GEOLOGIC COLUMN AND UNIT DESCRIPTION

AGE	ROCK UNIT	LITHOLOGY; THICKNESS WHERE KNOWN	UNIT DESCRIPTION
QUATERNARY	Alluvium	Qal — Sand, gravel and secondary loess; thickness less than 10 meters	Alluvium consists of sand, gravel, and secondary loess of fluvial and aeolian origin. It also constitutes low terraces fringing rivers.
	Diluvium	Qdl — Primary loess, gravel and clay; thickness less than 20 m	Diluvium consists chiefly of primary loess of aeolian and fluvio-aeolian origin, accompanied by gravel and sand. Lenticular limestone gravel is found near the base, where residual red clay occurs in places. In the vast Huang Ho delta, unconsolidated silty fluvial deposits of Pleistocene age are several hundred meters thick and underly the alluvium.
	UNCONFORMITY		
TERTIARY	Paleogene(?) basalt	Ol — Basalt flows and tuff; thickness variable	Paleogene (?) basalt is mostly flows accompanied by tuff, with variable thickness.
	UNCONFORMITY		
MESOZOIC	Quartz porphyry	qp — Quartz porphyry and granite porphyry	Quartz porphyry accompanied by granite porphyry occurs in the district of Tan-shan southwest of T'ai-pao-chuang [大堡庄]. It represents a marginal facies of the Cretaceous granite (g_3) and is thought to be the orebringer of the lead-silver deposits in the map area.
	Cretaceous granite	g3 — Biotite granite, aplitic granite, pegmatite, lamprophyre and felsite	Cretaceous granite occurring as laccoliths consists of pinkish biotite-granite showing medium to rather coarse texture. Occasionally it contains aplitic granite and with numerous dikes of pegmatite, lamprophyre and felsite. It may have been erupted in the latter part of the Cretaceous.
	INTRUSIVE CONTACT		
	Cretaceous system	Mk — Mk: sandstone, conglomerate, clay and shale Mka — Mka: andesitic agglomerate and tuff, clay and andesite lava Mk — Thickness more than 4,000 m	The Cretaceous system is distributed widely in the map area. The strata in the district of Chiao Hsien [膠縣] consists in descending order of the Wangshih [王氏] formation, the andesite of the Ch'ing-shan [青山] formation, and the Laiyang [萊陽] formation. 3) The Wangshih formation, 2,000 m in combined thickness, was named after the Wangshih village in Chiao Hsien. It is composed in descending order of c) sandstone and conglomerate, 1,000 m thick; b) red clay with Reptilian bones, 300 m thick; and a) Cyrena shale and sandstone, 700 m thick, yielding Cyrena (Sphaerium?) tani GRABAU, C. (Pisidium) shantungensis GRABAU, C. (P.?) wangshihensis GRABAU, C. (P.) retrorosta GRABAU, C. (P.) altiformis GRABAU, Limnaeus sp., and Cyclophorus? sp. The formation is probably Middle or Upper Cretaceous in age. 2) Andesite of the Ch'ingshan formation (Mka) is 1,000 m thick, consisting in descending order of b) andesitic agglomerate and tuff, 700 m thick, and a) red clay and andesite lavas, 300 m thick. It represents a complex of volcanic rocks of andesitic composition, which may be assigned to the upper part of the Lower Cretaceous. 1) The Laiyang formation, 900 m thick, consists in descending order of c) yellow-greenish sandstone and dark-gray to green clayey shale, b) yellow-greenish hard conglomeratic sandstone, accompanied by greenish to gray clayey shale containing plant remains, and a) greenish gray or brownish hard sandstone and clay shale in association with conglomerate.
	UNCONFORMITY		
	Jurassic andesite	Mja — Andesite, porphyrite, breccia and tuff; thickness variable	Jurassic andesite is predominantly flows and sheets of andesite and porphyrite, intercalated with breccia and tuff. It intrudes the Jurassic coal-bearing formation. The andesite is similar to those distributed in the district of the Tzu-chuan [淄川] and Chang-ch'iu [章邱] coal fields, west of the map area. Lithologically, all these andesites seem to have resulted from contemporaneous eruptions.
