrusion the country rocks underwent pneumatolysis, replacement by skarn zones, carbonatization and chloritization, succeeded by the precipitation of metallic sulphides in a hydrothermal solution. However, such continual processes of mineralization are not found in individual deposits. This may be attributable to the scope of magmatic differentiation. For the formations of ore deposits, the most important factor is the relation between mineralization and geologic structure, especially the fissure system in which ore minerals would be deposited. It is regretted that any conclusive comments cannot be given here, due to the lack of exploration data. The author believes that in an early stage of mineralization, boron and part of the iron were introduced by the action of pneumatolysis, but the absence of other pneumatolytic minerals (such haloids as fluorite) suggests that the pneumatolysis was of a small scale. Skarnization is represented by diopside, in association with allanite, scheelite, bismuthic minerals, molybdenite, etc. The sulphides in the high-grade copper ore replacing skarn minerals in irregular form are thought to have been produced in the hydrothermal stage.

A. Distribution of ore deposits

Ore deposits are found in the dolomite, within a 500 m wide area, along the zone of contact with granodiorite. Ores are scattered in the skarn zones. The maximum length of ore bodies is several tens of meters. Major ore bodies are those

* According to ISHIBASHI, the optical properties of the scapolite are $(-)\omega=1.554$ and $\varepsilon=1.542$, which suggest that the mineral is connected with dipyrie.

of Nan-kou, Nan-shan open pit, Nan-shan new adit, north shaft and Seaside pit, from north to south, with a total extension of 2 km. Borate minerals are found in the Nan-shan open pit and new adit and in the Seaside pit. Exploration for copper ore was carried out in the north shaft.

B. Ore deposits of the north shaft

Deposits consist chiefly of diopside skarn impregnated with metallic minerals. The skarn was also affected by hydrothermal alteration, resulting in the formation of vein-like bodies of sulphide ore containing more than 3% Cu. The metallic minerals in the impregnated portion are mostly magnetite, accompanied by subordinate amounts of gold, bismuth, bismuthinite, tetradymite,[2] molybdenite, scheelite* and chalcopyrite; those in the vein-like bodies are chalcopyrite, pyrrhotite and pyrite.

C. Mode of occurrence of some metallic minerals

The mode of occurrence of some of the metallic minerals is excerpted here from ISHIBASHI's report.

a. Bismuthic minerals

Native bismuth always occurs in association with bismuthinite, showing an eutectic relation. Chalcopyrite and pyrrhotite are found as inclusions in the native bismuth. Tetradymite occurs as inclusions in the bismuthinite. Native gold, that can be obtained by panning, is thought to have a close relationship to the bismuthic minerals.

b. Chalcopyrite

Almost always accompanied by pyrrhotite, and contains some zincblende stars, cubanite and valleriite.

c. Pyrrhotite

Occasionally occurs as small irregular particles included in zincblende. In the oxidized zone it changes into marcasite and pyrite, presenting a bird's eye structure.

5. Some Genetical Considerations

The ore deposits at Hua-tung-kou are typical contact deposits which occur along the zone of contact between the Precambrian dolomite and granodiorite. The dolomite was thermally metamorphosed by intrusion of the granodiorite and altered to hornfels of various kinds. These hornfels have undergone a series of mineralizing actions, starting with pegmatite intrusion, going through formation of skarns in association with pneumatolysis and ending with the deposition of sulphide ores by a hydrothermal process.* Worth special mention is the impregna-

* Hand-picked concentrate showed 0.93% WO_3.

* Minerals newly formed from the time of granodiorite intrusion to the end of mineralization amount to about 50 species.

tion of borates, allanite, scheelite, molybdenite and bismuthic minerals, in association with the formation of skarns. It is an important fact that molybdenite is a common mineral in the contact deposits in South Manchuria, as exemplified by the Hua-tung-kou mine. It gives a clue to the study of the metallogenetic epoch and petrographic provinces of Manchuria, as well as for the future prospecting of ore deposits.

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CHINA

Banded Magnetite Ore Deposits and Metamorphic Rocks in the Vicinity of Yen-tou-tsun, Wu-tai-shan, Shan-hsi Province, China (with Appendix on Hematite Ore Deposits in the Vicinity of Ting-hsiang and Tung-yeh-chen)

Shuichi IWAO

Introduction

From May to June 1952, the author, as a member of the First Scientific Expedition to Shan-hsi, had an opportunity to visit and observe banded iron ore deposits of the Pre-Cambrian metamorphic system in the Wu-tai-shan region, Shan-hsi Province, China.

The route of travel began in Tai-yuan, passing through Tai-chou, Fan-chih-hsien, Yen-tou-tsun, Cha-pu, Chu-lin-ssu, Tai-huai-chen, Wang-hai-feng, Shih-tzu-ping, Cha-fang-tzu, Shih-hui-li, Sha-ho-chen, Ho-pien-tsun, Tung-yen-chen, Kuo-chia-chai, and ended at Ting-hsiang.

The present paper summarizes the results of the author's observations chiefly along the above route, as well as the oral statements of Dr. S. MATSUSHITA of Kyoto University, Prof. T. ISHIKAWA of Hokkaido University and Mr. Kamezo MATSUDA of the Geological Institute, South Manchuria Railway Company, who took different routes of survey. Critical comments were given by Dr. T. TOMITA of Pei-ping University. The author's study was immeasurably assisted by the amazingly attentive field observations of Mr. Kenkichi MASUBUCHI of the South Manchuria Railway Co., who shared the joys and sorrows of the trip. To these people, the author expressed his hearty thanks.

Rock specimens collected during the expedition were lost by fire during the war, but about two hundred and fifty thin sections of rocks have fortunately remained with the author. It is a matter of regret, however, that the optical and chemical properties could not be determined due to loss of the specimens.

1. Gneissic Rocks found between Kuan-ti-tsun and Fan-chih-hsien

About 10 km west of Fan-chih-hsien, a tributary branches off the Hu-to Ho

toward the southeast. Along this tributary a group of gneissic rocks is exposed for about 10 km upstream as far as the village of Kuan-ti-tsun.

The gneissic complex was formerly called the Taishan gneiss by WILLIS and BLACKWELDER,[1] and the Sangkan gneiss by Kieh YANG.[2] On the southeast side of Kuan-ti-tsun, this gneissic complex is thrust upon the Wutai crystalline schists.

Away from the thrust fault, the gneissic rocks are poor in basic schlieren and characterized by microcline, while nearer the thrust fault they are tonalitic and rich in schlieren. This fact suggests that the varied rock facies of the gneiss is due to an assimilation of amphibole schist by granitic magma, and that the scarcity of microcline in granitic dikes penetrating either amphibolite or other basic schists of the Wutai system does not mean that microcline was originally absent in the intruded magma.

Microcline granitic gneiss

The rock is gneissose, exfoliates along an E-W or N 70–80°E direction, is either coarse- or medium-grained, and void of cataclastic texture.

(a) Main constituent minerals: Quartz, microcline, oligoclase, dark greenish-brown biotite.

(b) Accessory minerals:— Zircon, apatite, muscovite.

Microcline, partly filling the interstices of quartz crystals, occasionally has a fine lattice structure. It is usually surrounded by a myrmekitic zone between oligoclase.

Xenolith of amphibole schist in tonalitic gneiss

Basic xenoliths are elongated sub-parallel to the schistosity of the tonalitic gneiss, and vary in color according to the amount of amphibole present.

(a) Main constituent minerals:—Green hornblende, brown biotite, basic plagioclase.

(b) Accompanying minerals:—Titanite, epidote, garnet. The epidote is always ferriferous near the edge.

Xenolith of biotite schist in microcline granitic gneiss

The rock resembles the biotite schist of the Ryōke metamorphics of Japan.

(a) Main constituent minerals:—Quartz, oligoclase, microcline (variable in amount), dark-brownish biotite (sometimes associated with newly formed muscovite)

(b) Additional constituents:—Zircon, apatite and myrmekite, the mode of occurrence of which is the same as in the gneiss.

The gneiss, from the viewpoint of petrographic features, is characterized by microcline and may correspond to the Taishan granite of TOMITA.[3] That the gneiss becomes more tonalitic to the south indicates the possiblility of lit-par-lit injection of granitic magma into the basic schists of the Wutai system, giving the latter the effect of contact-metamorphism. It also supports the idea that the banded

iron ore near Yen-tou-tsun belongs to the Shihtsui system, and also supports TOMITA's view that the Taishan granite is younger than the Shihtsui system.

2. Granitic Gneiss in the Vicinity of Shih-tzu-ping

The granitic gneiss in the vicinity of Shih-tzu-ping has hitherto been correlated with the granitic gneiss near Fan-chih-hsien, but they are quite different in petrographic features.

The gneiss is characterized by fine lamellae of albite twins as well as by inclusions of small sericite flakes arranged with a definite orientation. The granitic gneiss near Fan-chih-hsien is characterized by microcline.

The gneiss is also characterized by albite and dark green biotite. These characteristic features are not attributed to contamination of plagioclase granite magma by amphibolite or by biotite schist, but to the initial variance of the original magma. The rocks are void of cataclastic texture.

3. Crystalline Schist of the Wutai System—Wall Rock of the Iron Ore Near Yen-tou-tsun

Extending southward from the thrust fault of Kuan-ti-tsun to the Yen-tou-tsun area, Pre-Cambrian metamorphic rocks belonging to the so-called Wutai system are found, non-uniformly covered by Mantou shale.

These metamorphic rocks constitute the wall rock of the banded iron ore deposits and correspond to the Wutai gneiss of WILLIS and BLACKWELDER, and the gneiss of the Taihuai series of the Wutai system of YANG. TOMITA suggested that these rocks may include rocks of the Shihtsui system.

On the basis of field observations and petrographic evidence, it may be safely said that the microcline gneiss is younger than the deposition of the original metamorphic rocks near Yen-tou-tsun.

The Hsitai system near Tai-huai-chen may be younger than the deposition of the banded iron ore deposit near Yen-tou-tsun, because the system contains pebbles of banded magnetite ore.[4] It may be also younger than the microcline gneiss.

A. *Kind and origin of the metamorphic rocks*

The constituent minerals, textures and original rocks of the crystalline schists and related metamorphics near Yen-tou-tsun are listed below.

B. *Textures and mineral compositions of the metamorphics*

1) Metamorphic rocks of basic or intermediate intrusive origin

The rocks partly retain the original texture and original minerals such as augite, brown hornblende and oligoclase, giving rise to pseudomorphs consisting of bluish-green hornblende and albite. Bluish-green hornblende is usually deeper in color near the periphery, and albite is clouded by epidote crystals. Epidote is

Table 1

Kind	Original rocks	Metamorphic equivalents
Igenous rocks	Ultrabasic rocks	Serpentine, amphibolite
	Basic and intermediate intrusives	Meta-diorite, meta-diabase, schistose meta-diabase, chlorite-biotite-actinolite schist, biotite schist
	Basic lavas and tuffs	Meta-dolerite, chlorite-actinolite schist, chlorite-epidote-actinolite schist, biotite-epidote-actinolite schist, biotite-actinolite schist, actinolite schist
	Intermediate lavas and tuffs	Feldspathic chlorite schist, epidote-chlorite-sericite schist
	Basic igneous rocks or alumino-calc-magnesian rocks	Sericite amphibolite, chlorite amphibolite, biotite amphibolite, cummingtonite-bearing amphibolite, garnet amphibolite
Pyroclastics	Sandstone	Schistose grit, sericite schistose grit
Chemically precipitated sediments	Aluminous shale	Biotite schist, garnet-biotite schist, two-mica schist, kyanite-staurolite schist, garnet-kyanite-staurolite schist, chlorite-epidote-mica schist
Chemically precipitated sediments	Aluminous or alumino-siliceous sediments containing carbonate minerals	Sericite-quartz schistose marble, two-mica schistose marble, biotite schistose marble, chlorite-quartz schistose marble
	Banded chemical sediments, consisting of Fe-, Mg- or Ca-carbonates, hematite, silica, etc.	Banded magnetite ores

usually more ferriferous toward the core.

They contain either cholorite, sericite or quartz as a principal constituent, and titanite or apatite as an accompanying mineral.

In some cases they are remarkably schistose, grading into crystalline schist.

2) Crystalline schists derived from basic lavas and tuffs

Crystalline schists derived from basic lavas and tuffs closely resemble the schistose varieties of the above rocks, but differ in the respect that traces of the original fluidity or porphyritic texture of lava are preserved in the large porphyroblasts of either actinolite or blue hornblende metamorphosed from augite.

The mineral composition is almost the same as the rocks mentioned in 1, but the parts where the degree of metamorphism was high are accompanied by garnet

and are often penetrated by veinlets of either quartz or calcite. In places, brown or green biotite occurs, partly chloritizing the rock.

The rocks are also hardly distinguishable from hornblende schist derived from aluminous or dolomitic rocks, but those which are extremely rich in calcite are excluded from the group under consideration.

3) Schistose grit

The texture of original sandstone is well preserved in the large porphyroblasts of albite. The porphyroblasts are pseudomorphs of original feldspar. It sometimes happens that recrystallized quartz retains its initial outline. In the albite, minute flakes of sericite and small grains of zoisite are occasionally found. Biotite, which is sometimes associated with large plates of sericite, is brown and often partly altered to chlorite. Apatite, calcite and tourmalines (bluish-green) are found as additional constituents.

4) Crystalline schist derived from argillaceous shale

There are two groups of mica schists, one characterized by a simple combination of mica, chlorite and feldspar, and the other by kyanite-staurolite association.

Biotite is light reddish-brown or green, and partly altered to chlorite. Sericite is occasionally associated with biotite, or is an alteration product of feldspar. The feldspar belongs to the oligoclase class, and twinned is commonly after the albite law. Quartz is also one of the principal constituents. Epidote, calcite, chlorite, apatite and bluish-green tourmaline are the most common accessory minerals. Epidote is ferriferous in the core.

Kyanite-staurolite mica schist is found 50 to 60 meters from the village of Kuanti-tsun, and occurs as part of the mica schist found on the east side of the thrust fault which bounds the southern margin of the granitic gneiss. Crystals of kyanite and staurolite are about 0.5–2 mm in length, and are surrounded by light reddish-brown biotite. The rock is often penetrated by kyanite-staurolite-quartz veins.

Although the occurrence of staurolite in metamorphic rocks of the Wu-tai region was reported[5] previously, this is the first discovery of kyanite in North China. The association of kyanite with staurolite is also noteworthy.

5) Schistose marble

What is called "schistose marble" here is characterized by a rather high content of carbonate which, under a microscope, is found to occur as thin bands intercalated within layers of mica, chlorite and quartz. Actinolite is rather common, while diopside, garnet, epidote and other skarn minerals are rare.

Carbonate minerals consist of calcite and ankerite.

6) Banded iron ore

Quartz, magnetite, hematite, calcite, ankerite and biotite are common constituents of banded iron ore. A stilpnomelane-like mineral, anthophyllite and sericite are also found.

C. *Grade of metamorphism*

Excluding kyanite-staurolite mica schist, most metamorphic rocks are charac-

terized by either actinolite or actinolitic amphibole, and show actinolite schist facies.

From the manner of zoning of epidote and amphibole, which are ferriferous at the core in the former and toward the edge in the latter, the metamorphism is thought to be progressive. However, superposition of hydrothermal alteration such as partial chloritization of biotite and the partial forming of sericite flakes along feldspar crystals suggest a retrogressive hydrothermal metamorphism.

Although it is very difficult to find the cause and age of such retrogressive metamorphism, it is specially noticed that crystalline schist and gneiss near Shih-tzu-ping are also characterized by fine flakes of sericite scattered in feldspar crystals, and also by epidote which is rich in iron along the exterior of crystals. A probable case is that the intrusion of microcline gneiss near Fan-chih, Tai-hsien caused a progressive metamorphism while the gneissose rocks gave retrogressive effects.

Kyanite and staurolite, which were previously regarded as "stress" minerals, are found to occur as large crystals along the walls of quartz veins which run subparallel to the schistosity of the wall rock kyanite-staurolite schist. This fact suggests that the application of the "stress" mineral idea is unnecessary. The author agrees with YAMAGUCHI,[6] READ[7] and MIYASHIRO,[8,9] who reject the "stress" environment in the forming of kyanite.

D. *Relationships among various metamorphic rocks*

Igneous rocks, which are thought to be the source of, or to have an intimate relation to, metamorphic rocks, are listed below.

Microcline gneiss (so-called "Taishan" gneiss of Fan-chih-hsien)

Basic to intermediate intrusives
Basic to intermediate lavas or tuffs
Quartz veins

Occupying the greater portion of the original rocks of the so-called Wutai crystalline schist near Yen-tou-tsun

It may be of great importance to investigate the mutual relations among these igneous rocks and to study the history of metamorphism.

The relationship of microcline gneiss to the Wutai crystalline schist was already mentioned.

Basic or intermediate intrusive rocks, from the fact that they discordantly intrude adjacent metamorphic rocks, may be younger than the deposition of the volcanic rocks described below. They are also partly younger than the original sediments of the banded iron ore deposits, since they cut across the ores.

It seems most probable that these rocks intruded nearly simultaneously with the original rocks of the schistose metamorphics, because there are common associations of dolerite, diorite, or diorite porphyry with their effusive equivalents. It is impossible to consider the microcline gneiss to have intruded earlier than these intrusive rocks.

Basic or intermediate effusive rocks obviously accumulated continuously with

other sediments, including grit and the original ore sediments.

Many quartz veinlets occur in the crystalline schist, running subparallel to, or cutting across, the schistosity. Although the origin and age of most of the veins are not known, some are quite characteristic, showing intimate genetic relationship to metamorphic rocks. Tourmaline-quartz-copper veins and kyanite-staurolite-quartz veins are of this type.

As mentioned, crystalline schists often contain bluish-green tourmaline. For instance, garnet-bearing two-mica schist contains tourmaline-quartz sheet veinlets which are developed along the schistosity, and chlorite-actinolite schist is penetrated by pegmatitic tourmaline-copper-quartz veins.

Kyanite-staurolite-quartz veins were mentioned previously.

Tourmaline-copper-quartz veins, regardless of their origin, would have some effect on the crystalline schist.

4. Banded Iron Ore

The banded iron ore deposits in the vicinity of Yen-tou-tsun are chiefly composed of magnetite and quartz, interbedded in schists. Deposits on a smaller scale are found at Ta-shui-yen, Shang-tzu-miao, Pei-tai, Shih-tzu-ping and several other places.

A. *Location, communication and status of exploitation*

The ore deposits are located about 15 km south of Fan-chih-hsien. The road to the deposits through E-kou-chen has a gently rising slope, and is in very bad slope, but is passable for trucks.

The deposits are distributed over an area of about 2 km by 1.5 km, at about 1,300–1,800 meters above sea level or about 200–500 meters above the nearby riverbed.

The land surface near the deposits is void of vegetation and is rugged. Valleys dry-up in summer and are flooded in the wet season.

The deposits have not been exploited, and were surveyed once by a Japanese geologist, H. Toyoda, during an early period of the Pacific War.

B. *Structure and scale of the deposits*

There are two major ore beds and two or three subordinate beds. They are intensely folded and so disturbed that they seem to be more numerous than is actually the case (see figures 1 and 2).

The fold axis plunges east at an angle of 50°–60° in the northern half of the area and 20–60° in the southern half. Thus, the distribution of ore deposits is exceedingly complicated. Swelling and pinching of the ore beds and variation in grade are marked. They are also partly cut by basic intrusives.

