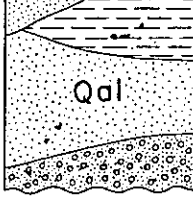
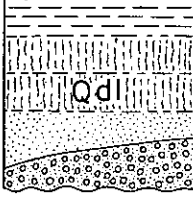
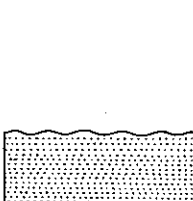
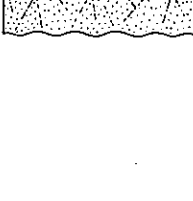
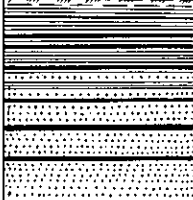
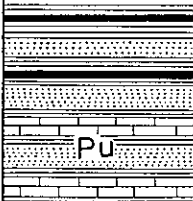
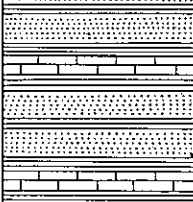
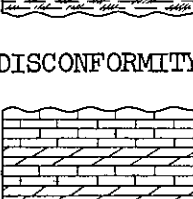
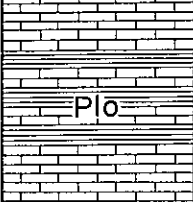
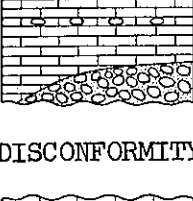
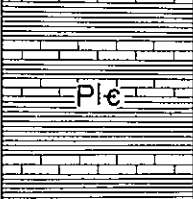


# GEOLOGIC COLUMN AND UNIT DESCRIPTION

AGE	ROCK UNIT	LITHOLOGY; THICKNESS WHERE KNOWN	UNIT DESCRIPTION	ECONOMIC VALUE																																																																																																																																																			
QUATERNARY	Alluvium	 <p>Sand, clay, and gravel; thickness less than 20 meters</p>	Alluvium, consisting of sand, clay, and gravel, is widely distributed in the southern part of the map area, covering flood plains and low terrace remnants along the Chi-yün Ho (新運河) and the Huan-hsiang Ho (運河).	<p><b>Coal</b></p> <p>The K'ai-luan (開遼) coal field occupies an area of 30 km E-W and 6 km N-S. The coal-bearing formation forms one anticline and two synclines that extend ENE. The bedrock consists of the Ordovician limestone. The southern syncline, generally called the K'ai-p'ing basin, extends along the railway between T'ang-shan-chen (唐山鎮) and Lin-hsi (林西). Coal seams occurring between Ma-chia-kou and Chiao-ko-chuang strike ENE dipping 65° to 90° S, and seams between T'ang-chia-chuang (唐家庄) and Lin-hsi strike N-S, dipping gently, 5° to 15°, to the W or N. The northern syncline was discovered by the South Manchuria Railway Company in 1944 when test drilling was carried out at Ta-fo-t'ou (大佛頭) (not shown on map) 9 km north of K'ai-p'ing-chen (開平鎮) and a depth of 360 m was reached.</p> <p>The formation contains 13 coal seams, of which Nos. 5, 8, 9 and 12 are workable. The thicknesses of the coal seams are tabulated below:</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Pit Coal seam</th> <th>T'ang-shan</th> <th>Ma-chia-kou</th> <th>Chiao-ko-chuang</th> <th>T'ang-chia-chuang</th> <th>Lin-hsi</th> </tr> </thead> <tbody> <tr> <td>No. 3</td> <td>0.9 m</td> <td>0.6 m</td> <td>1.5 m</td> <td>0.9 m</td> <td>0.9 m</td> </tr> <tr> <td>5</td> <td>1.5 - 1.8</td> <td>0.6 - 1.5</td> <td>1.5</td> <td>1.1</td> <td>1.1</td> </tr> <tr> <td>6</td> <td>0.6</td> <td>0.5</td> <td>0.6</td> <td>0.6</td> <td>0.6</td> </tr> <tr> <td>7</td> <td>0.8</td> <td>0.5</td> <td>0.5</td> <td>0.3</td> <td>0.6</td> </tr> <tr> <td>8</td> <td>2.4</td> <td>1.5 - 1.8</td> <td>2.0</td> <td>1.8</td> <td>1.2 - 2.0</td> </tr> <tr> <td>9</td> <td>3.6</td> <td>2.4 - 3.0</td> <td>5.0</td> <td>3.3</td> <td>2.0 - 4.2</td> </tr> <tr> <td>10</td> <td>0.9 - 1.8</td> <td>---</td> <td>---</td> <td>---</td> <td>---</td> </tr> <tr> <td>11</td> <td>2.1</td> <td>---</td> <td>0.8 - 1.8</td> <td>1.3</td> <td>1.7</td> </tr> <tr> <td>12</td> <td>7.9 - 9.1</td> <td>61.0 - 10.0</td> <td>4.2 - 9.2</td> <td>0.6 - 0.9</td> <td>1.8 - 2.7</td> </tr> <tr> <td>13</td> <td>1.5</td> <td>---</td> <td>---</td> <td>1.8</td> <td>---</td> </tr> </tbody> </table> <p>The coal is generally middle-ranked strongly caking bituminous coal and is useful for iron smelting. The analytical results are as follows:</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Coal seam</th> <th>Water (%)</th> <th>Ash (%)</th> <th>Volatile matter (%)</th> <th>Fixed carbon (%)</th> <th>Sulphur (%)</th> <th>Heat value (cal/kg)</th> </tr> </thead> <tbody> <tr> <td>No. 