	INTRUSIVE AND EFFUSIVE CONTACT		
	Jurassic coal-bearing formation	Mj — Sandstone, shale, conglomerate and coal; thickness less than 200 m	The Jurassic coal-bearing formation consists of an assemblage of sandstone and shale, intercalated with three or more coal seams. It overlies the Precambrian and Cambrian rocks with distinct unconformity. In the Fang-tzu [坊子] area south of Wei-hsien the formation is covered by the Lower Cretaceous andesitic tuff breccia. Fossils including Todites williamsoni (BRONGN.), Coniopteris hymenophylloides (BRONGN.), Otenis sp., and Podozamites lanceolatus, were identified by Matajirō YOKOYAMA (1906) from the shale near the coal seams. The coal-bearing formation in the Wu-tu-chuang [五圖庄] coal field south of Ch'ang-lo-hsien [昌樂縣] is unconformably covered by an extensive aggregation of andesite, porphyrite, breccia and tuff, and contains Podozamites, Coniopteris, Asplenium, Baiera, and Elatides as reported by T'AN and ANDERSON (1923).
	UNCONFORMITY		
PALEOZOIC	Permo-Carboniferous formation	Pup — Sandstone, shale, limestone and coal; thickness unknown	The Permo-Carboniferous formation was reported from the Kao-chen [高鎮], about 36 km south of Ch'ang-lo-hsien, where the formation forms a narrow area with a maximum stretch of 600 m, and in a fault contact with the Cambrian and Jurassic rocks. The formation consists of sandstone in the upper part and an assemblage of black shale and sandstone in the lower part intercalated with coal seams and some limestone. No fossils were obtained, but K. WATANABE assigned a Permo-Carboniferous age to the formation.
	UNCONFORMITY		
	Ordovician formation	Plo — Limestone and shale; thickness 800 m	The Ordovician formation, called the "Chinan limestone" by WILLIS and BLACKWELDER (1912), is exposed in the southwestern part of the map area. It consists of dolomitic limestone and argillaceous limestone with some shale. The thickness is about 800 meters, as computed from the sheet adjacent to the west (Chi-nan, NJ 50-15).
	DISCONFORMITY		
	Cambrian formation	Plc — Limestone, shale, conglomerate, marl, sandstone and quartzite; thickness more than 500 m	The Cambrian formation southwest of the Fang-tzu coal field consists in descending order of 3) the Upper Cambrian, or Chaomitien [炒米店] limestone, consisting chiefly of dark gray limestone marked with intraformational lenses of conglomerate consisting of limestone pebbles; 2) the Middle Cambrian, or Kushan [固山] shale and Changhsia [張夏] limestone, which is oolitic; and 1) the Lower Cambrian, or Mant'ou [饅頭] shale, consisting mainly of reddish brown shale intercalated with thin marl and sandstone, and locally with hard sandstone or quartzite at its top and base. At Shan-pei-t'ou [山北頭], 5 km southwest of Fang-tzu, the basal quartzite is as thick as 20 m, and is quarried as building stone.
	UNCONFORMITY		
PRECAMBRIAN	Precambrian(?) schist or Wutai system	PCSh — Biotite schist, hornblende schist, crystalline limestone and talc-hornblende schist; thickness variable	The Precambrian (?) schist consists chiefly of biotite schist, hornblende schist and crystalline limestone, locally accompanied by talc-hornblende schist. It is occasionally intruded by granite, pegmatite, and other dike rocks of probable Precambrian age.
	RELATION UNKNOWN		
	Precambrian gneiss or Taishan complex	PCgn — Granite gneiss, tonalitic gneiss and undifferentiated gneiss and schist; thickness unknown	The Taishan complex consists of granite gneiss and tonalitic gneiss with other gneiss and schist of unknown origin and character. It is usually intruded by granite, pegmatite, and dioritic rocks which are relatively young but are probably Precambrian in part.