The beds average about 20–30 m in thickness (about 40–50 m in maximum thickness). They extend for about 1,000 m or more in the direction of the strike.

C. *Texture and mineral composition of ore*

The ore is composed of thin alternating dark and light bands.

Table 2

	Dark band	Light band
Constituent minerals	Magnetite, hematite, quartz, chlorite, calcite, ankerite, biotite, stilpnomelane, anthophyllite	Quartz, calcite, ankerite, biotite, stilpnomelane, anthophyllite, sericite, calcite (ankerite and calcite only are sometimes alternated)
Grain size	0.1–0.2 mm	0.1–0.2 mm
Thickness of bands	1–2 mm	1–2 mm

Crystals of ankerite are generally smaller than calcite, often surround a calcite crystal and have a bladed structure.

D. *Grade of ore deposit*

The chemical compositions of the collected samples given by the Reserach Institute of the North China Development Company are as follows:

Table 3

Sample No.	Fe (%)	SiO_2 (%)	S (%)	P (%)
135	28.71	52.77	0.156	0.082
139	42.19	37.56	0.036	0.036
140	37.18	46.27	0.027	0.048
142	37.76	49.93	0.035	0.054
145	30.27	46.97	0.138	0.065
154	45.76	22.93	0.015	0.073
155	28.50	41.33	0.112	0.053
156	31.75	40.61	0.288	0.076
157	35.25	42.16	0.066	0.045
158	30.69	37.60	0.031	0.064
182	37.25	37.02	0.050	0.066
183	32.95	41.46	0.050	0.025
190	35.70	35.74	0.270	0.073
191	26.88	46.20	0.081	0.053
206	40.43	41.76	0.006	0.031
210	31.47	42.45	0.017	0.051
213	35.77	46.78	0.014	0.082
216	56.72	19.12	0.017	0.044

As seen in the table, there are only three ore samples with more than 40 percent Fe content, and the mean value of the Fe content is 30–35 percent. More detailed sampling may be needed to ascertain the extent of high grade ore. It seems practically impossible to obtain high-grade ore by hand-picking, because the ore is so finely laminated with either siliceous or carbonate layers. Magnetic separation on a large scale is the only practical method of ore concentration.

E. *Ore reserves*

Although data is not available for calculating ore reserves with respect to different grades, the total sum of the reserves in the area is estimated at about 20,000,000 metric tons, of which about 4,000,000 metric tons are of 40 percent Fe and about 500,000 metric tons of 50 percent or more. The inferred extension of the ore bed in the strike direction is about 500 meters and the mean thickness of beds is about 30 meters.

F. *Genesis of the ore deposit*

Judging from the grade of metamorphism of the wall rock, which corresponds roughly to the actinolite-amphibole schist facies, the ore is thought to be a product of rather high-grade metamorphism, although pyroxene has not been formed as yet.

Gorō Asano,[10~14] in his excellent studies on the banded iron ore deposits in Manchuria, concluded that hematite in sedimentary rocks is easily converted into magnetite by metamorphism, that carbonates, such as $FeCO_3$, $MgCO_3$, $CaCO_3$, are either combined with silica or dissociated into CO_2 and magnetite and calcite remains unaltered in rocks of actinolite-amphibolite schist facies.

The banded magnetite ore of Yen-tou-tsun may be correlated with the banded iron ore of intermediate metamorphism after G. Asano, and may have had an initial mineral assemblage of silica gel, hematite, siderite, ankerite and calcite. It is worth special note that anthophyllite is the unique amphibole in this iron ore, which suggests the scarcity of aluminous minerals before metamorphism such as iron chlorite, clay minerals and aluminium-hydrates.

The existence of amphibolite and garnet-amphibolite, intercalated with finely laminated magnetite shows that the original rock of these amphibolites were composed of carbonates, silica and aluminous minerals. Some of the amphibolites, which have no trace of igneous texture, are probably of the same origin as the associated rocks of the iron ore.

Sakamoto's idea[15,16] concerning the mechanism of elements precipitating to form the original sedimentary rock of the ore may be correct. But the interpretation that the source of the deposits of both the iron ore and its country rock were independent of volcanic activity at that time should not be applied to the present case, because there are so many occurrences of rocks of volcanic origin adjacent to the deposits.

Stilpnomelane in some kind of banded iron ore in North Korea was reported,

though not very conclusively, by SUDO[17]. This mineral seems relatively common in this type of ore.

5. Hematite Ore Deposit of Ting-hsiang

This ore deposit was previously studied and reported by Kenkichi MASUBUCHI. A brief description will be given here, with special reference to a comparison with the ore of Yen-tou-tsun, because more studies were made on the part of the deposit that was developed after MASUBUCHI's survey.

The deposit is composed of hematite phyllite interbedded in the green schist of TOMITA's Ting-hsiang group of the Wutai system.

A. *Location and Access*

At the time of the survey, the ore deposit was worked by the Shan-hsi Industrial Co. The deposit is situated at the foot of Mt. Tu-ling-kou about 10 km from Ting-hsiang, and access from Chang-tsun Station is easy. The mine office is in Shih-chia-kang, which is situated midway between Chang-tsun Station and Tu-ling-kou. The ore-bearing area borders the Wu-tai mountain block. The gentle slope between Tu-ling-kou and Shih-shia-kang is covered with thick loess. The ore is transported by mine car and carriage from Tu-ling-kou to Shih-chia-kang, and by train to Chang-tsun.

B. *Topography*

Tu-ling-kou is about 1,300 meters above sea level, and is located in the western border area of a mountain block opposite the Wu-tai mountain block beyond the flood plain of the Hu-to Ho. The exposures of ore extend eastward from Tu-ling-kou along the valley, and reach the top of a ridge about 200 meters or more in relative height. The land exhibits a mature stage of erosion.

C. *Geology*

The petrographic characters of the crystalline schist as well as of the ore are considerably different from those of Yen-tou-tsun as described in detail by T. TOMITA.[3]

Actinolite occurs only in skarn, and is not so widely distributed as at Yen-tou-tsun. Sericite and chlorite are remarkably predominant. Hematite is common instead of magnetite. From this evidence, it is inferred that the schist in this area is somewhat lower in metamorphic grade than the rocks of Yen-tou-tsun, and lacks siderite in its initial composition.

According to T. TOMITA, the schist is characterized by microcline and magnetite grains, and schistose grit with sericitic matrix. The schist, which is characterized by hematite, chlorite, sericite and calcite, is well developed. Spilitic texture is partly retained.

The strike of the schist is roughly east-west, and the dip is very steep either to

the north or to the south, thus presenting apparently a very simple structure. At the southeastern corner of the area, the schist is non-uniformly covered with the Mantou shale.

D. *Ore deposit*

The ore deposit is phyllitic hematite schist interbedded within the schist which abounds in chlorite and sericite, and dips north at an angle of about 60–70°:

There are three ore beds, the first bed, the second bed and the third bed in ascending order. The second bed is continuous in an E-W direction up to about 1,000 meters or more, and is about 4 meters or more in thickness. Small NE-SW faults can be seen.

At the time of survey, the second bed was being worked at a level about 100 meters below the surface. No difference can be seen from top to bottom of the developed deposit.

E. *Ore deposit*

The ore deposit is chiefly composed of sericite and hematite, often associated with quartz and tourmaline, and looks like a graphite schist. The low-grade parts are finely alternated with green schist in the hanging and foot walls.

The ore is friable and easily pulverizes while being excavated or transported.

F. *Grade and reserves of ore*

According to data at the mine office, the average Fe content is about 52 percent and low grade ore contains about 40 percent Fe, which is higher than the average grade of Yen-tou-tsun ore.

The ore reserves, according to MASUBUCHI, are estimated at about 2,410,000 metric tons, but may be much larger because the deposit continues deeper than estimated by him.

G. *Mining, ore-dressing and transportation*

Ore of the second bed was being worked in 1942 by overhand stoping in three adit levels with vertical intervals of about 20 meters. Hand-picking of ore was done both underground and on the ground. The route of transportation of ore is as follows:

adit level —(mine car)→ surface —(mine car)→ hand-picking
plant at Tu-ling-kou —(endless belt, inclined 4°)→ ore bin
at Shih-chia-kang —(train and horse-car)→ Chang-tsun.

H. *Power, facilities*

16 KWH generator, 1 set, at Shih-chia-kang (in operation)
250 KWH generator, 1 set, at Chang-tsun station (under construction)
Rail for mine car, 32 lb.

I. *Underground water*

No underground water is found even at the deepest level. The underground water level at Shih-chia-kang is about 20 meters from the surface.

J. *Employees*

Japanese 50, Chinese 1,000 (as of 1942)

K. *Production and distribution*

Daily production, about 200–300 metric tons
Monthly production, about 5,000 metric tons
The ore was sent to the Tai-yuan Iron Works.

6. Hematite Ore Deposit of Tung-yeh-chen

The deposit consists of thick lenticular high-grade hematite ore which was formed by replacing the Tung-yu limestone north of Tung-yeh-chen. The ore is genetically related to the adjacent "brick silica stone" deposits (a kind of white cherty rock penetrated by red ferruginous quartz veins).

A. *Location, access and topography*

The deposit is situated about 6 km north of Tungyeh-chen, or 1.5 km west of the "silica stone" deposit, and about 1,300 m above sea level. It is accessible by truck from Tung-yeh-chen.

The ridge behind the deposit rises toward the east and meets the hill of "silica stone" at a relative height of 200–300 m. The northwestern slope is gentle and thickly covered with loess.

B. *Geology and ore deposit*

The country rock of the ore is the Tung-yü limestone which contains somewhat siliceous parts, strikes generally east-west and dips steeply to the south. In the north, it is in fault contact with the Tou-tsun shale and the Wutai green schist.

The ore deposit is surrounded by ferriferous silica shale with transitional layers in between. Both rocks are brecciated, with angular blocks cemented by more ferruginous material.

The workable part of the deposit is about 50 m by 20 m by 30 m or more.

C. *Ore*

The ore consists mainly of hematite, is rather variable in grade according to the amount of associated quartz present. The low-grade parts grade into the brick silica stone as mentioned before.

Chemical analysis by the North China Development Company gave the following results:

The average grade may be somewhat lower than this.

Table 4

	Fe (%)	SiO_2 (%)	S (%)	P (%)
No. 293	68.01	0.67	0.018	0.165
No. 295	65.87	2.21	0.012	0.301
No. 305	59.19	9.76	0.016	0.644

D. *Genesis of ore deposit*

The ore is assumed to have been formed by the replacement of limestone by ascending siliceous ore solutions, followed by brecciation and deposition of more ferriferous material filling the interspaces of the breccia. Where the ascent of ferriferous solutions continued, the breccia was almost completely replaced by hematite.

E. *Prospecting and mining*

Two adits had been abandoned for five years or more. Under the government of Yang-shan YEN, 200–300 metric tons of ore were worked. The most promising area lies between this deposit and the silica deposit. Open-cut mining may be more suitable for this deposit than underground mining.

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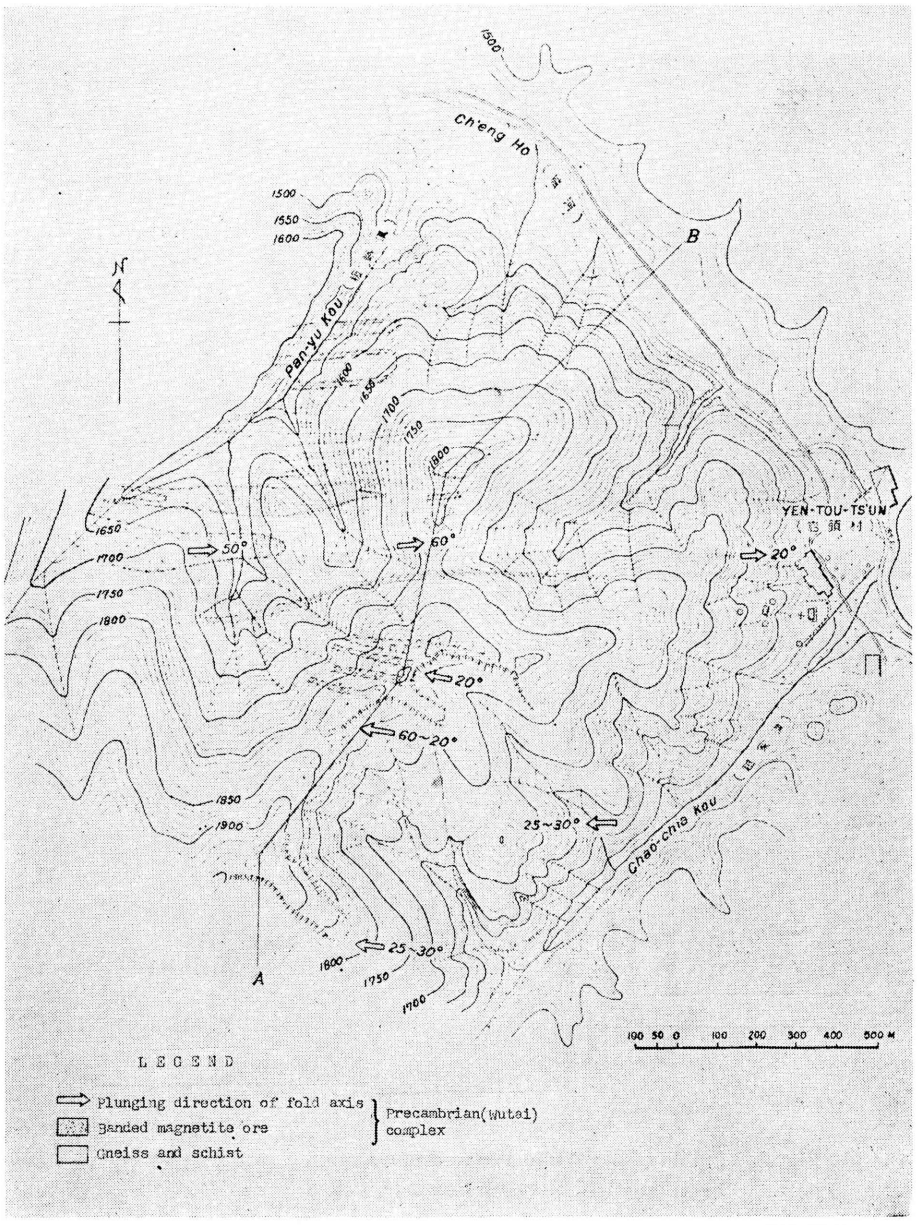


Fig. 1. Topographic and Geologic Map near Yen-T'ou-Ts'un, Fan-chih Hsien, Shan-hsi China.

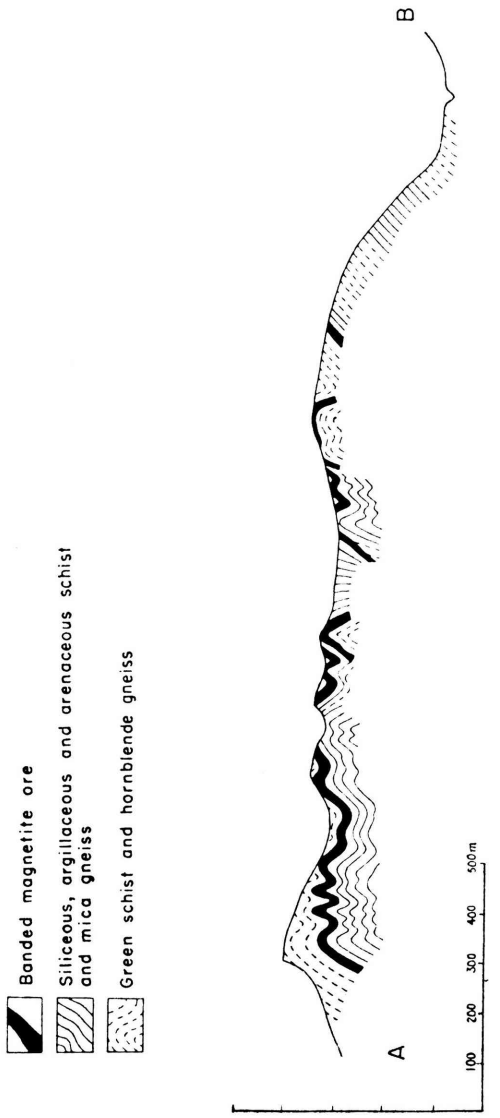
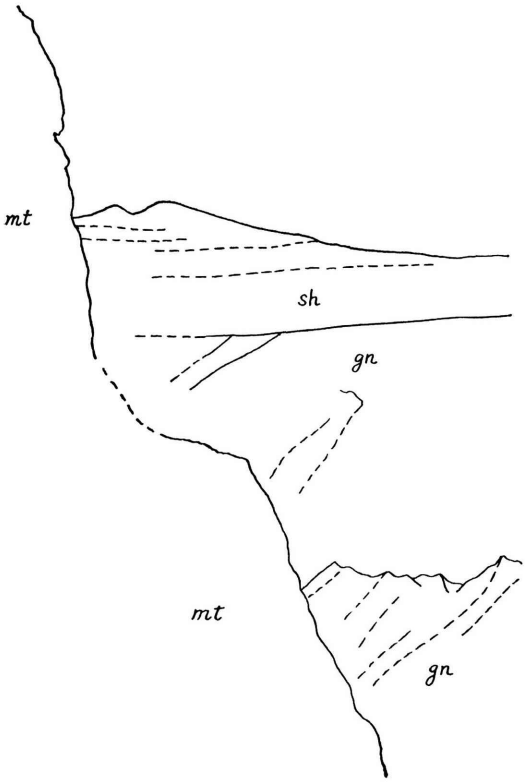


Fig. 2. Profile of the Wutai Precambrian Complex near Wu-tai Shan, Yen-t'ou-ts'un, Shan-hsi Province, China.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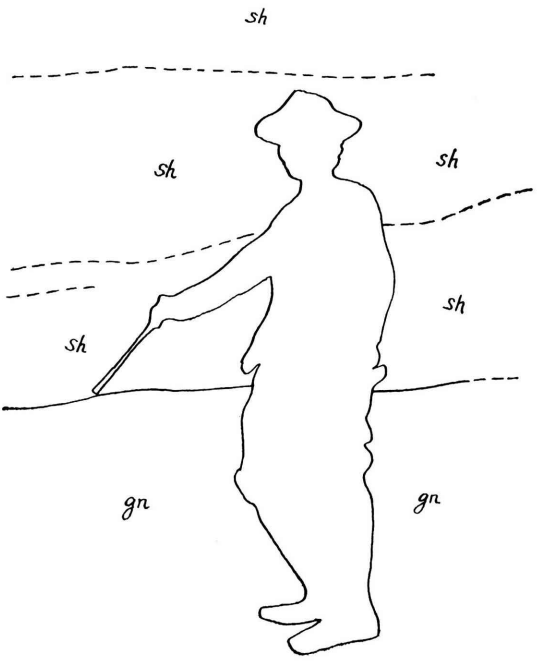
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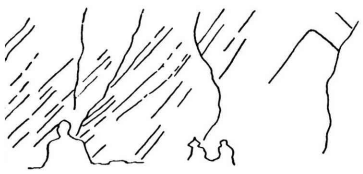

Fig. 3. Outcrops of the banded magnetite ore (mt) and Cambrian formation (sh) horizontally overlying the folded Pre-Cambrian gneiss and schist complex (gn), as viewed from the ridge southwest of Yen-t'ou-ts'sun, Wu-tai Shan, Shanhsi Province, China.

