GEOLOGIC COLUMN AND UNIT DESCRIPTION

AGE	ROCK UNIT	LITHOLOGY; THICKNESS WHERE KNOWN	UNIT DESCRIPTION
QUATERNARY	Alluvium	Qal — Sand, clay, and gravel; thickness less than 20 meters	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[霸 運 河] and the Huan-hsiang Ho[渙 鄉 河].
	UNCONFORMITY		
	Diluvium	Qdl — Loess, redeposited loess, sand, red clay, and gravel; thickness more than 40 m	Diluvium, consisting of aeolian loess, redeposited loess, sand, red clay, and gravel, covers terrace remnants of hilly land and fills major valleys. The loess proper is less than 40 m thick, but a hole drilled in T'ien-ching revealed that the Quaternary deposits are more than 800 m thick.
	UNCONFORMITY		
MESOZOIC	Permian-Triassic formation (Kuyeh series)	PuR — Sandstone, conglomerate, and quartzose sandstone; thickness more than 300 m	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.
	DISCONFORMITY		
PALEOZOIC	Permian-Carboniferous formation: Shanhsi series, Taiyuan series, Kaiping series, Penhsi series	C1–C13, C1A, C1G, L1–L5, Pu — Shale, sandstone, limestone (L) fire clay (Cl), and coal (C); thickness more than 400 m (Numbers refer to unit description).	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): 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 Eremopteris, Pecopteris, Alethopteris, Callipteridium, Odontopteris, Desmopteris, Taeniopteris, Neuropteris, Aphlebia, Calamites, Annularia, Sphenophyllum, Lepidodendron, Stigmaria, Cordaites, Artisia, and Zamites. 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_1 and L_2 yields plant fossils Calamites, Cordaites, Annularia, Pecopteris, Sphenopteris, and Neuropteris; L_2 yields fossils Climacammina and Schwagerina. Shale between L_2 and L_3 yields plant fossils such as Sphenophyllum, Neuropteris, Cordiates, and Lepidodendron. The Chaokouchuang[趙 各 莊] limestone, L_3, yields such littoral invertebrate fossils as Productus, Marginifera, Chonetes, Spirifer, Spiriferina, Euomphalus, Derbyia, Parallelodon, Phillipsia, Polypora, Orthotetes, Cyathocrinus, Dalmanella, Phynsopora, Reticularia, Pseudomonotis, Schwagerina, Ozawainella, and Schbertella. 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. 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_4, yields marine invertebrate fossils such as Bradyina, Staffella, Fusulinella, Fusulina, Multithecopora, Chaetetes, Lithostrotion, Spirifer, Productus, Sinocrinis, and Cribrostomum. A crinoid limestone, L_5, contains fossils of crinoids, fusulines and Ozawainella. Fire clay bed G occurs at the base.
	DISCONFORMITY		
	Ordovician formation	Plo — Limestone, dolomite, shale and conglomerate; thickness 700 m	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. 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 Actinoceras, Lophospira and Pagodispira (OBATA, 1940), and trilobite fossils including Eoisotelus (CHANG, 1953 in KOBAYASHI, 1955). 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[碑 家 甸] 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 Manchuroceras, Parapiloceras, Yehlioceras, Hopeioceras and Kaipingoceras (OBATA, 1940). The lower part consists of massive dolomitic limestone with intraformational conglomerate, and locally exposed basal conglomerate; molluscan fossils are Ectenotiles, Ellesmoreoceras, Protocycloceras, Proterokaipingoceras, Kailuanoceras, (OBATA, 1940), and trilobites such as Asaphellus, Hystricurus and Bathyurus (KOBAYASHI, 1955). The relation between the Middle Ordovician formation and the Lower Ordovician formation is disconformable.
	DISCONFORMITY		
	Cambrian formation	Pl€ — Limestone and shale; thickness 300 m	The Cambrian formation, consisting of limestone and shale, is divided into three parts, upper, middle, and lower. The Upper Cambrian formation, or Fengshan[風 山] series, is 50 m thick, consists of thinly bedded platy and marly limestone and shale, and yields brachiopod fossils including Obolus luanhsiensis and Lingulella demorphas, and trilobites such as Ptychapsis, Illaenurus, and Ceratopyge. The Middle Cambrian formation, or Changshan[長 山] series, 100 m thick, consists of green shale and gray oolitic limestone, and yields trilobites such as Agnostus hoi and Changshania conica. The Lower Cambrian formation, or Mantou[饅 頭] series, is 150 m thick, consists of reddish purple shale interbedded with thin limestone, and contains the trilobite Redlichia chinensis.
PRECAMBRIAN	DISCONFORMITY AND UNCONFORMITY		
	Upper Precambrian formation (Sinian system)	p€u — Limestone, dolomite, phyllite, chert, shale, quartzite, sandstone, and conglomerate; thickness 2,500 m	The Upper Precambrian formation, known as the Sinian system, is widely exposed in the northern part of the map area. It is divided into upper and lower. The upper part, 2,000 m thick, consists in descending order of limestone, siliceous limestone, dolomite, and an alternation of siliceous phyllite and chert. Red slate occurs at the base. The lower part, 500 m thick, consists of thickly bedded quartzite, siliceous sandstone, and basal conglomerate. No marked unconformity is observed between the two parts.
	UNCONFORMITY		
	Crystalline schist (Wutai system)	Sch — Mica schist, hornblende schist, and iron ore	The crystalline schist, or Wutai system, is exposed in the northeastern part of the map area. It consists of mica schist and hornblende schist, accompanied by banded siliceous iron ore deposits containing hematite and magnetite. The system is intruded by pinkish porphyritic granite, and both are unconformably overlain by the Sinian system.

(Column not drawn to scale)

ECONOMIC VALUE

Coal

The K'ai-luan[開 灤] 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 莊] 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.

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:

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	0.9	0.8 - 1.8	1.8	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	---

The coal is generally middle-ranked strongly caking bituminous coal and is useful for iron smelting. The analytical results are as follows:

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

The probable and proven coal reserves, according to the Geological Survey of China, are 750 million tons and 320 million tons respectively.

Fire clay

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_2O_3 and less than 20% SiO_2, used in aluminum manufacture; (2) more than 40% Al_2O_3 and less than 4% SiO_2, used in fire brick manufacture; (3) 55 to 70% Al_2O_3 and more than 8% Fe_2O_3, used as an abrasive.

Limestone

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:

Locality	Pi-chia-tien (L_1)	T'ang-shan (L_2)
SiO_2	3.07 - 4.81%	4.71%
Fe_2O_3 - Al_2O_3	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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