5</td> <td>0.80</td> <td>6.77</td> <td>28.82</td> <td>63.61</td> <td>0.37</td> <td>7,970</td> </tr> <tr> <td>8</td> <td>0.74</td> <td>29.69</td> <td>23.65</td> <td>45.90</td> <td>0.28</td> <td>5,800</td> </tr> <tr> <td>9</td> <td>0.40</td> <td>11.80</td> <td>23.32</td> <td>64.48</td> <td>1.83</td> <td>7,510</td> </tr> <tr> <td>12</td> <td>0.73</td> <td>14.64</td> <td>24.08</td> <td>60.55</td> <td>1.28</td> <td>7,250</td> </tr> <tr> <td>5</td> <td>0.77</td> <td>10.31</td> <td>30.35</td> <td>58.57</td> <td>0.76</td> <td>7,450</td> </tr> <tr> <td>8</td> <td>0.66</td> <td>14.41</td> <td>31.48</td> <td>53.72</td> <td>0.36</td> <td>7,080</td> </tr> <tr> <td>9</td> <td>0.82</td> <td>19.47</td> <td>25.36</td> <td>54.35</td> <td>0.43</td> <td>6,800</td> </tr> <tr> <td>12</td> <td>0.96</td> <td>7.65</td> <td>25.95</td> <td>65.44</td> <td>0.51</td> <td>7,810</td> </tr> </tbody> </table> <p>The probable and proven coal reserves, according to the Geological Survey of China, are 750 million tons and 320 million tons respectively.</p> <p><b>Fire clay</b></p> <p>The fire clay beds A and G in the K'ai-p'ing basin were formerly worked in several places. The fire clay can be classified into three grades: (1) more than 50% Al<sub>2</sub>O<sub>3</sub> and less than 20% SiO<sub>2</sub>, used in aluminum manufacture; (2) more than 40% Al<sub>2</sub>O<sub>3</sub> and less than 4% SiO<sub>2</sub>, used in fire brick manufacture; (3) 55 to 70% Al<sub>2</sub>O<sub>3</sub> and more than 8% Fe<sub>2</sub>O<sub>3</sub>, used as an abrasive.</p> <p><b>Limestone</b></p> <p>The Ordovician limestone near Pi-chia-tien and T'ang-shan stations is quarried for iron smelting and cement manufacture. The analytical results and mineral reserves are as follows:</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Locality</th> <th>Pi-chia-tien (I<sub>1</sub>)</th> <th>T'ang-shan (I<sub>2</sub>)</th> </tr> </thead> <tbody> <tr> <td>SiO<sub>2</sub></td> <td>3.07 - 4.81%</td> <td>4.71%</td> </tr> <tr> <td>Fe<sub>2</sub>O<sub>3</sub> - Al<sub>2</sub>O<sub>3</sub></td> <td>1.15 - 1.36</td> <td>---</td> </tr> <tr> <td>CaO</td> <td>50.20</td> <td>52.83</td> </tr> <tr> <td>MgO</td> <td>0.24</td> <td>0.05</td> </tr> <tr> <td>Mineral reserves</td> <td>600,000 tons</td> <td>2,300,000 tons</td> </tr> </tbody> </table>	Pit Coal seam	T'ang-shan	Ma-chia-kou	Chiao-ko-chuang	T'ang-chia-chuang	Lin-hsi	No. 3	0.9 m	0.6 m	1.5 m	0.9 m	0.9 m	5	1.5 - 1.8	0.6 - 1.5	1.5	1.1	1.1	6	0.6	0.5	0.6	0.6	0.6	7	0.8	0.5	0.5	0.3	0.6	8	2.4	1.5 - 1.8	2.0	1.8	1.2 - 2.0	9	3.6	2.4 - 3.0	5.0	3.3	2.0 - 4.2	10	0.9 - 1.8	---	---	---	---	11	2.1	---	0.8 - 1.8	1.3	1.7	12	7.9 - 9.1	61.0 - 10.0	4.2 - 9.2	0.6 - 0.9	1.8 - 2.7	13	1.5	---	---	1.8	---	Coal seam	Water (%)	Ash (%)	Volatile matter (%)	Fixed carbon (%)	Sulphur (%)	Heat value (cal/kg)	No. 5	0.80	6.77	28.82	63.61	0.37	7,970	8	0.74	29.69	23.65	45.90	0.28	5,800	9	0.40	11.80	23.32	64.48	1.83	7,510	12	0.73	14.64	24.08	60.55	1.28	7,250	5	0.77	10.31	30.35	58.57	0.76	7,450	8	0.66	14.41	31.48	53.72	0.36	7,080	9	0.82	19.47	25.36	54.35	0.43	6,800	12	0.96	7.65	25.95	65.44	0.51	7,810	Locality	Pi-chia-tien (I <sub>1</sub> )	T'ang-shan (I <sub>2</sub> )	SiO <sub>2</sub>	3.07 - 4.81%	4.71%	Fe <sub>2</sub> O <sub>3</sub> - Al <sub>2</sub> O <sub>3</sub>	1.15 - 1.36	---	CaO	50.20	52.83	MgO	0.24	0.05	Mineral reserves	600,000 tons	2,300,000 tons