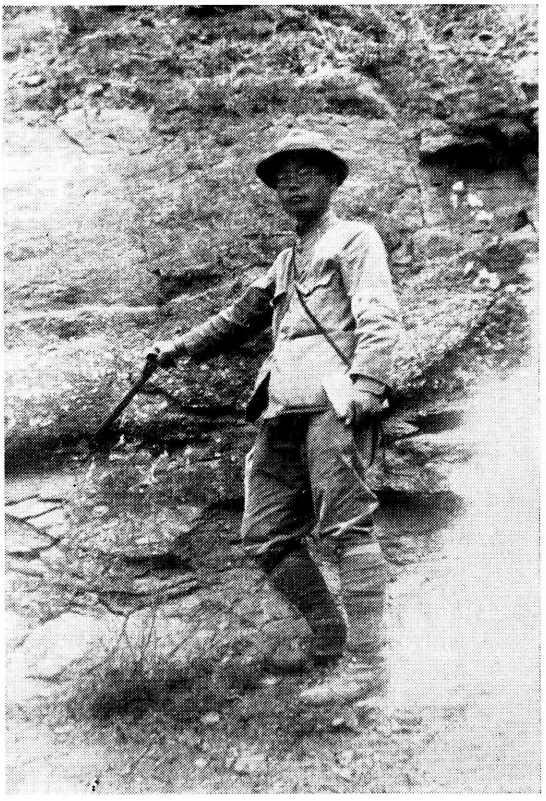

Fig. 5. Mantou Red Shale (sh) nonuniformly overlying the Wutai Pre-Cambrian gneiss and schist (gn), about 1 km east of Yen-t'ou-ts'un, Wu-tai Shan, Sh Shanhsi Province, China.

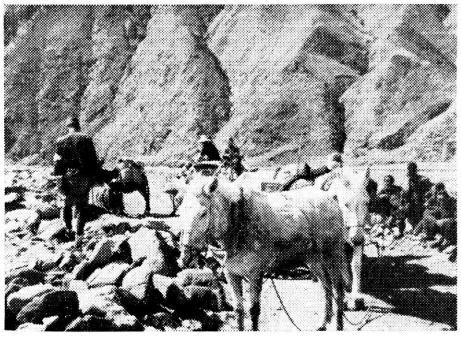

Fig. 4. Sculpture of the mountainland near Wu-tai-shan, Shanhsi Province, which is composed of folded gneiss and schist.

Exploration of Ground Water Resources in North China

Nobuo KURATA

I. GENERAL

1. Value of Ground Water as a Resource

Most rivers in North China, including the Huang Ho (Yellow River) which was the "King of Tragedy" in the history of China, exhibit special features. Topographically, these rivers are known as "tenjō-gawa". (Trans. note: The word "tenjō" means ceiling. These rivers transport an enormous amount of silt from loess-covered areas and deposit it on the river beds, which are constantly being raised. This necessitates the construction of higher embankments to prevent inundation. Often a tunnel is constructed beneath the river bed to join two towns on opposite sides of the river.) On the river banks, there is an extensive distribution of redeposited loess which is similar to "mugikogashi" or parched barley flour. The amount of water that percolates through the soil is so enormous that streams become intermittent or underflow results. This type of river is unusual in Japan. Those who utilize the water must pay particular attention to the seasonal fluctuations of discharge and muddiness of the surface water.

About 60 to 70 percent of the annual rainfall is concentrated in the two months of July and August, and during these months the rivers swell suddenly, usually followed by serious floods. However, with the exception of the rainy season, the amount of river water decreases extremely or is completely absent and a dry condition results. During the dry season there is a considerable fluctuation in ground water, with, of course, a time lag such a fluctuation can be divided into a high-water period and a low-water period.

The turbidity of the river water is a result of fine-grained loess which is in a colloidal suspension, as well as from active erosion because of scanty forests in the drainage basins. According to a survey carried out by the former Water Analysis Laboratory of the Railway Technical Research Institute of the North China Traffic Company, the turbidity of the *Yung-ting Ho* averages 1,000° during the high-water season and 600° in the dry season. The turbidity of the grand canal averages 300° during the high-water season and 150° during the low-water season. However, in the *Huang Ho* (Yellow River), the maximum is said to be about

12,000°. When such turbid river water is allowed to stand for 6 to 7 hours, the majority of coarse suspended particles are deposited, and in another 24 hours two distinct parts are visible, almost clear water and a deposited layer of mud and minute sand. This shows that when the surface water is utilized it will be necessary to install a filtration pool in which the water can stand for 7 to 8 hours. By putting aluminum sulfate in the water in the pool, water with a turbidity of 700°–800° can easily be converted into water with a turbidity of only several tens of degrees. In 1944 this method was adopted for part of the railway water supply.

However, because of the geographical distribution of river water, utilization was very limited, so that when a constant large supply was required ground water had to be utilized. But the ground water in North China is found in cavities in Ordovician limestone which forms a part of the basement rock, and as the region is covered by a loess deposit and has an arid climate, not only the agent that forms the ground water varies, but also the quality of the water. Consequently, for those who attempt to utilize ground water, it is necessary to take special precautions in selecting localities where wells are to be drilled. The ground water drawn from shallow wells located in densely populated villages is markedly polluted, sometimes with a large chlorine content, and is hard. The quality of this water is quite poor, and is unsuitable not only as a municipal water supply, but even for industrial use or for train locomotives. Under such circumstances, the general tendency is to look for deep aquifers.

2. General Features of Deep Aquifers

Japanese nationals managed various installations in North China from 1937 to 1945, and the water supply for these installations was drawn from relatively deep-seated aquifers. The municipal water supply for a majority of cities, with the exception of part of Tien-chin, Ching-tao and *Chi-nan,* and most of the water for locomotives, came from deep, cased wells, with the exception of areas along the Shih-tai and Chiao-chi Railways, where the bedrock is too shallow to drill such deep wells. However, it was fortunate that river water and subsurface flows were available along these railroad lines.

During the years 1937 to 1944, 800 artesian wells were drilled by the Japanese in the provinces of Ho-pei [Hopeh], Shan-hsi [Shansi], Shan-tung [Shantung], Mongolia and a part of Ho-nan [Honan], of which 500 were drilled in the North China Plain including Ho-pei, Shan-tung and part of Ho-nan.

The former Japanese army used 450 wells. The total length of the casing (pipe) was 17,000 m in Ho-pei, 13,000 m in Shan-hsi and 11,000 m in Mongolia. The average depth per well was 70 to 80 m in Ho-pei province, 100 to 110 m in Shan-hsi province and 70 m in Mongolia. In addition to these wells, cased wells previously drilled by Chinese, English, Americans and French for public organisations, private houses, industrial plants and municipal water works existed. About 65 of these wells are found in Tai-yuan, and 15 in Pei-ping. There were about 200

artesian or semi-artesian wells (including some bamboo-cased wells drilled by Japanese), of which 7 were in Tien-chin, about 100 elsewhere and about 30 in Mongolia (if the nearly abandoned wells are included, the number reaches about 60). The aggregate number of wells is about 400. At present the total number of cased wells, which are known through geologic columnar sections or well core samples, may be as great as 1,000.

All of these wells are called deep wells as the depth of the shallowest aquifer ranges from 20 to 30 meters. Among the wells drilled in the regolith, the deepest is 302 m in Te-hsien, and a well drilled in Ordovician limestone is 550 m deep in Chang-tien. The deepest artesian well (863 meters) was drilled by the French in Lao-hsi-kuan, Tien-chin.

Table 1 shows the distribution of public wells in the principal cities. The wells listed in the table are only those for which data is available from geologic cross-sections.

Table 1. Distribution and Uses of Deep, Cased Wells in North China.

Location	Municipal waterworks and railroad uses	For the Japanese Army	By foreign nationals other than Japanese
Pei-ping	30	10	6
Northern and western suburbs of Pei-ping	3	5	4
Tien-chin	7	4	About 100 (including wells extended by the use of pipes)
Shih-chia-chuang	2	2	—
Chi-nan	—	20 (including test borings)	—
Tai-yuan	4	25	About 65
Yun-cheng and Lin-fen	6	5	—
Te-hsien	2	—	—
Tang-ku	—	5	—
Kai-feng	—	8	—
Ta-tung	—	20 (including test borings)	—
Chin-huang-tao	—	20	—
Hsin-hsiang	—	6	—
Chang-hsin-tien and Liu-li-ho	6	—	—
Lang-fang	—	5	—
Chang-tien	4 (including test borings)	—	—

There are many high pressure artesian wells which were drilled into aquifers.

Hydrologically, these had very interesting features. Table 2 shows the depth of the aquifers in which the artesian cased wells were drilled.

Table 2. Location and Depth of Artesian Aquifers.

Location	Depth (m)	Location	Depth (m)
Yun-cheng	250–290 m	Tien-chin	650–690 m
An-i	200–250 m	Pao-ti	60 m (or more?)
Pao-tou	150 m	Western suburb of Pei-ping	40 m
Chang-tien	260–350 m		

The temperature of the water in the wells drilled in Lao-hsi-kuan, Tien-chin, varied from 31.5° to 34°C, the average geothermal gradient was 1°C every 30 m. The well yielded 400 tons per day.

About a half of the cased wells were drilled with portable army drilling machines. The time required for completion of a well was about 5 to 6 days in Ho-pei Province, 22 days in Shan-hsi Province and 10 days in the Mongolian Plateau. About half of the wells range from 100 to 150 mm in diameter. The amount of discharge is uncertain because various motive powers were used; however, a rough estimate is from 600 to 700 tons per day in the North China plain. Some large wells, 250 mm in diameter, in the vicinity of Pei-ping, yielded about 2,000 tons per day. In Shih-chia-chuang, a well discharged 2,800 tons per day and in Kai-feng one well discharged 4,300 tons per day through a 350 mm pipe.

3. General Features of Native Wells in China

In addition to the cased wells, which are known to draw deep-seated ground water, there are many hand-dug open wells which reach shallow aquifers (the first aquifer) and are utilized for various purposes. In most of the North China plain the ground water level is 2 to 3 m below the surface along the Chin-Pu Railway and 1 to 8 m along the Ching-han Railway.

Populated villages within the prefectural walls have utilized water from a few to several hundred wells for domestic purposes. Furthermore, such shallow wells have been widely used for farmland irrigation in the neighboring villages. Even within the North China Plain, a high density of distribution of shallow wells is found in the mountainous areas of Shan-tung and west of and along the Chin-Han Railway. It is believed that about 80 to 90 percent of a total of one million wells are distributed in these areas. The majority of hand-dug wells for farmland irrigation are shallower than 10 m or vary from 6 to 15 m in depth. Animals, mostly blindfolded horses or donkeys, are used in the pumping of these wells. The economic value of ground water in this arid loess region is high.

However, the natural ground water level is lower in both the loess tableland and

loess basin of the Shan-hsi Plateau, and to draw the water from the first aquifer excavation to a depth of 30 to 60 m is usually necessary. The deepest hand-dug open well of this type is found on red clay tableland in Wan-chuan and Jung-ho Prefectures in the Chin-nan area, south of Shan-hsi Province, where artesin wells 200 m deep, one well per village, have been an important source of water.

In the Mongolian Plateau, on the other hand, the water level is generally high and ground water can be obtained at a depth of 2–3 m in flat land. However, potable water from these wells is more important for domestic animals than for the Mongolian people. Under such circumstances utilization is very limited, and as a result the degree of pollution is high and the quality of the water usually very poor.

When the purpose of the well was to draw water from localities where the infiltration of water was possible or along the perennial river banks, shallow wells were dug for railway, municipal waterworks and industrial water supplies. One of the most typical examples of this type is found in the waterworks of the Lungyen Iron Foundry in Hsuan-hua, where four large wells, about 5 m in diameter, were dug on the floor of the Yang Ho in the upper reaches of the Yung-ting Ho. The discharge from some of these wells reached 4,000 tons per day. Large shallow reservoirs to collect water at the mouth of the Nan-kou-yu, which rises in Pa-ta-ling, have been used mainly for train locomotives at the Ching-Pao railway stations. The Shih-Tai and Chiao-Chi Railways have also relied on large shallow wells for water supplies.

The discharge from many native wells ranges from 40 to 50 tons per day in the central part of North China and in the coastal region; in the gently rolling piedmont district, the amount varies from 20 to 30 tons per day. In the piedmont where the basement rocks project immediately below the plain or the nature of the surface soil is not suitable, often in wells 1 to 1.2 m in diameter, a proper discharge of water was impossible. In the industrial district north of Chi-nan, the aquifers are inadequate for the alcohol plant, despite the group of springs to the immediate south, known as the "72 springs of Chi-nan", which yield a total amount of 140,000 to 150,000 tons per day. Under such conditions, large wells were dug with many small radially-placed strainers; by doing this, a water supply has barely been assured. In the vicinity of Lo-yang, Ho-nan Province, there is a tableland consisting of a loamy mud bed resembling hard "yōkan" (a hard bean jelly), and below this bed an aquifer known as the San-men gravel. To reach this aquifer, it was necessary to dig down at least 20 m, and to assure a proper supply of water large wells were needed. Some native oval-shaped wells used for irrigation, ranging from 1.8 to 2.5 m in diameter, had already been dug. Villages which depended on ground water used bucket wells (trans. note: water is drawn from the well with a bucket) 14 or 15 m in depth, and in places the water was obtained from the aquifer, the water level of which varies from 4 to 5 meters. In the Lu-an basin of Shan-hsi Province, a thick reddish clay-like mud bed extends 200 m below the surface, intercalated with no deep-seated aquifer. Thus, in that area a large

well was dug into the subsurface flow within the area of the river bed, and a supply was barely secured for the cooling device at the power station and for general water supply for the district.

The regolith that occurs in North China can easily be dug by hand because there is no danger of cave-in, as is usually the case with gravel beds in Japan. In spite of less trouble in digging wells in North China, however, the amount of discharge per well is usually small, so that in order to alleviate this difficulty many wells that had been used for potable water supply were converted into wells to supply water for locomotives. The native wells were deepened by connecting additional pipe. As a result of this method, several railway stations east of the Shih-Te Railway were able to obtain a large amount of good-quality water.

4. General Features of Shallow-seated Ground Water

A. *Ground-water level and seasonal fluctuations*

The ground-water resources in North China and Meng-chiang* are not scarce, but water levels in both Shan-hsi and Ho-nan Provinces where the loess bed is well developed, especially in the mountain and plateau districts, are generally very low. In order to have access to even an aquifer of the free ground water table, one must bore to a considerable depth. But in the North China plain and in several basins in Meng-chiang and the Mongolian plateau, the ground water level can be reached at a comparatively shallow depth, and potable water supplying villages and cities can also be used for farmland irrigation and various other purposes. Table 3 gives general features of the ground water.

Study of the ground water levels in 43 cities in North China was begun in 1943 under the direction of Dr. F. HOMMA, but the work was forced to be suspended in 1945. However, seasonal fluctuation of ground water levels was observed at Pei-ping, a western suburb of Pei-ping, Tung-chou, Chang-hsin-tien, Shih-men (Shih-chia-chuang), Shun-te, Han-tan, Cheng-te, Tien-chin, Chi-nan and Chang-chia-kou. Along the Ching-Han Railway, the highest water level is observed during the months of February and March (high-water season) and during August and September (rainy season), and the lowest water level during July and August (dry season) and in October (low-water season). The highest water level, during February and March, is brought about by a slow but constant increase since the month of November of the preceding year. The maximum increase in ground water along the Ching-Han Railway is thought to have been brought about by precipitation during the rainy season of the preceding year on the west side of Chi-hsi and Tai-hsing Mountains. The water soaks into the plain and becomes the source of ground water six or eight months later. It is thought that such a seasonal fluctuation in water levels cannot be seen along the Chin-Pu Railway. Going eastward

* Ed. note: Meng-chiang (or Meng-kiang) includes Mongolia and Hsin-chiang (or Hsin-kiang) Province in the northwest of China where it adjoins Mongolia and Siberia.

from the west side of the Chin-Pu Railway, fluctuation in shallow ground water, which is common along the Ching-Han Railway, seems to decrease.

Table 3. General Features of the Ground Water in North China and Meng-chiang

Location	Depth to water level from ground surface (m)	Location	Depth to water level from ground surface (m)
North China Plain		Canyon of the Fen Ho at the foot of the mountain	20–30
East of Pei-ping	4–5	Lu-an	4–8
Western part of Pei-ping	7–8	Wan-jung Tableland	
Outside the city of Pei-ping	8–10	Jung-ho	100
Western suburb of Pei-ping	5–25	Wu-wang-tu	150
Tien-chin	2.5±	Wan-chuan	220
Along the Ching-han Railway	4–6	North of Hua-chin	45±
Shun-te*	6–8	Ho-nan Province	
Along the Chin-pu Railway	2–4	Lo-yang	20
Chi-nan	2–30	Meng-chiang and Mongolia	
Hsu-chou	4–6	Chang-chia-kou	4–20
Shan-hsi Province		Ta-tung	10±
Tai-yuan	5–25	Pao-tou	Shallow in the west, deep in the east
Fen Ho Valley	6–8	Mongolian Plateau	0.5–2

* Based on the following literature:

KURATA, N., Nature of inorganic matter in shallow ground water in North China: *Japanese Jour. Limnology* (Rikusuigaku Zasshi), v. 14.

MIYOSHI, M., Nature of the irrigation water in North China: *Jour. of Sci. of Soil and Manure, Nippon* (Nippon Dojō Hirōgaku Zasshi), v. 15.

WADA, T., Agriculture of North China based mainly on water: pub. by Seibidō Shoten.

B. *Three factors governing the quality of ground water*

The quality of ground water in North China and in part of Meng-chiang is characterized by the high degree of hardness due to Ca and the large content of SO_4 and Cl.

The hardness, especially attributed to Ca content, ranges from 13° to 30° or 40°, German standard (231.3 to 534 or 712 ppm), in shallow ground water, and in some extreme cases the hardness reaches 120° to 130° (2,136 to 2,314 ppm) or even 150° (2,670 ppm). Such a high degree of hardness is due to the wide distribution of calcareous rocks. The warm and dry climate also accelerates the increase in hardness.

The SO_4 content is also high, generally ranging from 50 to 60 mg/l in good-quality water, but in poor-quality water it ranges from 300 to 400 mg/l. Such a

content is attributable to the presence of coal seams, pyrite beds and gypsum. In fact, water seeping into a coal pit often had a recorded SO_4 content of as high as 500 mg/l.

The above two examples are thought due to natural causes, particularly, the quality of the water is closely related to the geology of the area, and $CaSO_4$ is detected in most cases.

On the other hand, the Cl content has two origins, natural and artificial. The content of natural Cl is high in marine formations or in saline areas. Artificial Cl seems to be responsible for pollution.

C. *Characteristic features of water in saline areas*

Shallow wells in saline areas along the gulf of Po Hai, where the water level is very shallow and the Cl content is too high for the water to be potable for both men and animals. The Cl content is very high and ranges from 2,000 to 3,000 mg/l; however, the SO_4 content is comparatively small. Artesian water in Shan-hsi Province in the same saline area has a high SO_4 content and a low Cl content, showing the difference between white and black alkali. Basic land improvement is required in places where alkaline soil is present.

A special characteristic of the water in saline areas of the coast is that the content of sodium and potassium is very high. When such water is used in a boiler, foam appears. The origin of this phenomenon can be traced to the existence of a marine formation, and the sodium contents have been retained to the present due to the prevailing swampy topography. Moreover, the dense soil tends to retain otherwise easily dissolved and lost Cl, resulting in ground water charged with a high content of Cl.

Even though the water is somewhat different from that of the coastal saline areas, part of a former continental lake (a flood-control reservoir built on the Huang Ho in the days of Yu-kung) is also noted as a district of high Cl content. This is an inland saline area similar to the Pai-yang-ting district but differs considerably in quality of water from other inland saline areas. The area along the Lung-hai Railway is a well-known poor-water area. In areas where drainage is sluggish the accumulation and concentration of polluted matter is possible, and an increase in Cl content of ground water is noticeable.

D. *Pollution in populated villages*

Ground water drawn from shallow native wells in villages and cities has usually been polluted from outside sources. The original quality of the water itself has been greatly changed. The Cl content of the original water ranged from 10 to 20 mg/l, but subsequently became several hundred or even 2,000 to 3,000 mg/l. The solid matter content is 500 to 1,000 mg/l, and due to the presence of Mg the water has become bitter. Pollution of village water becomes worse toward the center of the village or within the prefectural walls from the periphery, but the degree of pollution decreases in neighboring rivers.

An example in the neighborhood of Ku-an, Ho-pei Province, is given below. The Cl content of the water from wells in more than ten villages was investigated. For this purpose, a tentative boundary was set at 7 km from the Yung-ting Ho. The investigation revealed that the villages where two-thirds or more of the total number of wells contain more than 100 mg/l of Cl are all located more than 7 km from the river, and reversely, the villages where only one-third or less of the total number of wells contain more than 100 mg/l Cl are all situated within 7 km of the river.

In the Mongolian Plateau, the ground water level lies near the surface. Mongolians use the wells under unsanitary conditions, and the quality of the water gradually becomes worse. Increase in organic matter and Cl content is noticed. For example, within To-lun-hsien, there are more than 100 shallow wells within the city walls, of which only two or three are potable from the standpoint of bacteria content and other factors. In Meng-chiang, especially in the Mongolian Plateau, the calcium content is low and the hardness not very high.

E. *Areas with comparatively good water supplies*

Throughout North China, so-called "good water districts" for agricultural uses are situated along the Ching-Han Railway, between Pei-ping and Pao-ting, and in the vicinity of Tai-an along the Chin-pu Railway. Here the Cl content is 50 mg/l, the hardness 12° (213.6 ppm) and the SO_4 content 35 mg/l, providing the best quality water in these districts.

Pei-ping and vicinity is generally considered a "good water district", because the ground water flows from the north and the northwest. But, the southern part of Hsi-cheng, within the city walls, and outside Chien-men are very poor water areas. However, comparatively good-quality water can be found in newly-developed areas in the southern part of Tung-cheng.

The Fe content is especially high in districts outside the city walls. Water for sale from wells within the city walls (special wells where water is sold by water merchants) has a Cl content of 100 mg/l and a hardness of 15° (267 ppm). The Cl content of the water from public wells is 300 mg/l and hardness ranges from 24° to 25° (427 to 445 ppm). Chi-nan is a good-quality water area containing the so-called "seventy-two springs of Chi-nan", which is near the hill on the south side of the city. A good aquifer zone is found there, the water of which has a Cl content of 50 mg/l, but in the city the quality of water gradually becomes poor. Especially in the low swampy area in the northern and northwestern parts of the city, the flow of water becomes sluggish and the Cl content reaches 300 mg/l. The Cl content of spring water within and outside the city is 12 (mg/l) and the SO_4 content 40 (mg/l). In Hei-hu-chuan, the SO_4 content decreases further, which means better quality. Even in shallow public wells in nearby areas, the SO_4 content remains around 30 mg/l.

F. *pH and water temperature*

The pH of ground water near the surface generally ranges from 7.2 to 7.5. Only part of the Lu-an basin, Shan-hsi Province; Ching-tao city, Shan-tung Province; near Hai-chou, Chiang-su Province; and the area between Ta-tung and Kou-chuan-chen is found to have acidic ground water. None of the water is particularly alkaline. The temperature of the water varies from 12° to 13° C in winter and from 14° to 15° C in summer.

II. Ground Water of Pei-Ping

1. Outline of Geology

Pei-ping (Peking) and its environs are located southeast of Pei-ping-Hsi-shan (the western mountains of Pei-ping), which is a branch of the Yen-shan mountain range or the Chi-tung mountain land, and are built on sand, gravel and loess deposits, thought to derive from the Yung-ting Ho of the Pai Ho system. The fans of the Yung-ting Ho are composed mainly of varicolored gravel beds, consisting of quartzite, siliceous limestone and altered sandstone (fist-size and occasionally head-size). This grades into alternating beds of quartz sand and alluvial loess, and extending southward (beneath Peiping Castle), form one corner of subsurface deposits of the North China Plain.

The ground water of the quartz sand bed is an important artesian aquifer in both quantity and pressure, being fed from the surrounding mountains, especially from the north and the northwest, and lying east (immediately below Peiping) of the line extending from the western wall of Peiping Castle to Wan-shou-shan.

2. Ground Water of the Western Suburbs of Pei-ping

The former river bed of the Yung-ting River lies in the western suburbs of Pei-ping, and deposits consist mainly of a varicolored gravel bed, 30 m thick, lying on a red clay bed. There are hills, (including Pa-pao-shan) composed of Triassic clay slate and quartzite. The depth of the bed rock seems to be 100 m or so, but there is no aquifer below the red clay bed. Three wells, which supply water to the western suburb (managed in 1942–43 by the Construction Office, Peiping Engineering Bureau) are all 50 m or 60 m in depth, and the gravel bed source is shallower than 30 m. There is a several meters thick alluvial loess bed near the surface, but the gravel bed reservoir is countinuous and does not intercalate any impervious stratum.

The water levels of the wells on the banks of the Yung-ting Ho rise rapidly about 2 m in the rainy season, but decrease rapidly after the rainy season. However, the ground water table is different by 15–20 m from the river water level, and the ground water seems to be independent of subsurface flow under the river. This area, inserted between Yung-ting Ho and the gate of the Pei-ping Castle, descends east-southeast with a slope of 1/800 from Shih-ching-shan; the gradient of the

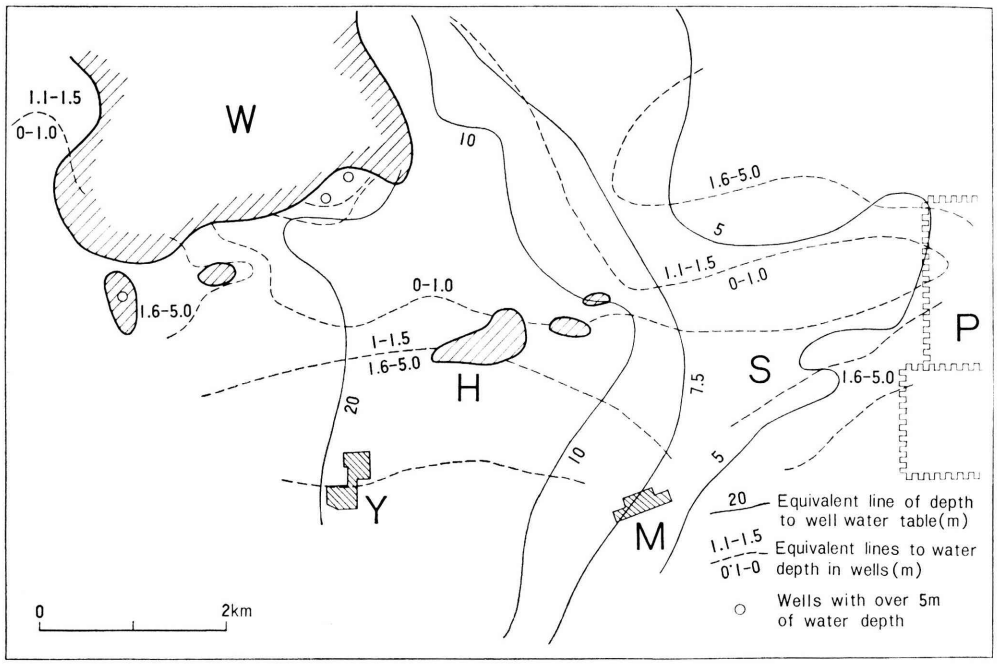

Fig. 1. Equivalent Lines of Depth to Water Surface and Water Depth in Wells of Peiping on the Western Suburbes

W: Pei-ping-hsi-shan
H : Pa-pao-shan
P : Pei-ping castle
Y : Ya-men-k'ou
M : Ta-ching-ts'un
S : Spring water near P'ao-ma-ch'ang Hsi; Pien-men-wai

ground-water table is 1/3,000, hence the water level becomes gradually lower from west to east. To be precise, it is a maximum of 24 m deep on the banks of the Yung-ting Ho, but becomes 5 m or so deep in the eastern part of the western suburbs. There are springs in a swampy zone near the Hsi-pien-men racecourse. The water level is 2 m or so and the yield is large in Ta-ching-tsun and Hsiao-ching-tsun to the south.

Existing wells in the western suburbs number 1 to 3 per settlement, and the water averages 1 m deep; the seasonal variation in water level is 0.5 m or so; the quality of the water is good and the Cl content is always less than 30 mg/l.

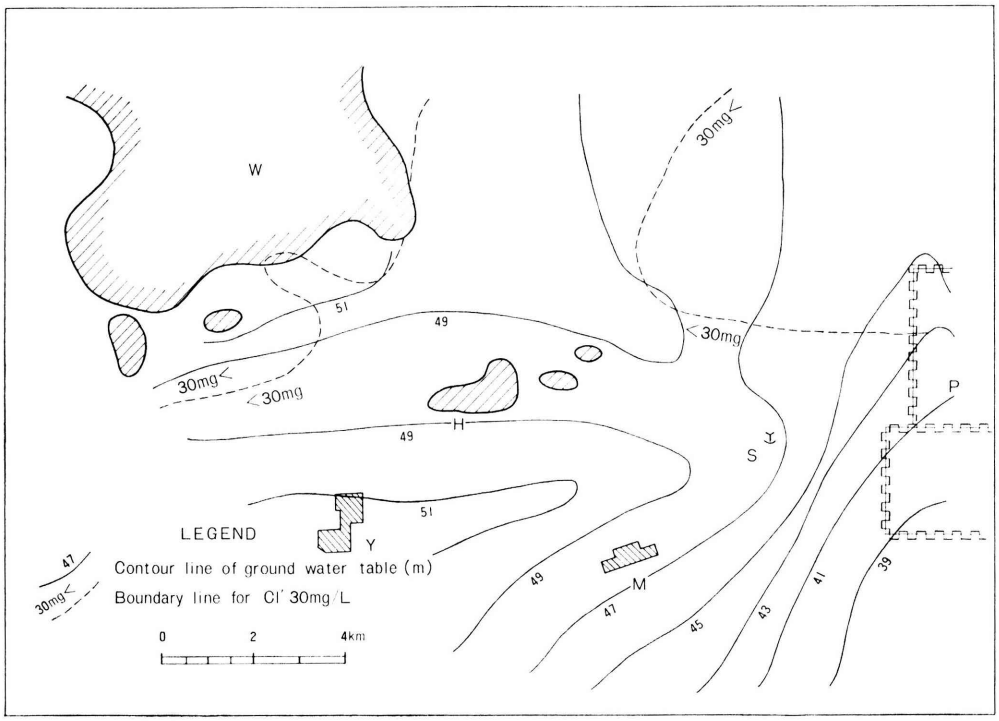

Fig. 2. Countour Lines of Ground Water Surface and Cl Content of Ground Water on the Western Suburbs of Peiping.

W, H, P, Y, M and S, are same as Fig. 1.

3. Confined (artesian) Ground Water in Pei-ping Castle and its Environs

In the subsurface of Pei-ping Castle, the varicolored gravel bed extending to the western suburbs alternates with yellowish-brown loessic mud beds and yellowish-white quartz sand beds. These three beds as a whole are mixed and a red clay-like mud bed lies underneath. The bed rocks are unknown, but the aquifer is a gravel bed in a horizon above the clay-like mud bed. All well drillings that encounters the red clay-like mud bed is stopped by the stickiness.

The depth to this clay-like impervious bedrock is 72–75 m in the western part of Hsi-cheng, 85 m in the vicinity of An-ting-men, 80 m in the vicinity of Hsuan-wu-men, 100–120 m in the vicinity of Chao-yang-men and Tung-pien-men and 90 m in the vicinity of Tung-chi-men; then the surface drops generally eastward.

The amount of superposition of the varicolored gravel bed, the quartz sand bed and loessic mud bed differs in places, but if the depositional layers are connected in accordance with data obtained from deep well drilling, small scale lenses seem

to be irregularly superposed. The quartz sand bed is intercalated frequently, especially in the vicinity of An-ting-men. A large number of *Planorbis* are contained.

The water of these aquifers seems to be supplied from the NNW or N. Deep wells depending on this aquifer are nearly flowing wells and show no annual variation. The breadth of this prominent zone of artesian flow is limited to between the west wall of Pei-ping Castle and the outside of Tung-men for a length of about 10 km; the zone does not reach the Tung-chou castle, where the water seems to be from another source. This artesian flow zone fosters springs where it is shallow at Tang-shan, Ma-fang-chen and Yu-chuan-shan, but the ground water flows southward due to pressure from above and behind.

Since the source of water of Pei-ping City was changed from the surface water of the Pai Ho to ground water, the water is being supplied by drilled wells, which in 1945 numbered 6 within the castle, 15 or 16 outside Tung-chi-men, and 6 or 7 outside An-ting-men and Te-sheng-men. A plan was being advanced to increase the total number by 24. The average yield was 2,000 tons per day (12 inches) per well, and pumpage totalling 50,000 tons per day. The plan was being initiated outside An-ting-men, Te-sheng-men and Tung-chi-men.

4. Variation in Ground Water Level in Pei-ping Castle

Concerning free ground water within Pei-ping Castle, including the inner and outer castle, W. T. Kuo of the North China Tungjen Society examined the quality from the viewpoint of sanitation in 1938, but since then no overall investigation or study has been made. The author began an investigation of the water level and other factors in 1943 for the purpose of establishing a model for prolonged observation of ground water levels in 43 cities in both North China and Mongolia by the All North China Research Institute. As a result, the author obtained data on the tendency, variation in level and quality of free ground water.

In April 1944, the water level and depth were observed for 800 Chinese wells (150 connected wells) in the castle, and the absolute water level obtained by levelling. From this a ground water contour map was made with a contour interval of 0.5 m and a map showing water depth (separated into regions of water depth from 0–1 m, 1–2 m, 2–3 m and over 3 m). As a result, it was found that the shallow ground water within the castle is related to the water of Shih-cha-hai, Pei-hai and Chung-nan-hai. Also, the water level is high in this area and descends eastward, westward and southward, and the depth to water in wells is generally low in the west part of the Castle—from 0 to 1 m, while it is over 3 m in one part east of Tung-tze of the East Castle and Wang-pu-ching Street. When some of these wells were re-examined in October of the same year, an average drop in the water level of 0.5 m was observed. Then, wells of various kinds were selected, namely wells for private use, public use and sale, connected wells, and wells along streets and ponds, and the variation in water level was observed every day. The variation in water level of these wells up to October 1945 is shown in Figure 3.

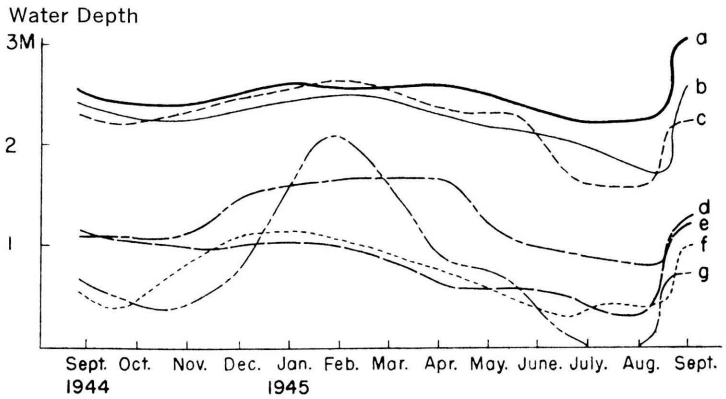

Fig. 3. Variation of Ground Water Level (showing as Water Depth) in the Various Wells in Pei-ping during a Period from Sept. 1944 to Sept. 1945.

a - Side of Tung-tan-kuang-chang
b - SW corner of Lung-fu-ssu
c - Within An-ting Men [Mai-shui-ching]
d - Side of San-tso-men-to-chieh
e - West well in front of Chien-ch'ang
f - East well in front of Chien-ch'ang
g - Road side of Fu-yu-kai

The water level decreased from September to October in 1944, but increased from November to December and through January in 1945, and became a maximum in February and March. It thereafter decreased from April to June and reached a minimum in the middle of August. At that time, dry wells amounted to about 30 percent in the northern part of the West and North Castle areas. After August 15th, the water level in all wells increased equally suddently due to several days of continued rain (twice: from the 15th to the 23d of August and from the 1st to the 10th of September), and reached a maximum level 2 weeks and several days after the beginning of the second period of rainfall. The level subsequently decreased rather rapidly.

During the period of observation, the average increase in water level from February to March was 1 m or so, and that of September 1–1.5 m. Some wells reached the highest level during the year in the former period, but others in the latter. In summary, the annual variation has two seasons of decrease (the lowest in June, July and August; and in October) and two seasons of increase (in February and March, and in August and September). The heavy rains of the rainy season in 1945 fell in the last half of August, later than usual, so the increase in water level seems to have been late. However, this may be a change in water level due in part to percolation and inflow accompanying the rain. On the other hand, the gradual increase in water in February and March was very remarkable. If this was due to the geology, the water must have percolated in the preceding year from the western and northern mountains into the deposits composed of 60 percent gravel

and 40 percent mud, and then flowed into the plain 6 to 8 months later, thus presenting a high water level during February and March in the vicinity of Pei-ping Castle.

Observations of the water levels of selected wells at Shih-chia-chuan, Shun-te Han-tan and Chang-te will be introduced in the following. All wells are similar to those of Pei-ping, and seem to be affected 6 to 8 months after rains in the western mountains (during the preceding year). Of course, pressure not only from a horizontal direction but also from a vertical direction through impervious strata is considered for the flow of ground water.

In this connection, R. KANEKO of Peiping University (now with the Agriculture Research Institute in Japan) closely observed the ground water level in the Agriculture Institute and on the University farm northeast of Tien-tsin. According to him, the increase phenomenon in February and March does not appear as clearly in the low dump of Tien-tsin as in Pei-ping, and only the increase in the rainy season is clear. Hence, the aspect of seasonal variation in water level seems to be different between the Ching-Han Railway and Tsin-Pu Railway regions.

In areas where the depth of water is greater than 3 or 4 m, an increase in water level does not appear without continued rain of more than 100 mm. Thus, rain water in seasons other than the rainy season is wholly exhausted at the spot.

III. GROUND WATER OF TSI-NAN

1. Topography and Geology

Tsi-nan (Chi-nan) is situated 350 km from Tien-tsin and 320 km from Hsu-chou along the Tsin-Pu Railway, on the northern slope of the Shan-tung mountainland in the center of Shan-tung Province. It is given the name of Tsi-nan (south of Tsi), because it is on the southern bank of the Huang Ho (Yellow River), which formerly was called "Tsi".

Ssu-li Shan, Ma-an Shan, Li Shan and Chien-fo Shan, all consisting of Ordovician limestone, can be seen in the background on the southern side of the city, and the North China Plain spreads widely to the front on the northern side. Part of a diorite body, which metamorphosed the Ordovician limestone along the zone of contact, stands on the sediments of the plain to the peaks of Chin-niu Shan, Feng-huang Shan, and others are scattered northwest [literal translation] of Tsi-nan. The portion having the aspect of an ancient archipelago extends southward along the Tsin-Pu Railway to the northern bank of Ta-sha Ho west of Tsi Shan.