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MESOZOIC	Permian-Triassic formation (Kuyeh series)	 <p>Sandstone, conglomerate, and quartzose sandstone; thickness more than 300 m</p>	The Permian-Triassic formation, or Kuyeh series, extends SW-NE between K'ai-p'ing (開平) and Ku-yeh (古冶). It consists, in descending order, of red sandstone, conglomerate, and yellowish white quartzose sandstone.																																																																																																																																																				
	PERMIAN-CARBONIFEROUS FORMATION	Shanhsi series	 <p>Fire clay (C1), and coal (C); thickness more than 400 m (Numbers refer to unit description).</p>	The Permian-Carboniferous formation is stratigraphically restricted between fire clay bed A and bed G. It contains 13 coal seams, 16 fire clay beds and more than 5 thin limestone beds. The formation comprises four series as described below in descending order (numbers refer to beds indicated on the columnar section):																																																																																																																																																			
		Taiyuan series	 <p>Shale, sandstone, limestone (L<sub>1</sub>, L<sub>2</sub>), fire clay (C1), and coal (C); thickness more than 400 m (Numbers refer to unit description).</p>	The Shanhsi series, Lower Permian (Artinskian) in age, is 135 m thick, and consists of fire clay bed A and red shale in the upper part and thick gray sandstone with black shale in the lower part. It is intercalated with coal seams No. 1 thru No. 9. The series yields plant fossils <i>Eremopteris</i> , <i>Pecopteris</i> , <i>Alathopteris</i> , <i>Callipteridium</i> , <i>Odontopteris</i> , <i>Desmopteris</i> , <i>Paenopteris</i> , <i>Neuropteris</i> , <i>Aphlebia</i> , <i>Calamites</i> , <i>Annularia</i> , <i>Sphenophyllum</i> , <i>Lepidodendron</i> , <i>Stigmaria</i> , <i>Cordaites</i> , <i>Artisia</i> , and <i>Zamites</i> .																																																																																																																																																			
		Kaiping series	 <p>Black shale interbedded with five thin coal seams, sandstone, and fire clay with kaolinite.</p>	The Taiyuan series, Lowermost Permian (Sakmarian) in age, is 110 m thick. It consists of black shale interbedded with light gray sandstone, limestone and coal seams No. 10 thru No. 13. Shale between limestone beds L <sub>1</sub> and L <sub>2</sub> yields plant fossils <i>Calamites</i> , <i>Cordaites</i> , <i>Annularia</i> , <i>Pecopteris</i> , <i>Sphenopteris</i> , and <i>Neuropteris</i> ; L <sub>2</sub> yields fossils <i>Climacumina</i> and <i>Schwagerina</i> . Shale between L <sub>2</sub> and L <sub>3</sub> yields plant fossils such as <i>Sphenophyllum</i> , <i>Neuropteris</i> , <i>Cordaites</i> , and <i>Lepidodendron</i> . The Chaokouhuang (趙各莊) limestone, L <sub>3</sub> , yields such littoral invertebrate fossils as <i>Productus</i> , <i>Marginifera</i> , <i>Chonetes</i> , <i>Spirifer</i> , <i>Spiriferina</i> , <i>Euomphalus</i> , <i>Derbyia</i> , <i>Parallelodon</i> , <i>Phillipsia</i> , <i>Polypora</i> , <i>Orthotetes</i> , <i>Cyathocrinus</i> , <i>Dalmanella</i> , <i>Phynsopora</i> , <i>Reticularia</i> , <i>Pseudomonotis</i> , <i>Schwagerina</i> , <i>Ozawainella</i> , and <i>Schbertella</i> .																																																																																																																																																			
Penhsi series		 <p>Limestone, grayish black shale, and light gray sandstone.</p>	The Kaiping series, Upper Carboniferous (Uralian) in age, is 45 m thick and consists of black shale interbedded with five thin coal seams, sandstone, and fire clay with kaolinite.																																																																																																																																																				