Geological surveys show that south of Tsi-nan, the Ordovician limestone dips 15 degrees northward and is folded with an east-west axis. The rock facies is a beded limestone composed of thin layers, less than several meters thick. Contact with the diorite on the north is found in the vicinity of former Hing-a street, running east to south west of Tsi-nan Castle, and in the western business section. A

calcareous breccia bed and loess overlie these limestones and diorite, and most of Tsi-nan City is situated on them.

This limestone gravel bed is called the Tsi-nan gravel bed by the author; its maximum thickness is 40 m and is interbedded with a muddy loess bed, although the geologic age is unknown. The mud bed is well developed in the upper reaches of the valley, while the gravel bed is well developed in the lower reaches of the valley, and occurs even in places as high as 100 m above sea level. In the north, including the northern half of Tsi-nan City, the flood plain deposits of the Yellow River cover the Tsi-nan gravel bed. They are very thin in the part of the corporate city, but become gradually thicker toward the river.

2. The "Seventy-two Springs" of Tsi-nan and Their Mechanism

Tsi-nan is commonly called the "city of seventy-two springs", and seems to deserve the name. Actually, there are two great springs, Hei-hu-chuan southeast of the outer castle and Pao-tu-chuan to the southwest. The number of springs both in and out of the city total about 50, and the total yield amounts to 140,000 or 150,000 tons/day, forming the largest spring group in yield throughout North China and Mongolia. The spring water of Hei-ho-chuan, Pao-to-chuan, etc., become the stream surrounding the castle wall, and water from the spring group within the castle flow into the historically famous lake of Ta-ming-hu, 8 km in circumference; the outflow joins with flows outside the city to form the Hsiao-ching Ho.

The quality of the water from the springs is generally 12 mg/l for Cl and 40 mg/l for SO_4; the water of Hei-hu-chuan is low in SO_4 and is the best quality ground water in North China.

The yield: the Hei-hu-chuan gushes from a small cliff of limestone conglomerate, but Pao-tu-chuan gushes up about 10 cm from a pipe, and tends to gush up everywhere in the bottom of the pond. Accordingly, the mechanism of the springs immediately before gushing out is considered as follows: The water intruded into limestone conglomerate has made irregular channels and is forced through the channels from the back to blow or gush out everywhere.

The source of the municipal water supply in 1942 was Pao-tu-chuan, but the water became muddy in the rainy season of that year, causing a three-day interruption of supply. In addition, the source is located in an area of the city that is crowded with houses, the topography is low and there is risk of pollution. On the other hand, a source was desired where water could be supplied by natural flow and under favorable circumstances, because coal for pumping power was in short supply. For this purpose, the water works station of Tsi-nan City (Y. YAMAMOTO, Japanese advisor) investigated the subsurface flows in the Chung-kung district south of Tsi-nan to investigate the old tale that the water of the seventy-two springs came from Tai Shan.*

* Primary report and photographs. 2 volumes.

In 1944, the author and others explored the geology of the southern part of the city and the southern suburbs, and 7 holes (three at depths of 96 m, 70 m and 42 m, and four at 30 m each) were bored in the vicinity of Tsi-lu University, Chi-li-wa and the foot of Chien-fo Shan.

Of these borings, those at Chi-li-wa twice encountered limestone caves, several m thick. A bed of rounded gravel and a red compact hard clay bed, 2 m thick, were found in the bottom of the caves, and indications of flowing water were, although the quantity was probably small. Then the chlor-calc test was performed in cooperation with the North China Dojin-kai, in order to examine whether or not the water was connected with the springs, but no reaction was found in the springs in the lower reaches. Therefore, it was decided that there was no connection between them. Furthermore, in two borings, one made in former Hing-a street and the other at Chien-fo Shan, the former encountered caves 2 or 3 m thick, but there was no clear indication of water. Therefore, a boring was made in the northeastern extremity of Tsi-lu University to examine the well lying in the university at the same time. It passed through the limestone conglomerate bed into the limestone bed rock 40 m below the surface, and was successful in obtaining a large amount of water 2 or 3 m below that depth.

An examination of the results of boring and measurements of 2 or 3 existing wells led to the following supposition: the ground water in the limestone comes from the south and encounters the diorite, which caused contact metamorphism in the limestone in the vicinity of former Hsing-a street. As the limestone is very compact and impervious, the water tends to ascend along the contact plane to some degree and intrudes the limestone conglomerate.*

In August of 1944, the subsurface geology of the environs of former Hing-a Street was surveyed by the resistivity method in cooperation with Y. KUROKAWA of Kyoto University for the purpose of a precise geographical survey of the course of water behind these springs. As a result of this survey, on the basis that a low resistivity suggests the occurrence of ground water, a water-bearing cave was detected at a depth of 40 m below the surface of the semi-dome structure on the northwestern ridge of Chien-fo Shan, a place which looked promising from the first. Thus, the possiblility of following the underground position of the water increased. This underground flow extends at least to the unique well in the district—the well in the Blind and Dumb School, which never dries up, is 27 m deep and has a natural water level of 27 m. The flow also extends to one or two wells of superior quality, and to Hei-hu-chuan.**

The results of this survey at least exploded the past conjecture that the source of the seventy-two springs of Tsi-nan might be percolating water of the Yellow River, and pointed out that the resistance of the diorite body is the mechanism that causes the ground water in limestone in Chien-fo Shan to gush up.

* Second survey on boring report by the well-drilling team of the Army.
** Third survey.

3. Ground Water in Part of the Corporate Town of Tsi-nan

In October 1944, an additional ground water survey was performed on the existing 200 wells. Test holes were bored into the limestone conglomerate in the business area, and in and west of the castle in order to make sure of the results. A water table map was made at a contour interval of 2 m, showing also lines of equal depth of water in wells and lines of equal values in chlorine content. Efforts were made to determine the flow of ground water in the limestone conglomerate by the flow gradient and water quality.

Results showed that the water levels range from 30 m to 60 m and the Cl content is less than 50 mg/l. The quality is good in the area of brick factories spotted along the mountain foot south of the city, but the water becomes suddenly worse northward in the corporate part of the city. The flow of ground water seems to be fast, with a rather steep slope in the business section. There, the quality is maintained and even among the shallow wells in the spring area the Cl content stays at 30 or so mg/l. However, where the amount of flow is small, pollution increases due to stagnation, and the Cl content reaches 300 mg/l. The water tends to be worse in the low swampy area in the northern and western suburbs.

In addition, the results of boring and electrical prospecting, shown on the map, more clearly indicated the flow mechanism behind the prominent spring Hei-hu-chuan. The Cl content indicates flow from south of the business area to the south-east corner of the outer castle, finally connecting with Pao-tu-chuan. Thus, a zone remarkable in flow and velocity was found.

In March 1945, S. HANADA of the North China Development Co. had an opportunity of re-examining the area south of Tsi-nan City with a Meggar-tester in search of a water source for the Army. As a result, he hypothesized that a flat lenticular water vein was the mechanism of ground water distribution in the limestone. This seems to be reasonable, considering the fact that the limestone as a whole is thin and very compact in the district.*

Several investigations involving surface exploration, boring, electrical prospecting and sanitation tests did not result in the discovery of a site to obtain a new source of water supply,** but gave a rather clear answer as to the tendency and mechanism of occurrence of ground water in the vicinity of and behind the seventy-two springs of Tsi-nan.

* Fifth survey.

** The war had terminated when boring materials were transported to make sure of the result, and the plan was abandoned.

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PLACE NAMES

KOREA

A

Aejŏn-myŏn	薤田面
Agan-myŏn	阿間面
Ami-san	峨嵋山
Amnok-kang	鴨緑江
Amnyang-myŏn	押梁面
Anak (Annak)	安岳
Anang-myŏn	安岳面
Anbyŏn	安辺
Andol	安乭
Angsŏng-myŏn	仰城面
Anjŏng-ni	安静里
Anju-gun (Anju-kun)	安州郡
Ansim-nyŏng	安心岑
Ansimu	安心羽
Ansŏng-gun	安城郡
Ansu-myŏn	安水面
Ap'a-ri	丫波里
Asan-gun	牙山郡

C

Ch'acha'ng-myŏn	車倉面
Chaeil mine	在日鉱山
Chaeryŏng-gang	載寧江
Ch'aesok-san	採石山
Chaedŏk-san	在徳山
Ch'ail-bong	遮日峰
Chakch'ŏl-li	鵲川里
Changbaek	長白
Changbaeng-myŏn	長白面
Chang-bong	将峰
Changdong-myŏn	長洞面
Changhyŏl-li	長峴里
Changjin-gun	長津郡
Changmunnae	長門内
Changnae	墻内
Ch'angnak-tong	昌楽洞
Ch'ang-ni	倉里
Changnim	長林
Changnim-myŏn	長林面
Changnyong	長龍
Changp'yŏng-ni	長坪里
Ch'angsŏng-gun	昌城郡
Changsu-gun	長水郡
Ch'angsu-myŏn	蒼水面
Changsu-san	長寿山
Ch'angwŏn-gun	昌原郡
Ch'angyŏl-tong	彰烈洞
Changyŏn	長淵
Changyŏn-gun	長渕郡
Ch'aryŏn'gwan	車輦館
Chasŏng-gang	慈城江
Ch'e-bong	體峰
Chech'ŏn-gun	堤川郡
Cheju-do	済州島
Chewŏn mine	済原鉱山
Chikchŏn-dong	稷田洞
Chik-hyŏn	直峴
Chiksan	稷山
Ch'ilbo-san	七宝山
Ch'ilbong-san	七峰山
Chil-li	榛里
Chinan-gun	鎮安郡
Chindong-myŏn	鎮東面
Chinsa-ri	進士里
Chinsa-ri	陳沙里
Chip'o-ri	芝浦里
Chisa-ri	智士里
Chiun-myŏn	池雲面
Choch'iwŏn-ŭp	鳥致院邑
Chodong-ni	鳥洞里
Choga-dong	趙哥洞
Chogae	早開
Chŏgam-myŏn	積岩面
Chŏgum-ni	笛音里
Chohowŏn-ŭp	鳥湖院邑
Choidŏk-san	槽二徳山
Chokkong-ni	赤谷里
Chŏlla-namdo	全羅南道
Chŏlla-pukto	全羅北道

Ch'ŏlsan-gun 鉄山郡
Ch'ŏl-wŏn 鉄原
Ch'ŏlwŏn-ŭp 鉄原邑
Ch'ŏnan-gun 天安郡
Chŏnch'ang-myŏn 田倉面
Chŏngbang-san 正方山
Ch'ongch'ŏn-gang 清川江
Ch'ŏnggye-ri 清溪里
Ch'ŏngju 清州
Chŏngju-dong 正州洞
Chŏngju-gun 定州郡
Ch'ŏngna-myŏn 青羅面
Ch'ŏngnyong-myŏn 青龍面
Ch'ŏngp'yŏng mine 清平鉱山
Ch'ŏngsŏktu 青石頭
Chŏngsŏn-gun 旌善郡
Ch'ŏngsong-gun 青松郡
Ch'ongsŏng-jin 清城鎮
Chŏnju 全州
Ch'ŏnju-san 天柱山
Ch'ŏnma-ri 天馬里
Ch'ŏnsang 天上
Ch'ŏnsŏng-ni 天聖里
Ch'ori-myŏn 草里面
Ch'osan 楚山
Ch'osan-gun 楚山郡
Chosŏn 朝鮮
Chuch'ol-li 舟村里
Ch'uchŏng-ni 楸井里
Ch'udang-ni 楸唐里
Chugŏm-ni 注驗里
Ch'ujŏngsu 椒井水
Chuksal-li 竹山里
Ch'umogwŏn 椒木院
Chunae-myŏn 州内面
Chunam-myŏn 朱南面
Ch'unch'ŏn-gun 春川郡
Chŭng-bong 甑峰
Chŭngbong-san 甑峰山
Chungbong-san 中峰山
Ch'ungch'ong-pukto 忠清北道
Ch'ung-gang 忠江
Chunggangjin 中江鎮
Chunghwa 中和
Chunghwa-gun 中和郡
Chungjŏng mine 重鼎鉱山
Ch'ungju 忠州
Chungman-gang 中満江
Chungnam-myŏn 竹南面
Chungoebang-ni 中外坊里
Chunggye-ri 中溪里
Ch'unhŭng-dong 春興洞
Chuam-san 酒岩山
Ch'usu 椒水
Chuul 朱乙
Chuuron 朱乙温
Chuyŏmjŏng 朱染亭

H

Hach'owŏl-li 下草院里
Hada-myŏn 何多面
Haeju 海州
Haeundae 海雲台
Haewŏl-myŏn 海月面
Hago-myŏn 下古面
Haju-ri 下注里
Hajuul 下朱乙
Haksang-myŏn 鶴上面
Haksŏl-li 鶴仙里
Haksŏ-myŏn 鶴西面
Haksŏng-myŏn 鶴城面
Haktong-myŏn 鶴東面
Haman-gun 咸安郡
Hamch'ŏn 鹹泉
Hamgyŏng 咸鏡
Hamgyŏng-pukto 咸鏡北道
Hamhŭng 咸興
Hamusan-myŏn 下茂山面
Hanbong-san 漢峰山
Hangnam-myŏn 鶴南面
Han'gyo-ch'ŏn 漢橋川
Hanim-ni 下林里
Hanjŏn-dong 閑田洞
Hansu-myŏn 寒水面
Haun-myŏn 下雲面
Haunsŭng-ni 下雲承里
Hoengsŏng-gun 横城郡
Hoeam-san 檜巖山
Hoesal-li 檜山里
Hoeyang-gun 淮陽郡
Holgol 笏洞
Homal-li 湖満里

Homyŏng-ni	虎鳴里
Hongbung-myŏn	洪北面
Hongchŏm	紅店
Hŏngch'ŏn-gang	洪川江
Honghyŏnsi	紅峴市
Hŏngsŏng	洪城
Huch'ang	厚昌
Huch'ang-myŏn	厚昌面
Hugong-ni	後谷里
Hŭich'ŏn-gun	熙川郡
Hŭkkyo	黒橋
Hŭun	浩雲
Hwaam-ni	画岩里
Hwach'ŏl-li	花泉里
Hwach'ŏn-myŏn	化村面
Hwanggang-ni	黄江里
Hwanghae-do	黄海道
Hwangju	黄州
Hwangim-myŏn	黄林面
Hwangjŏl-li	黄田里
Hwangnim-myŏn	黄林面
Hwap'yo mine	華表鉱山
Hwap'yŏng	和坪
Hyangp'ung-san	香楓山
Hyangsu-ni	香水里
Hyesanjin	惠山鎮
Hyŏngje-san	兄弟山
Hyŏngmyŏng-san	玄明山
Hyŏnnae-myŏn	県内面

I

Ibam	立岩
Ibsŏng-ni	立岩里
Ich'ŏn	利川
Ich'ŏn	伊川
Ich'ŏn-gun	伊川郡
Ich'ŏn-ŭp	利川邑
Iha-ri	梨下里
Ijung-myŏn	二竹面
Iksan-gun	益山郡
Ilgŏm-dong	日建洞
Ilgwang-myŏn	日光面
Ilwŏl-myŏn	日月面
Imch'ŏn	林村
Imdong	林洞
Imgi-ri	林基里
Imnam-myŏn	臨南面
Inam-dong	夷南洞
Inch'ŏn	仁川
Inhŭng-myŏn	仁興面
Inje-gun	麟蹄郡
Inmong-myŏn	寅目面
I-ri	二里

K

Kach'a-do	加次島
Ka-dong	駕洞
Kaech'ŏn	价川
Kaegong-ni	開谷里
Kaema	蓋馬
Kalch'ol-li	葛田里
Kalgŭm-ni	葛琴里
Kalmal-myŏn	葛末面
Kalsan	葛山
Kambuk-san	坎北山
Kamch'ŏn	甘泉
Kan'gang-myŏn	降崗面
Kanggye	江界
Kanggye-gun	江界郡
Kanggyŏng mine	江慶鉱山
Kanghwa-gun	江華郡
Kang-myŏn	江面
Kangnam	江南
Kangnŭng-gun	江陵郡
Kangsŏ	江西
Kangtong-gun	江東郡
Kangwŏn-do	江原道
Kanji-dong	澗芝洞
Kanjin-san	江津山
Kappi	甲斐
Kapsan-gun	甲山郡
Kap'yŏng	加平
Kasan-myŏn	加山面
Kasa-ri	佳士里
Kasin mine	嘉神鉱山
Kibong-dong	起鳳洞
Kilch'ŏn-hwangsu	吉村黄水
Kilch'ŏn-myŏn	吉村面
Kilchu	吉州
Kiyang	岐陽
Koan-myŏn	高安面
Kobang-san	高坊山

Kŏch'ang-gun 居昌郡
Kojansang-ni 高棧上里
Koegong-ni 槐谷里
Koep'yŏng-ni 槐坪里
Koesan-gun 槐山郡
Kogwan-myŏn 古館面
Kohyŏn mine 高峴鉱山
Kojang 古場
Kŏjil-li 巨津里
Kŏjin-myŏn 巨津面
Kojŏng-ni 高亭里
Kojŏng-san 高亭山
Kŏmdŏk mine 検徳鉱山
Kŏmsan-myŏn 検山面
Kŏmsan-yangsu 検山薬水
Kŏmun-dong 巨文洞
Kongch'i-dong 空峙洞
Konggŭn-myŏn 公根面
Kŏnsang-dong 乾上洞
Kop'yŏng-myŏn 古平面
Koraegol 鯨谷
Koraesu-ri (Kyŏngsu-ri) 鯨水里
Kosŏng-gun 高城郡
Kowŏn 高原
Koryŏng-san 高霊山
Kuhyŏn-ch'i 駒峴峙
Kukkun mine 菊根鉱山
Kŭmche 金祭
Kŭmch'ŏn 金川
Kŭmch'ŏn-gun 金川郡
Kŭmgang-san 金剛山
Kŭmgong-ni 金谷里
Kŭmhae-gun 金海郡
Kŭmhwa 金化
Kŭmhwa-gun 金化郡
Kumi-ri 九尾里
Kŭmjik-san 金織山
Kŭmju 金州
Kŭmma-myŏn 金馬面
Kŭmsal-li 金山里
Kŭmsan-gun 錦山郡
Kŭmsok mine 金錫鉱山
Kŭmsŏng 金城
Kŭmsŏng 錦城
Kunbung-myŏn 郡北面
Kŭnbung-myŏn 近北面
Kung-dong 宮洞
Kunghŭng-myŏn 弓興面
Kungno-dong 弓弩洞
Kunnae-myŏn 郡内面
Kuro-ŏni 九老里
Kunsan 群山
Kunt'al-li 軍炭里
Kuryong-myŏn 九龍面
Kusan 九山
Kwanam-ni 冠岩里
Kwangch'ŏn-myŏn 廣泉面
Kwangyang-gun 光陽郡
Kwich'ol-li 貴泉里
Kyebung-myŏn 溪北面
Kyech'ol-li 桂村里
Kyenae-myŏn 溪内面
Kyerim 鶏林
Kyŏmip'o 兼二浦
Kyŏnggi 京畿
Kyŏnggi-do 京畿道
Kyŏngju-gun 慶州郡
Kyŏngnam line 京南線
Kyŏn'gŏng-myŏn 見谷面
Kyŏngsang-namdo 慶尚南道
Kyŏngsang-pukto 慶尚北道
Kyŏngsan-gun 慶山郡
Kyŏngsŏng 京城
Kyŏngsŏng-gun 鏡城郡
Kyŏngwŏn line 京元線

M

Mach'ŏl-lyŏng 摩天嶺
Maengsan-gun 孟山郡
Maengyang-dong 孟陽洞
Magŭm-san 馬金山
Majang-myŏn 馬場面
Majŏl-lyong 麻田嶺
Majŏn-nyŏng 馬転嶺
Mandal-san 晩達山
Manin-bong 萬仁峰
Manp'ojin 満浦鎮
Masal-li 馬山里
Mi-myŏn 米面
Miryang 密陽
Monggŭmp'o 夢金浦
Muhak-san 舞鶴山

Munch'ŏn 文川
Mundŏk-tong 文德洞
Mun'gyŏng 聞慶
Mun'gyŏng-myŏn 聞慶面
Munhwa-myŏn 文化面
Munhyŏn 文峴
Munsal-li 文山里
Munŭi-myŏn 文義面
Munwŏl-li 文源里
Murŭng-ni 武陵里
Musan-gun 茂山郡
Myŏngbong-dong 鳴鳳洞
Myŏngch'ŏn 明川
Myŏngch'ŏn-gun 明川郡
Myŏngdŏng-ni 明德里
Myŏnghwa-dong 明化洞

N

Nabu-dong 羅府洞
Naech'ang 內倉
Nae-myŏn 內面
Naengch'ŏn 冷泉
Naep'yŏng-ni 內坪里
Nangnang 樂浪
Namch'ŏl-li 南川里
Namch'ŏn-ŭp 南川邑
Namdae-ch'ŏn 南大川
Namduil-myŏn 南斗日面
Namjŏng 楠亭
Nam-gang 南江
Namhach'ang 南下倉
Nam-myŏn 南面
Namsan-ch'ŏn 南山川
Namdae-ch'ŏn 南大川
Namwŏn-gun 南原郡
Nangnim 狼林
Nodong-ni 芦洞里
No-gang 魯江
Noji-myŏn 鷺池面
Nojŏn-dong 芦田洞
Nokkaktŏng-ni 鹿角德里
Noksan-myŏn 綠山面
Nonsan-gun 論山郡
Nosŏng-ni 魯聖里
Nŭngam-ni 陵岩里

O

Ŏbok 業億
Obong-ni 五峰里
Och'ang-myŏn 梧倉面
Odae-myŏn 梧垈面
Oedong-myŏn 外東面
Oegŭmgang-myŏn 外金剛面
Oegwi-myŏn 外貴面
Oejungbang-ni 外中坊里
Ŏha-myŏn 漁下面
Ohwa-dong 五花洞
Ojŏng-ni 五亭里
Okch'ŏn 沃川
Okka-bong 玉珂峰
Okku-gun 沃溝郡
Okp'ok 王瀑
Okp'o-myŏn 玉浦面
Oksan-myŏn 玉山面
Oku-hyŏn 玉峴
Omong-ni 吾夢里
Onch'ŏn-dong 溫泉洞
Ongjin-gun 甕津郡
Onhwa 溫和
Ŏnjin-san 彦真山
Onjŏng 溫井
Onjŏng-ni 溫井里
Onjung-dong 溫中洞
Onp'ung 溫豊
Onsup'yŏng 溫水坪
Onyang 溫陽
Oryong-san 五龍山
Osaeg-yangsu 五色藥水
Osamp'o 五三浦

P

P'achang-ni 坡長里
Paegam 白巖
Paegsŏk 白石
Paegun-san 白雲山
Paegyang-ni 白楊里
Paekch'ŏn 白川
Paeksam-bong 白三峰
Paekt'o-dong 白土洞
Paektu-san 白頭山
Paengnang-myŏn 柏梁面
Pagam-ni 博岩里

Pakch'ŏn-gun 博川郡
P'allyung-ni 板六里
P'altam 八潭
Panggye mine 芳桂鉱山
Panghyŏn mine 芳峴鉱山
Pangjang-myŏn 方丈面
Pangnim-myŏn 芳林面
P'an'gyo-myŏn 板橋面
P'anhang-ni 板項里
P'an-myŏn 板面
P'ano-ri 板五里
Pansong-yangsu 盤松薬水
Pich'ŏn 沸泉
Pirang-dong 飛浪洞
Piryu-gang 沸流江
Pisŏk-tong 碑石洞
Pogwang-ni 宝光里
Pokkwi-myŏn 福貴面
Pokkye 福溪
Poksap'yŏng 福沙坪
Poksin-san 福辰山
Pŏlgong-myŏn 伐谷面
P'onam-ni 浦南里
Ponghwa-gun 奉化郡
Pongjil-li 鳳津里
Pongjŏng 鳳亭
Pongmyŏng-ni 鳳鳴里
Pongnae-ni 鳳来里
Pongsan 鳳山
Pongsan-myŏn 鳳山面
Pongsu-ri 鳳岫里
Pophŭng-ni 法興里
Poryŏng-gun 保寧郡
Posan 宝山
Posan-ch'ŏn 保山川
Posan-dong 保山洞
Posan-myŏn 宝山面
P'osyu 砲手
Pudong-ni 富洞里
Pugang 芙江
Pugil-myŏn 北一面
Pugong-ni 復谷里
Pugyang-ni 北陽里
Puhae-myŏn 富海面
Puhŭng-dong 富興洞
Pujŏm-myŏn 富店面
Pukchin 北鎮
Pukch'ŏng-gun 北青郡
Pukhan-gang 北漢江
Pukhu-myŏn 北后面
Puksam-myŏn 北三面
Puksang-ni 北上里
Puksanoe-yangsu 北山外薬水
Puktuil-myŏn 北斗日面
Pulguk-sa 佛国寺
Pultanggol 佛堂谷
Punae-myŏn 府内面
P'unggi-myŏn 豊基面
P'ungha-myŏn 豊下面
P'ungjŏng 風亭
Pung-myŏn 北面
Pung-ni 北里
Puam 鳧岩
Pup'yŏng 富平
Pura-myŏn 府羅面
Puryŏng-gun 富寧郡
Pusan 釜山
Pusŏng-ni 富盛里
Pusung-dong 富崇洞
Puyong-myŏn 芙蓉面
P'yoga-san 表哥山
Pyŏksŏng-myŏn 碧城郡
Pyŏlgŭm-ni 別衾里
P'yŏngan 平安
P'yŏngan-namdo 平安南道
P'yŏngbuk 平北
P'yŏngbuk mine 平北鉱山
P'yŏngch'ang 平昌
P'yŏngch'ang-gun 平昌郡
P'yŏnggang 平康
P'yŏnggang-gun 平康郡
P'yŏngnam 平南
P'yŏngp'ung-san 屏風山
P'yŏngsan 平山
P'yŏngt'anji 平湯池
P'yŏngwŏn 平原
P'yŏngwŏn-gun 平原郡
P'yŏngyang 平壌

S

Sa-bong 沙峰
Sach'ang-ni 史倉里

Sach'i-ri 沙峙里
Sach'ol-li 舍村里
Sach'ong-san 射庁山
Sa-dong 寺洞
Sadangmol 祠堂隅
Sado-san 四道山
Saenggŭm-ni 生金里
Sainjang 舍人場
Sakchu-gun 朔州郡
Sakkok 朔谷
Sakkŭm-ni 遡衾里
Samch'ŏl-li 蔘川里
Samch'ŏk 三陟
Samch'ŏk-kun 三陟郡
Samch'ŏn 酸泉
Samch'ŏn 三泉
Samdŏk 三德
Samdŭng 三登
Samgul-li 三斤里
Samhwa-myŏn 三和面
Samjang-myŏn 三長面
Samjŏng mine 三政鉱山
Samno 三路
Samsal-li 三山里
Samsang-dong 三湘洞
Samul-li 寺門里
Sanae-myŏn 史内面
Sangangaji 上安哥地
Sangdŏkku 上德邱
Sanggo 上古
Sangmo-myŏn 上芼面
Sangmu-myŏn 上茂面
Sangnong-ni 上農里
Sangnyŏng-myŏn 朔寧面
San'gok-tong 山谷洞
Sangp'al-tong 上八洞
Sangp'ung mine 上豊鉱山
Sangwŏl 常越
Sangwŏl-tong 上月洞
Sangwŏn 祥原
Sangwŏn-ŭp 祥原邑
Sanhyŏl-li 山峴里
Sanmyŏng-ho 山明湖
Sannae-myŏn 山内面
Sansŏ-ri 山西里
Sariwŏn 沙里院
Sat'anji 舍湯池
Sat'ansu 砂湯水
Sayang-ni 舍陽里
Sech'ŏn 細川
Segong-myŏn 細谷面
Sŏhojin 西湖津
Simch'ŏn-dong 深川洞
Simgi-ri 深基里
Sinam-dong 新岩洞
Sinam-myŏn 新岩面
Sinanju-myŏn 新安州面
Sinbung-myŏn 新北面
Sinch'ang 新倉
Sinch'ŏn 信川
Sindae-ri 新垈里
Sin-dong 新洞
Sindong-myŏn 新東面
Sindŏng-ni 新德里
Sinhŭng mine 神興鉱山
Sinhŭng-myŏn 新興面
Sinju 信州
Sinma-dong 新麻洞
Sinmak 新幕
Sinmak-tong 新幕洞
Sinnamch'ŏl-li 新南川里
Sinp'ung-myŏn 新豊面
Sinp'yŏng-dong 新坪洞
Sinsam-ni 新三里
Sint'anjin 新灘津
Sinŭiju 新義州
Sibijup-san 十二輯山
Sobaeng-myŏn 小白面
Sobuk-dong 小北洞
Soch'ŏn-myŏn 小川面
Sodŏk mine 昭德鉱山
So-dong 小洞
Sodŭngnyŏng-dong 小登峯洞
Sŏgŭi-ni 西綺里
Sŏgwangsa-yangsu 釈王寺薬水
Soggyŏlsu 小結水
Sŏha-myŏn 西河面
Soha-ri 召下里
Sŏhŭng-gang 瑞興江
Sŏjŏng-ni 西亭里
Sokhu-myŏn 俗厚面
Sŏktal-li 石達里

Sŏktam 石潭
Sŏkt'anji 石湯池
Solbong 松峰
Sŏlhwa-san 雪花山
Somin-dong 蘇民洞
Sŏ-myŏn 西面
Sŏnam 仙岩
Sŏngch'ŏn 成川
Sŏngch'ŏn-gun 成川郡
Sŏngdae-myŏn 星台面
Sŏngdŏk 城徳
Songgye-ri 松界里
Songgye-ri 松溪里
Songhak-san 松鶴山
Songhŭng 松興
Songhwa 松禾
Songhyang-ni 松香里
Sŏngjin 城津
Sŏngjŏn mine 成田鉱山
Songjŏng-ni 松亭里
Songnae 松内
Songna-san 松羅山
Songnim-ni 松林里
Sŏn'gyo-ri 船橋里
Sŏnnyong 鮮龍
Sŏnsŏn 嬋妍
Sonyang-myŏn 巽陽面
Sŏsang-myŏn 西上面
Sŏsan-gun 瑞山郡
Sot'anji 小湯池
Ssangnyŏng 双龍
Suan 遂安
Suanbo 水安堡
Subi-myŏn 首比面
Such'ŏl-tong 水鉄洞
Sudong-myŏn 水洞面
Sugu-myŏn 水口面
Suha-myŏn 水下面
Suip 水入
Suju-myŏn 水周面
Sujung mine 水重鉱山
Sukch'ŏn 粛川
Sukch'ŏn-gun 粛川郡
Sunan-myŏn 順安面
Sunch'ŏn 順川
Sunch'ŏn-gun 順天郡
Sunga-san 崇峨山
Susan-myŏn 水山面
Susin-myŏn 修身面
Suwŏn-gun 水原郡

T

Taeam 大岩
Taebaek-san 大白山
Taebo-myŏn 大宝面
T'aech'ŏn-gun 泰川郡
Taedal-li 大達里
Taedang mine 大当鉱山
Taedŏk-kun 大徳郡
Taedong-gang 大同江
Taedong-gun 大同郡
Taegang-myŏn 大崗面
Taegyo-ch'ŏn 大橋川
Taehwa mine 大華鉱山
T'aejawŏn 太子院
Taejŏn-gun 大田郡
Taeryŏng-dong 大岺洞
Taeryong-dong 大龍洞
Taesal-li 大山里
Taesan-myŏn 大山面
Taesŏngji 大城趾
Taesŏng-ni 大成里
Taesŏng-ni 大聖里
Taesŏng-san 大聖山
Taesŭngbang-dong 大勝芳洞
Taeya-ri 大也里
Taeyu 大有
Tahak-tong 多鶴洞
Tajihol mine 多知忽鉱山
Talchŏlli mine 達田里鉱山
Talch'ŏn 達泉
Talgok 達谷
Talli-dong 達利洞
T'allok mine 丹緑鉱山
Talsŏng-gun 達城郡
Tanch'ŏn-gun 瑞川郡
T'angjisu 湯池水
Tanje mine 丹堤鉱山
T'anjŏng 湯井
Tannok mine 丹緑鉱山
Tannong line 端農線
Tanp'ung 端豊

Tansŏng	端城
Tanyang-myŏn	丹陽面
T'apko-ri	塔距里
Toch'i	都峙
Todu-san	都頭山
Togo-myŏn	道高面
Tŏgwŏn	德源
To-hyŏn	刀峴
Tŏkchae	德在
Tŏkch'ŏn	德川
Tŏkha-ri	德下里
Tŏksan	德山
Tŏktong-ni	德洞里
Tolpinul	石鱗
Tomok-tong	都目洞
T'ongch'ŏn	通川
T'ongch'ŏn-gun	通川都
Tonggong-ni	桐谷里
Tonghyan-myŏn	銅鄕面
Tongjin-myŏn	東津面
Tŏngmong-ni	德木里
Tongmol	德隅
Tong-myŏn	東面
Tongnae	東萊
Tongno-myŏn	東魯面
Tongsong-myŏn	東松面
T'osal-li	兎山里
Tul-li	屯里
Tuman-gang	豆滿江
Tŭngch'angŏgu	登晶於ㅁ
Turyu-san	頭流山
Tuwŏl	斗月

U

Ŭiju	義州
Ŭiju-gun	義州郡
Ŭiyŏn-myŏn	委延面
Ulchin-gun	蔚珍郡
Ŭllungdo	鬱陵島
Ŭllyong	銀龍
Ŭllyong-dong	隱龍洞
Ŭmdŏng-myŏn	陰德面
Ŭmnae-myŏn	邑內面
Unbong-myŏn	雲峰面
Unbong-ni	雲峰里
Ŭnch'ol-li	隱泉里
Ŭnch'ŏng-myŏn	銀川面
Ŭngok mine	銀谷鉱山
Ungyo-ri	雲橋里
Unhang	雲頂
Ŭnhong-myŏn	銀紅面
Unhŭng-dong	雲興洞
Unhŭng-yangsu	雲興藥水
Ŭnjin-myŏn	恩津面
Ŭnjŏk	銀積
Unp'yŏng-ni	雲坪里
Unsal-li	雲山里
Unsan	殷山
Unsan-gun	雲山郡
Ullyong-ni	雲龍里

W

Wanggung-myŏn	王宮面
Wangjing-myŏn	旺澄面
Wiing-myŏn	衛益面
Wiwŏn	渭原
Wiyŏng-dong	威靈洞
Wŏlha-dong	月下洞
Wŏl-li	院里
Wŏndŏng-myŏn	遠德面
Wŏn-myŏn	院面
Wŏnnam-myŏn	遠南面
Wŏnp'yŏng-dong	院坪洞
Wŏnsan	元山
Wŏndŏng-ni	元德里
Wŏnnyu-ri	元柳里

Y

Yangdŏk	陽德
Yangdong-myŏn	陽東面
Yanghwa-myŏn	两花面
Yanghwa-myŏn	陽化面
Yangjang mine	良蔵鉱山
Yangp'yŏng-gun	楊平郡
Yangsal-li	陽山里
Yangsa-myŏn	暘社面
Yangsa-myŏn	两寺面
Yangsu	藥水
Yangyang-gun	襄陽郡
Yesan-gun	礼山郡
Yesŏng-gang	礼成江
Yŏhang-myŏn	艅航面

Yŏju 驪州
Yŏmisan mine 女美山鉱山
Yŏnan 延安
Yŏnbaek-kun 延白郡
Yŏnch'ŏn-gun 漣川郡
Yŏndae-dong 煙台洞
Yŏndu-bong 燕頭峰
Yongbong-ni 龍鳳里
Yŏngbung-myŏn 英北面
Yŏngbyŏn-gun 寧辺郡
Yŏngch'ŏl-li 永川里
Yongch'ŏn 龍泉
Yŏngch'ŏn 霊泉
Yongch'ŏn-gun 龍川郡
Yŏngch'ŏn-gun 永川郡
Yŏngch'ŏn-myŏn 霊泉面
Yŏngdae-ri 霊台里
Yongdam-ni 龍潭里
Yongdang-ni 龍塘里
Yŏngdŏk-kun 盈徳郡
Yongdong 龍洞
Yongdang-dong 龍塘洞
Yonggang 龍岡
Yonggye-ri 龍溪里
Yŏnghae 寧海
Yŏnghŭng-gun 永興郡
Yonghŭng-myŏn 龍興面
Yonghwa-dong 龍華洞
Yonghwa-dong 龍化洞
Yonghwa-san 蓮花山
Yŏn'gi-gun 燕岐郡
Yongjŏng 龍井
Yŏngju-gun 栄州郡
Yŏngju-ŭp 栄州邑
Yongmun-myŏn 龍門面
Yŏngok 連谷
Yŏn'gol 錬洞
Yŏn'gong-ni 連谷面
Yŏngp'ung-ch'ŏn 永豊川
Yongsan-myŏn 龍山面
Yongso-dong 龍沼洞
Yongsŏng-myŏn 龍城面
Yŏngsŏng-ni 永成里
Yongt'aek 龍沢
Yŏngt'ae-san 霊台山
Yŏngwŏl 寧越
Yŏngwŏl-baengnyŏn mine 寧越百年鉱山
Yŏngwŏn 寧遠
Yŏngwŏn-gun 寧遠郡
Yŏngwŏn-onch'ang 寧遠温倉
Yŏngyang-gun 英陽郡
Yongyŏl-li 龍渕里
Yongyŏn 龍渕
Yŏngyu mine 永柔鉱山
Yŏnil 延日
Yŏnjŏng-myŏn 蓮井面
Yŏnju-ri 連珠里
Yŏnp'ung-myŏn 延豊面
Yŏnsan 連山
Yŏnsu mine 連寿鉱山
Yuhwa-dong 祐和洞
Yujŏm-sa 楡岾寺
Yukpaek-san 六百山
Yukyŏng 柳京
Yulla 栗蘿
Yulli-san 栗梨山
Yulp'o-dong 栗浦洞
Yusŏng 儒城

MANCHURIA and CHINA

(* Japanese name)