PALEOZOIC	Ordovician formation	 <p>Limestone, dolomite, shale and conglomerate; thickness 700 m</p>	The Penhsi series, Middle Carboniferous (Moscovian) in age, is 120 m thick and consists of limestone, grayish black shale, and light gray sandstone. The T'angshan (唐山) limestone, L <sub>4</sub> , yields marine invertebrate fossils such as <i>Bradyina</i> , <i>Staffella</i> , <i>Fusulinella</i> , <i>Fusulina</i> , <i>Multithecopora</i> , <i>Chaetetes</i> , <i>Lithostrotion</i> , <i>Spirifer</i> , <i>Productus</i> , <i>Sincrinis</i> , and <i>Gribovostomum</i> . A crinoid limestone, L <sub>5</sub> , contains fossils of <i>crinoids</i> , <i>Fusulines</i> and <i>Ozawainella</i> . Fire clay bed G occurs at the base.																																																																																																																																																				
	Cambrian formation	 <p>Limestone and shale; thickness 300 m</p>	The Ordovician formation is zonally distributed in an east-northeast direction. It is divided into the upper part or Middle Ordovician formation and the lower part or Lower Ordovician formation.																																																																																																																																																				
	Upper Precambrian formation (Sinian system)	 <p>Limestone, dolomite, phyllite, chert, shale, quartzite, sandstone, and conglomerate; thickness 2,500 m</p>	The Middle Ordovician formation, 300 m thick, corresponds to the Machiakou (馬家溝) limestone of GRABAU (1924) or the Machiakou series of OBATA (1940). It consists of massive limestone and dolomite, and yields molluscan fossils including <i>Actinoceras</i> , <i>Lophospira</i> and <i>Pagodispira</i> (OBATA, 1940), and trilobite fossils including <i>Eoisotelus</i> (CHANG, 1953 in KOBAYASHI, 1955).																																																																																																																																																				
PRECAMBRIAN	Crystalline schist (Wutai system)	 <p>Mica schist, hornblende schist, and iron ore</p>	The Lower Ordovician formation is divided by GRABAU (1924) into two units, Coralline limestone, 200 m thick, in the upper part and Yehli limestone, 200 m thick, in the lower part; it is divided by OBATA (1940) into the Pichiatien (碧峯山) series, 250 m thick, in the upper part, and Yehli series, 150 m thick, in the lower part. The upper part consists of shale, limestone, and coralline massive limestone in descending order, and yields molluscan fossils including <i>Manchuroceras</i> , <i>Parapiloceras</i> , <i>Yehlioceras</i> , <i>Hopeloceras</i> and <i>Kaipingoceras</i> (OBATA, 1940). The lower part consists of massive dolomitic limestone with intraformational conglomerate, and locally exposed basal conglomerate; molluscan fossils are <i>Ectenotiles</i> , <i>Ellesmeroceras</i> , <i>Protocycloceras</i> , <i>Proterokaipingoceras</i> , <i>Kailuoceras</i> , (OBATA, 1940), and trilobites such as <i>Asaphellus</i> , <i>Hystericurus</i> and <i>Bathyrus</i> (KOBAYASHI, 1955).																																																																																																																																																				
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(Column not drawn to scale)

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