A

A-chia-kou	阿家溝
A-erh-ha-wo	阿爾哈倭
A-erh-ha-wo-chi-ling	阿爾哈倭集岭
A-li-ko-tu-ho	阿立各図河
A-lu-ko-erh-chin Chi	阿魯科爾沁旗
A-lun-ho	阿倫河
A-pu-hsin-ho	阿布心河
A-shih-ho	阿什河
A-tang (Ya-tang)	亜当
Ai-chuan	愛川
Ai-gun (Ai-hun)	愛琿
Ai-ho	靄河
Ai-hun (Ai-gun)	愛琿
*Aikawa	愛川
An-i	安邑
An-shan	鞍山
An-ta	安達
An-ting-men	安定門
An-tu Hsien	安図県
An-tung	安東
An-tung Hsien	安東県
An-tzu Shan	案子山
Ang-ang-chih	昻々溪

B

Barga	巴爾彦
Bayer Lake	貝爾湖

C

Cha-fang-tzu	茶房子
Cha-ha-erh (Chahar)	察哈爾
Cha-ho	察河
Cha-kou	岔溝
Cha-peng	茶棚
Cha-pu	茶舗
Cha-tzu-yao	炸子窰
Chahar (Cha-ha-erh)	察哈爾
Chai-ma-chi	寨馬集
Chang-cheng	長城
Chang-chia-kou	張家口
Chang-chia-pu-tzu	張家堡子
Chang-chun	長春
Chang-hsin-tien	長辛店
Chang-hsing Island (Chang-hsing-tao)	長興島
Chang-liang-tzu	長良子
Chang-ling-tzu	長岭子
Chang-pai-shan	長白山
Chang-san-ying	張三営
Chang-shan-ssu	長山寺
Chang-shan-tzu	長山子
Chang-tai-tzu	張台子
Chang-tien	張店
Chang-tsun	蔣村
Chang-tu	昌図
Chang-tzu-tuan	城子疃
Chao-chia-tun	趙家屯
Chao-ho	潮河
Chao-yang	朝陽
Chao-yang-chen	朝陽鎮
Chao-yang Hsien	朝陽県
Chao-yang-men	朝陽門
Cheng-chia-tun	鄭家屯
Cheng-te	承徳
Cheng-te	彰徳
Chi-an	輯安
Chi-chi-ha-erh	斉々哈爾
Chi-chia-fang	七家房
Chi-fu	芝罘
Chi-hsi	冀西
Chi-hsing-shan	七星山
Chi-hu-li	七虎力
Chi-hu-lin-ho	七虎林河
Chi-lao-tu	七老図
Chi-li-wa	七里窪
Chi-lin (Kirin)	吉林
Chi-nan (Tsi-nan)	済南
Chi-pan-me	棋盤磨
Chi-tao-kou	七道溝

Chi-ting-shan	七頂山
Chi-tung	冀東
Chia-chia-kou	賈家溝
Chia-mu-ssu	佳木斯
Chia-shan	甲山
Chiang-chia-tun	姜家屯
Chiang-su	江蘇
Chiao-tou	橋頭
Chien-chang	城廠
Chien-chang-ying-tzu	建昌営子
Chien-fo Shan	千仏山
Chien-jen-shan	仙人山
Chien-kuan-tun	前関屯
Chien-men	前門
Chien-pan-chuang	前藩莊
Chien-shan	千山
Chien-shan	尖山
Chien-shan-kou	尖山溝
Chien-shih-hui-yao-tun	前石灰窰屯
Chien-shih-hui-yao-tzu	前石灰窰子
Chien-shui-ting-tzu	域水頂子
Chien-ta-fang-shen	前大房身
Chien-ta-lien-tao	前大連島
Chien-tao	間島
Chien-tzu-shan	尖子山
Chih-feng	赤峰
Chin-chang-tun	金廠屯
Chin-chia	金家
Chin-chia-cheng-tzu	金家城子
Chin-chou	錦州
Chin-chou	金州
Chin-chou-pei-men	金州北面
Chin-chuan	金川
Chin-fu-kou	金福溝
Chin-hsi	錦西
Chin-hsien	金県
Chin-huang-tao	秦皇島
Chin-ku	錦古
Chin-lung-ting-tzu	金龍頂子
Chin-nan	晋南
Chin-niu Shan	金牛山
Ching-he-cheng	清河城
Ching-ho	清河
Ching-lung-ho	青龍河
Ching-peng	経棚
Ching-po Lake (Ching-po-hu)	鏡泊湖
Ching-shui	清水
Ching-tao	青島
Ching-yun-ho	青雲河
Chiou-ke-yu	九個峪
Chiu-hsin-hou	秋新後
Chiu-lien-cheng	九連城
Cho-erh-ho	綽爾河
Cho-su-ho	卓蘇河
Chou-chia-kou	周家溝
Chou-shan-tzu	周山子
Chou-shui-tzu	周水子
Chou-shui-tzu	臭水子
Chu-chuan-kou	珠圈溝
Chu-lin-ssu	竹村寺
Chuan-chia-pu-tzu	全家堡子
Chuan-chueh-fang	転角房
Chuan-shan-tzu	転山子
Chuan-shih-kou	転石溝
Chuan-shui-yen-tzu	泉水眼子
Chuan-shui	泉水
Chuang-mien-shan	壯年山
Chung-he-tien	中和店
Chung-ke-chen-pao	中革鎮堡
Chung-kung	中宮
Chung-ling-ssu	鐘霊寺
Chung-nan-hai	中南海
Chung-sheng-tang-shan	中生堂山

D

Dairen (Ta-lien)	大連
Dalai (Hu-lun) Lake	達頼(呼倫)湖
Dja-la-mu-teh	札拉木特
Dja-lai-no-erh	札賚諾爾
Dja-tun-ho	札敦河

E

E-kou-chen	峨口鎮
Erh-chan	二站
Erh-fo-miao	二仏庙
Erh-ko-shan	二克山
Erh-lung-wan	二龍湾
Erh-shih-li-tai	二十里台
Erh-tao-ho-tzu	二道河子
Erh-tao-kou	二道溝
Erh-tao-pai-ho	二道白河
Erh-tseng-tien-tzu	二層甸子

F

Fa-chung-men	法重門
Fa-ku	法庫
Fan-chia-tung	范家屯
Fan-chih	繁峙
Fan-chih-hsien	繁峙県
Fan-niu-kou	放牛溝
Fei-chia-tun	斐家屯
Fen-ho	汾河
Feng-chia-tun	馮家屯
Feng-huang-cheng	鳳凰城
Feng-huang Shan	鳳凰山
Feng-ming-tao	鳳鳴島
Feng-shan	奉山
Feng-tien	奉天
Fu-chin	富錦
Fu-chin-ling	福金岭
Fu-chou	復州
Fu-erh-kou	富児溝
Fu-hsin	阜新
Fu-Hsien	復県
Fu-lung-shan	富隆山
Fu-shun	撫順
Fu-sung	撫松

H

Ha-erh-pa-ling	哈爾巴岭
Ha-erh-pin (Harbin)	哈爾浜
Ha-la-ha-ho	哈拉哈河
Ha-ma-kou	哈嗎口
Ha-ma-shan	哈螞山
Ha-ma-tang-ho	哈螞塘河
Ha-wu-erh-ho	哈烏爾河
Hai-chou	海州
Hailar	海拉爾
Hai-lin	海林
Hai-lun	海倫
Hai-lung	海龍
Hai-lung-hsien	海龍県
Hai-miao-tuo-tzu	海猫砣子
Han-chia-chuang	韓家庄
Han-pe-ling	寒坡岭
Han-tan	邯鄲
Harbin (Ha-erh-pin)	哈爾浜
He-hua-wan	荷花湾
He-lan-kou	河欄溝
Hei-ho	黒河
Hei-hsia-tzu-kou	黒瞎子溝
Hei-hu-chuan	黒虎泉
Hei-lung-chiang	黒龍江
Hei-ni-ho	黒泥河
Hei-shan	黒山
Hei-shui	黒水
Hei-tao	黒島
Heng-tao-ho-tzu	横道河子
Ho-chia-tun	何家屯
Ho-kang	鶴崗
Ho-lo-huang-te	赫勒皇徳
Ho-lung Hsien	和龍県
Ho-nan	河南
Ho-pei	河北
Ho-pien-tsun	河辺村
Ho-tou-kou	河頭溝
Hou-shih-huei-yao-tun	後石灰窯屯
Hou-ti	後地
Hsi-cheng	西城
Hsi-chia-pao-tzu	西家堡子
Hsi-chiao-te-pu-shan	西焦得布山
Hsi-chien-shan	西尖山
Hsi-chung-tao	西中島
Hsi-ha-la-pa-shan	西哈拉巴山
Hsi-heng-tao-shan	西恒道山
Hsi-ho	細河
Hsi-hsiao-ho-yen	西小河沿
Hsi-kou	西溝
Hsi-liao-ho	西遼河
Hsi-lu-ka-ho	西路嘎河
Hsi-lung-men-shan	西龍門山
Hsi-ma-i Tao	西螞蟻島
Hsi-pai-tzu-lung-wan	西牌子龍湾
Hsi-piao	西票
Hsi-pien-men	西便門
Hsi-po-hu	錫伯河
Hsi-shan	西山
Hsi-ta-ting-shan	西大頂山
Hsi-tao	西島
Hsi-yao	西窯
Hsia-cheng-tzu	下城子
Hsia-chia-he-tzu	夏家河子
Hsia-hei-yu-kou	下黒魚溝
Hsia-niu-hsin-tai	下牛心台
Hsia-pao-tzu	下堡子

Hsiang-shui-ho 响水河
Hsiang-shuei-ssu 響水寺
Hsiao-chao-chia-tun 小趙家屯
Hsiao-chia-chi 小佳気
Hsiao-chin-chuan 小金川
Hsiao-ching Ho 小清河
Hsiao-ching-tsun 小井村
Hsiao-i-shan 小椅山
Hsiao-ko-shan 小克山
Hsiao-ku-shan 小孤山
Hsiao-ku-shan-tzu 小孤山子
Hsiao-li-chia-tun 小李家屯
Hsiao-lin-chia-tun 小林家屯
Hsiao-ling-ho 小凌河
Hsiao-lo-la-mi 小羅拉密
Hsiao-lung-wan 小龍湾
Hsiao-miao-kou 小庙溝
Hsiao-mu-ling-ho 小穆稜河
Hsiao-nan-kou 小南溝
Hsiao-pei-ho 小北河
Hsiao-pei-ho-chen 小北河鎮
Hsiao-sha-ho 小沙河
Hsiao-shih 小市
Hsiao-shih-tou-ho-tzu 小石頭河子
Hsiao-sui-fen-ho 小綏芬河
Hsiao-ssu-shan 小寺山
Hsiao-tan-ping-ho 小坦平河
Hsiao-tu-ko-chi-shan 小吐各吉山
Hsiao-tu-ko-erh-chi-shan 小吐各爾祭山
Hsiao-wen-chuan 小甕圈
Hsiao-yen-chih-feng 小臙脂峰
Hsiao-yin-chia-tun 小尹家屯
Hsieh-hsiao 斜哨
Hsien-chang 城廠
Hsin-chia-tun 辛家屯
Hsin-hsiang 新郷
Hsin-kai-ho 新開河
Hsin-kai-ling 新開岭
Hsin-min 新民
Hsin-tsao-ping 新草坪
Hsin-tun-tzu 辛屯子
Hsin-tung-kou 新洞溝
Hsing-an-ling 興安岭
Hsing-an-nan-shan 興安南山
Hsing-ching 興京
Hsing-kai-hu 興凱湖
Hsing-lung 興隆
Hsiu-yen 岫巖
Hsiung-yao-cheng (Hsiung-yueh-cheng) 熊岳城
Hsiung-yueh-cheng (Hsiung-yao-cheng) 熊岳城
Hsu-chia-tun 許家屯
Hsu-chou 徐州
Hsuan-hua 宣化
Hsuan-wu-men 宣武門
Hsun-chieh 訓戒
Hu-chia-kou 胡家溝
Hu-lan-ho 呼蘭河
Hu-lu-lung-wan 葫芦龍湾
Hu-to Ho 滹沱河
Hu-yu-erh-ho 呼裕爾河
Hua-chin 化津
Hua-chuan 樺川
Hua-shu-lin-tzu 樺樹林子
Hua-tien 樺甸
Hua-tung 華銅
Hua-tung-kou 化銅溝
Huan-jen 桓仁
Huan-jen-hsien 桓仁県
Huang-chi 黄旗
Huang-chi-kou 黄旗溝
Huang-chia-pao-tzu 黄家堡子
Huang-hai (Yellow Sea) 黄海
Huang-ho 黄河
Huang-i-shan 黄椅山
Huang-ni-chuan 黄泥川
Huei-nan (Hui-nan) 輝南
Huei-shan 灰山
Hui-ho 輝河
Hui-nan (Huei-nan) 輝南
Hui-ning 会寧
Hulunbayer 呼倫貝爾
Hun-chiang 渾江
Hun-chiang-kou 渾江口
Hun-chun-ho 琿春河
Hun-ho 渾河
Hung-lien-kou 紅瞼溝
Hung-miao-tzu-shan 紅庙子山
Hung-tu-ya-he-kou-kai 紅土崖河口街
Hung-yao 紅窯
Huo-lien-chai 火連寨

Huo-shao-shan 火燒山
Huo-shen-miao 火神庙

I

I 沂
I-chia-shan 一架山
I-chou 義州
I Hsien 義県
I-lan 依蘭
I-ma-tu-ho 蟻嗎吐河
I-mien-po 一面坡
I-mien-shan 一面山
I-min-ho 伊敏河
I-tung 伊通
I-tung-ho 伊通河

J

Je-ho (Jehol) 熱河
Jehol (Je-ho) 熱河
Jen-ho-pu 人和堡
Jen-tou-shan 人頭山
Jung-ho 栄河

K

Ka-tsung 嘎叢
Ka-ya-ho 嘎呀河
Kai-feng 開封
Kai-lu 開魯
Kai-luan 開滦
Kai-ping 蓋平
Kai-shan-tun 開山屯
Kai-tung 開通
Kai-yuan 開原
Kan-chang-kou 城廠溝
Kan-chia-tun 干家屯
Kan-ching-tzu 甘井子
Kan-chu-erh-miao 甘珠爾庙
Kan-ho 甘河
Kan-kuei 甘魁
Kan-su 甘肅
Kang-chia 康家
Kang-ping 康平
Kang-ta-jen-tun 康大人屯
Kang-tzu-tien 崗子店
Kang-yao 缸窰
Kang-yao-ling 缸窰岭
Kao-chia-tun 高家屯
Kao-li-ching-tzu 高力井子
Kao-li-feng-chu 高力坎具
Kao-ling 高岭
Kao-ling-tzu 高岭子
Kao-shan-tun 蠏山屯
Ke-chen-pao 革鎮堡
Ken-ho 根河
Ken-teh (Kento) 肯特
Kento (Ken-teh) 肯特
Kerlen (Ko-lu-lun) 克魯倫
Kirin (Chi-lin) 吉林
Ko-lo 科洛
Ko-lo-chan 科洛站
Ko-lo-nan-shan 科洛南山
Ko-lu-lun (Kerlen) 克魯倫
Ko-shih-ko-ten Chi 克什克騰旗
Ko-tung 克東
Ko-tung-hsien-cheng 克東県城
Kou-chuan 口泉
Ku-an 固安
Ku-chia-kou 胡家溝
Ku-chia-tzu 孤家子
Ku-hsiang-tun 顧鄉屯
Ku-shan 崮山
Ku-shan-tzu 孤山子
Ku-tsang-kou 庫倉溝
Kuan-chuang 官莊
Kuan-tien 寬甸
Kuan-tso-ling 官挫岭
Kuan-ti-tsun 官地村
Kuan-tung Province 関東州
Kuang-ning-ssu 広寧寺
Kuei-ho 魁河
Kung-chang-ling 弓張岭
Kung-chia-pu-tzu 孔家堡子
Kung-chu-ling 公主岭
Kung-pie-la-ho 公別拉河
Kuo-chia-chai 郭家寨
Kuo-tou-ku 鍋頭峪

L

La-fa-ho 拉法河
La-ma-shan 喇嘛山
La-shu-shan 拉樹山
Lan-ho 藍河

Lan-ku-shan 嵐崮山
Lang-fang 郎坊
Lang-tung Shan 狼洞山
Lang-tzu-shan 狼子山
Lao-chang-kuang-ssu-ling (Lao-chang-kuang-suei-ling) 老張広歲岭
Lao-ha-ho 老哈河
Lao-hei-shan 老黑山
Lao-hsi-kuan 老西関
Lao-kuan-tzu-kou 老獾子溝
Lao-mei-tung-kou 老煤洞溝
Lao-shan-tou 老山頭
Lao-sung-ling 老松岭
Lao-tao-kou 老道溝
Lao-teng-tai 老燈台
Lao-tu-ting-tzu-shan 老禿頂子山
Lao-tzu-kou (Lo-tzu-kou) 羅子溝
Lao-yeh-miao 老爺庙
Lao-yen-kang 老奄崗
Lao-yeh-ling 老爺岭
Lao-yu-fang 老油房
Lei-shan 磊山
Li-chia-pu-tzu 李家堡子
Li-chia-suei-tzu 李家歲子
Li-chia-tun 李家屯
Li-chia-we-peng 李家窩棚
Li-chia-yao 李家窯
Li-kuan-tsun 李官村
Li-liao-ho 裸遼河
Li Shan 歷山
Li-shan-tao-kou 裏山道溝
Li-shu 梨樹
Li-shu-chen 梨樹鎮
Li-shu-kou 梨樹溝
Li-tai-fang 李太房
Liang-chia-tien 亮甲店
Liang-shui-ho 凉水河
Liang-yen-ching 両眼井
Liao-chung 遼中
Liao-ho 遼河
Liao-ning-sheng 遼寧省
Liao-tung 遼東
Liao-yang 遼陽
Lien-ho 連河
Lien-hua-shan 蓮花山
Lien-shan-kuan 連山関
Lin-chia 林家
Lin-chia-pao-tzu 林家堡子
Lin-chia-suei-tzu 林家歲子
Lin-chia-wei-tzu 林家威子
Lin-chiang 臨江
Lin-fen 臨汾
Lin-hsi 林西
Ling-nan 凌南
Ling-yuan 凌源
Liou-shu-tun 柳樹屯
Liou-tang (Liu-tang) 柳塘
Liu-chia-tun 劉家屯
Liu-ku-ho 六股河
Liu-tang (Liou-tang) 柳塘
Lo-chia-shan 羅家山
Lo-tzu-kou (Lao-tzu-kou) 羅子溝
Lo-yang 洛陽
Lu-an 潞安
Lu-chia-tun 芦家屯
Lu-chia-tun 呂家屯
Lu-chuan-tzu 鹿圈子
Lu-li-ho 琉瑠河
Lu-pei 魯北
Lu-shun 旅順
Lu-tai 旅大
Luan-ho 滦河
Lung-chen 龍鎮
Lung-chiang 龍江
Lung-hua 隆化
Lung-kang 龍崗
Lung-kang-shan 龍崗山
Lung-tou 龍頭
Lung-wan 龍湾
Lung-wan-miao 龍王庙
Lung-wang-tan 龍王潭
Lung-wang-tang 龍王塘
Lung-yen 龍烟
Luo-han-ku 羅寒窟
Luo-tuo-shan 駱駝山

M

Ma-an-shan 馬鞍山
Ma-chia-chuang-tzu 馬家庄子
Ma-chia-kou 馬家溝
Ma-chia-tun 馬家屯

Ma-fang-chen 馬房鎮
Ma-i-tsun-kou 螞蟻村溝
Ma-lan 馬蘭
Ma-pan-shan 礤盤山
Ma-pi-chiang-kou 馬皮匠溝
Ma-tai-kou 馬太溝
Ma-tien-ling 摩天岭
Man-chiang 漫江
Man-chou-li 滿州里
Mao-shan 茂山
Meng-chia-pao-tzu 孟家堡子
Meng-chiang 濛江
Mergen (Mo-erh-ken) 墨爾根
Miao-erh-kou 庙児溝
Miao-kou 庙溝
Miao Tao 庙島
Mien-yang-tien-tzu-shan 綿羊頂子山
Ming-cheng 明城
Ming-shan-kou 明山溝
Mo-erh-ken (Mergen) 墨爾根
Mo-erh-ko-ho 墨爾格河
Mo-erh-ko-lo-ho (Morkoho) 黑爾格勒河
Mo-ku-yuan-tzu 蘑菰円子
Mo-la-pu-shan 莫拉布山
Mo-li-chiang-shan 莫里清山
Morkoho (Mo-erh-ko-lo-ho) 墨爾格勒河
Mo-tien-yu 摩天隅
Mu-la-tung-tzu-shan 木羅通子山
Mu-leng 穆稜
Mu-leng-ho 穆稜河
Mu-ling-wo-chi-ling 穆稜窩集岭
Mu-tan-chiang 牡丹江

N

Nai-tou-shan 仍頭山
Nan-fen 南坟
Nan-hai-ma-tou 南海碼頭
Man-ko-la-chu-shan 南格拉球山
Nan-kou 南溝
Nan-kou-yu 南口峪
Nan-kuan-ling 南関岭
Nan-ling 南岭
Nan-lung-wan 南龍湾
Nan-piao 南票
Nan-shan 南山
Nan-ta-feng 南大峰
Nan-ta-wa Shan 南大凹山
Nan-ti-tzu 南狄子
Nao-pao-shan 鬧宝山
Nen-chiang 嫩江
Niang-niang-kou 娘々溝
Nien-tzu-shan 碾子山
Ning-an 寧安
Ning-ku-ta 寧古塔
Niu-hsin-tai 牛心台
No-min-ho 諾敏河
No-mo-erh-ho (Nomorho) 訥謨爾河
Nomorho (No-mo-erh-ho) 訥謨爾河
Nu-erh-ho 女児河
Nung-chia 能家

P

Pa-chia-shan 八家山
Pa-hu-li 八虎力
Pa-lin-chiao 巴林橋
Pa-lin-tso-i Chi 巴林左翼旗
Pa-pan-ling 八盤岭
Pa-pao-shan 八宝山
Pa-ta-ling 八達岭
Pa-tao-chiang 八道江
Pa-tao-kou 八道溝
Pa-wang-shan 八王山
Pa-yen-chieh 巴彦街
Pa-yen-wu-lan-feng 巴顔五藍峰
Pai-chia-shan 白家山
Pai-chia-tun 白家屯
Pai-chuan 拜泉
Pai-ho 白河
Pai-hsing-chai 白康寨
Pai-miao-tzu 白庙子
Pai-shih-la-tzu-shan 白石拉子山
Pai-tou-shan 白頭山
Pai-tsai-ti 白菜地
Pai-tzu-shan 白子山
Pai-yang-mu-kou 白楊木溝
Pai-yang-ting 白洋淀
Pai-yen 白岩
Pai-yin-tai-lai 白音太来
Pan-chia-hsi-kou 潘家西溝
Pan-chiao 板橋
Pan-chieh-ho 半截河
Pan-chuan-tzu 半圈子

Pan-la-chiang 半拉江
Pan-la-tao 半拉島
Pan-ling 蟠岑
Pan-pan-lung-wan 板板龍湾
Pao-chi-tao 薄箕島
Pao-chia-wa-tzu 鮑家窪子
Pao-ho 瀑河
Pao-kuo-tu 宝国図
Pao-te 保徳
Pao-ti 宝砥
Pao-ting 保定
Pao-tou 包頭
Pao-tu-chuan 跑突泉
Pei-an 北安
Pei-ha-la-pa-shan 北哈拉巴山
Pei-hai 北海
Pei-ho-pu 北河舗
Pei-hsiang 北郷
Pei-hu 北湖
Pei-Pei-ko-la-chiu-shan 北格拉球山
Pei-ma-chuan-tzu 北馬圏子
Pei-piao 北票
Pei-ping 北京
Pei-ping-hsi-shan 北京西山
Pei-ta-la-tzu-shan 北大拉子山
Pei-ta-ling 北大岑
Peitai 北台
Pei-tai-he 北太河
Pe-tai-kou 北台溝
Pei-tai-yang 北太洋
Pen-chi (Pen-hsi) 本溪
Pen-chi-hu (Pen-hsi-hu) 本溪湖
Pen-hsi (Pen-chi) 本溪
Pen-hsi-hu (Pen-chi-hu) 本溪湖
Ping-shan-chen 鳳山鎮
Pi-chia-kou 筆家溝
Pi-chia-shan 筆架山
Pi-li-ho 畢利河
Pi-liu Ho 碧流河
Pi-pu-hsien Pass 貔普見峠
Pi-tzu-we 貔子窩
Pien-ling 偏岑
Pien-ling-pao-tzu 偏岑堡子
Pin-chiang 浜江
Ping-chuan 平泉
Ping-hsien 浜県
Ping-shan 平山
Ping-shih-yen 兵使岩
Ping-sui 浜綏
Ping-ting-shan 平頂山
Po-hai (Gulf of Chihli) 渤海
Po-li 勃利
Po-li-shan 玻璃山
Po-po-tu-shan 餑吐山
Po-tu-na 伯都納
Pu-chi-szu 普済寺
Pu-hsi 布西
Pu-lan-tien 普蘭店
Pu-shih-ho 蒲石河
Pu-tao-chia-ling-tzu 葡萄架岑子

R

*Roppyakuzan 六百山

S

Sa-ha-liang 薩哈亮
Sa-ha-liang-ling 薩哈亮岑
San-cha-ho 三叉河
San-cha-tzu 三岔子
San-chan 三站
San-chia-tzu 三家子
San-chiang-kou 三江口
San-chiao-lung-wan 三角龍湾
San-chien-tzu-shan 三尖子山
San-ching-kung 三清宮
San-ho 三河
San-hsing 三姓
San-ling-shan 三稜山
San-ke-ling 三箇岑
San-kuan-miao 三官庙
San-leng-shan 三稜山
San-men 三門
San-shih-li-pu 三十里堡
San-tao-he-tzu 三道河子
San-tao-kang-tzu 三道崗子
San-tao-yang-chia 三道陽岔
San-tung-ho 三統河
Sha-ho 沙河
Sha-ho-chen 沙河鎮
Sha-kuo-tun 沙鍋屯
Sha-ti-erh-shan 沙的爾山
Sha-tu 沙禿

Shan-cheng-chen 山城鎮
Shan-cheng-kou 山城溝
Shan-cheng-tzu 山城子
Shan-hai-kuan 山海関
Shan-hsi 山西
Shan-tien-ho 閃電河
Shan-tung 山東
Shang-fu-erh-kou 上富児溝
Shang-niu-hsin-tai 上牛心台
Shang-pien 上辺
Shang-shan-tzu 响山子
Shang-tsai-hsiu-tung 上彩秀洞
Shang-tzu-miao 上子庙
Shatir 沙的爾
She-li-ko-ho 舍利喝河
Shen-we 身窩
Shih-cha-hai 十刹海
Shih-chia-chuang 石家莊
Shih-chia-kang 史家崗
Shih-chiao-tzu 石橋子
Shih-ching-shan 石景山
Shih-hui-li 石灰裡
Shih-men-tzu-shan 石門子山
Shih-po-tung 石坡洞
Shih-san-li-tai 十三里台
Shih-san-li-tun 十三里屯
Shih-tzu-ping 獅子坪
Shou-shan 首山
Shuang-chuan-szu 双泉寺
Shuang-shan 双山
Shuang-yang-ho 双陽河
Shuang-yang-tung-ho 双陽洞河
Shuei-chuan-tzu 水泉子
Shuei-yu-kou 水峪溝
Shun-te 順德
Ssu-chan 四站
Ssu-chia-tzu 四家子
Ssu-li Shan 四里山
Ssu-ping 四平
Ssu-ping-chieh 四平街
Su-chia-tun 蘇家屯
Su-mu-ho 蘇木河
Su-tzu-ho 蘇子河
Sui-fen-ho 綏芬河
Sun-chia-tun 孫家屯
Sung-chia-tun 宋家屯
Sung-chiang 松江
Sung-ho 松河
Sung-hua-chiang (Sungari) 松花江
Sung-ling 松岭
Sung-pi-la-ho 孫畢拉河
Sung-shu 松樹
Sung-shu-chen 松樹鎮
Sung-shu-mao 松樹卯
Sung-shu-pai 松樹排
Sung-shu-tai 松樹台
Sung-te-ssu 宗德寺
Sung-wan 松湾
Sungari (Sung-hua-chiang) 松花江
Szu-ping-kai 四平街

T

Ta-chang-shan-tao 大長山島
Ta-chang-tzu 大障子
Ta-cheng-chia-tun 大鄭家屯
Ta-cheng-feng 大正峰
Ta-cheng-tzu 大城子
Ta-ching-shan 大青山
Ta-ching-tsun 大井村
Ta-erh-kan Chi 達爾罕旗
Ta-fang-shen 大房身
Ta-hei-shan 大黑山
Ta-ho-shang-shan 大和尚山
Ta-hsi-cha 大西岔
Ta-hsi-kou-shan 大西溝山
Ta-hsing-an-ling 大興安岭
Ta-huang-kou 大荒溝
Ta-huang-pai-yu 大黃柏峪
Ta-hun-ho 大渾河
Ta-i-shan 大椅山
Ta-l**an**ɜ-ling 大崗岭
Ta-ko-tsang 大疙瘩
Ta-ku-miao 大姑庙
Ta-ku-shan 大谷山
Ta-ku-shan 大孤山
Ta-ku-shan-tzu 大孤山子
Ta-liao-ho 大遼河
Ta-lien (Dairen) 大連
Ta-lin-chia-tun 大林家屯
Ta-ling 大岭
Ta-ling-ho 大凌河
Ta-lu-chia-tun 大盧家屯
Ta-luan-ho 大滦河

Ta-lung-wan	大龍湾
Ta-lung-wan-shan	大龍湾山
Ta-mao-ying-tzu	大毛塋子
Ta-ming-hu	大明湖
Ta-pan-shang	大板上
Ta-pao-tzu	大砲子
Ta-pu	大堡
Ta-sha Ho	大沙河
Ta-shih-chiao	大石橋
Ta-shui-yen	大水彦
Ta-sui-fen-ho	大綏芬河
Ta-tien-tzu	大甸子
Ta-tu-ko-erh-chi-shan	大吐各爾祭山
Ta-tu-ko-chi-shan	大吐各吉山
Ta-tun	大屯
Ta-tun-ping-ling-shan	大屯平岑山
Ta-tun-ping-ting-shan	大屯平頂山
Ta-tun-tung-shan	大屯東山
Ta-tung	大同
Ta-tung-kou	大東溝
Ta-tung-kou	大通溝
Ta-wang	大汪
Ta-wang-chia-tun	大王家屯
Ta-wang-shan	大王山
Ta-wei-chia-tun-huei	大魏屯会
Ta-yao-kou	大窰溝
Ta-yen-chih-feng	大臙脂峰
Ta-yu	大峪
Ta-yu-kou	大峪溝
Ta-yu-shan	大楡山
Tai-an	泰安
Tai-chou	代州
Tai Hsien	代県
Tai-hsing Mts.	太行山脉
Tai-huai-chen	台懐鎮
Tai-ma-kou	代馬溝
Tai-ping-hsiao	太平哨
Tai-ping-kou	太平溝
Tai-ping-ling	太平岑
Tai-shan	台山
Tai Shan	泰山
Tai-tzu-ho	太子河
Tai-yuan	太原
Tang-chia-kou	董家溝
Tang-chia-tun	糖家屯
Tang-chia-tzu	唐家子
Tang-chin-kou	譚金溝
Tang-he-yen	湯河沿
Tang-ho	湯河
Tang-hsien	唐県
Tang-ku	塘沽
Tang-mao-tzu-shan	唐帽子山
Tang-shan	湯山
Tang-shui-chang	湯水長
Tang-shui-ping	湯水平
Tao-erh-ho	洮爾河
Tao-erh-shan	桃児山
Tao-kou-tzu	陡溝子
Tao-li-ho	撓力河
Tao-nan	洮南
Tao-shan	桃山
Tao-yuan-kou	陶円溝
Te-chang-tzu	鉄廠子
Te-erh-pu-erh-ho	得爾布爾河
Te-hsien	得県
Te-sheng-men	徳勝門
Te-tu	徳都
Tei-li-szu	得利寺
Teng-chia-wang	騰家旺
Teng-sha-ho	登沙河
Tiao-hu-tzu (Tiao-hu-tsui)	刀虎咀
Tiao-shui-lou	吊水樓
Tiao-yu-shan	釣魚山
Tiao-yu-tai	釣魚台
Tieh-cha Shan	鉄叉山
Tieh-chang-tzu	鉄廠子
Tieh-ling	鉄岑
Tieh-pei-shan	鉄背山
Tien-chiao-shan	天橋山
Tien-chih	天池
Tien-chin	天津
Tien-chuang-tai	田荘台
Tien-shan-pao	鉄山包
Tien-shih-fu-kou	田師付溝
Tien-ting-shan	天頂山
Tien-tzu-shan	鉄子山
Ting-chia-tun	丁家屯
Ting-hsiang	定襄
To-lun	多倫
To-lun-hsien	多倫県
To-lun-no-erh	多倫諾爾
Tou-chan	頭站

Tou-fang-kou 豆房溝
Tou-man-chiang (Tu-men-chiang) 豆満江
Tou-tsun 竇村
Tsai-chia 彩家
Tsai-chia-shan 蔡家山
Tsai-chia-tun 彩家屯
Tsai-hsiu-ling 彩秀岭
Tsan-chang-tien 蚕廠店
Tsao-he-tang 草河堂
Tsao-lai-ho 走萊河
Tsao-shih 草市
Tseng-yen 層岩
Tsi-nan (Chi-nan) 済南
Tsitsihar (Chi-chi-ha-erh) 斉々哈爾
Tsung-wang-miao 従王庙
Tu-chuan 突泉
Tu-hu-lu-shan 禿葫芦山
Tu-ling-kou 土岭口
Tu-men 図們
Tu-men-chiang (Tou-man-chiang) 豆満江
Tuan-shan-tzu 団山子
Tuan-tzu-shan 団子山
Tuei-mien-shan 対面山
Tun-hua 敦化
Tung-an 東安
Tung-cheng 東城
Tung-chi-men 東直門
Tung-chia-kou 董家溝
Tung-chiang 同江
Tung-chien-shan 東尖山
Tung-chiao-te-pu-shan 東焦得布山
Tung-ching-cheng 東京城
Tung-chou 通州
Tung-ha-la-pa-shan 東哈拉巴山
Tung-hai 東海
Tung-hai-ma-tou 東海碼頭
Tung-heng-tao-shan 東恒道山
Tung-ho 通河
Tung-hua 通化
Tung-ken-ho 通肯河
Tung-liao 通遼
Tung-liao-ho 東遼河
Tung-lung-men-shan 東龍門山
Tung-lung-wan 東龍湾
Tung-men 東門
Tung-ning 東寧
Tung-pien-men 東便門
Tung-pien-tao 東辺道
Tung-pin 同賓
Tung-shan 東山
Tung-ta Ho 東大河
Tung-ta-ling 東大岭
Tung-ta-tai-shan 東大台山
Tung-yang-chia-tzu 東楊家子
Tung-yao 東窯
Tung-yeh-chen 東冶鎮
Tung-yu 東峪
Tzu-erh-shan 茨児山

U

Uyunhordongi 烏雲和爾冬吉

W

Wa-fang-tien 瓦房店
Wai-tou-shan 歪頭山
Wan-cheng-shan 王城山
Wan-chuan 万泉
Wan-fang-tien 瓦房店
Wan-jung 万栄
Wan-kou 湾溝
Wan-shou-shan 万寿山
Wan-ta 完達
Wan-ta-shan 完達山
Wan-wan-kou 湾々溝
Wang-chia-pu-tzu 王家堡子
Wang-chia-tun 王家屯
Wang-chia-wei-tzu 王家隈子
Wang-hai-feng 望海峰
Wang-kuang-kou 王官溝
Wang-niu-pao-tzu 汪牛泡子
Wang-pa-shan 王八山
Wang-tien-hou 望天吼
We-lung 臥龍
We-lung-tun 臥龍屯
Wei 濊
Wei-chang 囲場
Wei-chia-kou 魏家溝
Wei-ning-cheng 威寧城
Wei-shan 尾山
Wei-tzu-kou 葦子溝

Wen-chuan 甕圈
Wo-hu-shan 臥虎山
Wo-ken-ho 倭肯河
Wo-na-ho 倭那河
Wu-chi-mi-ho 烏吉密河
Wu-chia-tun 吳家屯
Wu-erh-sun-ho 烏爾遜河
Wu-hang-shan (Wu-hsing-shan) 五行山
Wu-hsing-pai-tzu Shan 五姓牌子山
Wu-hsing-shan (Wu-hang-shan) 五行山
Wu-hu-tsuei 五湖嘴
Wu-hu-tsui 五湖咀
Wu-ko-no-erh 吳克諾爾
Wu-lung-shan 五龍山
Wu-su-li-chiang 烏蘇里江
Wu-ta-lien-chi 五大連池
Wu-tai 五台
Wu-tai-shan 五台山
Wu-tao-chiang 五道江
Wu-tao-ling 五道岭
Wu-ting-shan 五道山
Wu-wang-tu 吳王渡
Wu-yun-ho-erh-tung-chi 烏雲和爾冬吉

Y

Ya-ko-shih 牙克石
Ya-lu-chiang 鴨緑江
Ya-lu-ho 雅魯河
Ya-pa-kang 啞叭崗
Ya-tang (A-tang) 亜当
Ya-tzu-kou 鴨子溝
Yang-chuan-tzu 羊圈子
Yang Ho 洋河
Yang-shu-fang 楊樹房
Yao-chia-tun 姚家屯
Yao-chuan-shan 薬泉山
Yao-pao 腰堡
Yao-pao-tzu 腰堡子
Yao-tzu-yu 窰子峪
Yeh-chih-pei 野雉背
Yeh-pai-show 葉柏寿
Yellow Sea (Huang-hai) 黄海
Yen-chia-lu 閻家樓
Yen-chia-pao-tzu 閻家堡子
Yen-pai-shan 影背山
Yen-shan 燕山
Yen-tai 煙台
Yen-tou-tsun 岩頭村
Yin-chia-tun 尹家屯
Yin-ho 音河
Yin-shan 陰山
Ying-cheng-tzu 営城子
Ying-chi-erh-ko-chi-ta-ling 英吉爾克吉達岭
Ying-chin-ho 英金河
Ying-ke-shih 英歌石
Ying-kou 営口
Ying-ning 永寧
Ying-pan 営盤
Yu-chia-tun 油家屯
Yu-chuan-hu 魚圈湖
Yu-chuan-shan 玉泉山
Yu-he 峪河
Yu-kung 禹貢
Yu-shan 玉山
Yu-shu-chuan 楡樹川
Yuan-chia-kou 袁家溝
Yun-cheng 運城
Yun-mu-shan 雲霧山
Yun-tai-shan 雲台山
Yung-an-tai 永安台
Yung-feng-chen 永豊鎮
Yung-ning 永寧
Yung-ting Ho 永定河