(Column not drawn to scale)

ECONOMIC VALUE

Lead and silver

1) The Tan-shan [撣山] lead mine lies near Chiao-chia-p'u [趙家舖] 12.5 km southwest of T'ai-pao-chuang. The mine was operated about 60 years ago for galena-bearing quartz veins in the crystalline limestone which is intruded by granite porphyry.

2) The Kai-chia-chuang [蓋家庄] lead veins occur in the Middle Cambrian limestone at Kai-chia-chuang 12 km south of the Fang-tzu coal field. These galena-bearing calcite veins of hydrothermal origin similar to the above were exploited about 80 years ago, ending in failure.

Fluorite

1) The Wang-t'ai [王台] fluorite mine, 25 km south of Chiao-hsien, worked more than ten fluorite-quartz veins for several years after 1938, and the products were shipped to Japan. The veins occur in the gneiss and schist complex. The total output from 1938 to 1939 attained 20,000 tons. The ore reserves are said to be promising at depth.

2) The Chi-pao-shan [七寶山] fluorite-galena quartz veins occur in a pinkish Cretaceous granite near the contact with the crystalline limestone, 12 km southwest of Wang-t'ai. They were worked for fluorite about a half century ago.

Coal

1) The Fang-tzu coal field had been operated by natives since more than a century ago. In 1900 a German acquired the mining rights for an area of 528 sq. km, and started test drilling. The Fangtzu shaft (250 m deep), 2 km southwest of Fang-tzu station, was opened in 1901, the Anny shaft (380 m deep) in 1904, and the Minna shaft (177 m) in 1905, in order to accomplish the plan for 0.6 million ton annual output. However, the coal field was not promising in either reserves or quality, due to extensive effects of igneous activities. Moreover, a disastrous mine explosion buried the underground levels. Thereafter only the shallower part was worked until the mine was abandoned in 1916. The peak annual production was 273,000 tons in 1909. With the outbreak of World War I, Japan possessed the mining rights, and the shallow workings in the western and eastern parts of the mine were operated by contract miners, with an annual output of less than 50 thousand tons. The coal seams are extremely variable in thickness. According to K. WATANABE (1923) the seams are as follows:

Seam	Seam Interval	Thickness of seams (m)			
		Fangtzu shaft	Anny shaft	East mine	West mine
Upper	8-40 m	-	3.25	0.6-5.25	-
Middle	13-30 m	3.92	3.00	1.21-6.0	1.21-6.0
Lower	20 m	1.30	0.80	-	-
Bedrock					

The Middle seam was the principal producer. The mean values (%) of eleven proximate analyses made in 1941 and 1943 are as follows: H_2O, 0.88; ash, 8.14; volatile matter, 16.07; fixed carbon, 74.47; total sulphur, 1.04; calorific value, 7,891. The remaining coal reserves to a depth of 500 m were estimated at 13 million tons.

2) The Wu-tu-chuang coal field lies 12 km southwest of Ch'ang-lo-hsien. Three seams of coal were worked by Chinese miners, but neither reserves nor quality were promising.

Coal

The Kao-chen coal field lies 36 km south of Ch'ang-lo-hsien, and 13 km north of Kao-yai [高崖]. A Chinese company named Yutai Kungssu worked there for a few years after 1919, succeeded by some other Chinese miners. There are three seams of workable coal, namely, the Upper (0.6-0.9 m thick), the Middle (0.3-0.6 m thick), and the Lower (0.6-0.9 m thick) with respective intervals of 2.4 m and 15 m. Some thin coal seams are found in the upper and lower parts. The coal is semianthracite. Analytical values (%) are: H_2O, 3.15; volatile matter, 32.63; fixed carbon, 54.20; ash, 10.02; total sulphur, 4.12; calorific value, 6,943 cals.; sp. gr., 1.426. The coal is mostly scaly and the reserves are small.

Asbestos

The Chi-chia-tun [齊家屯] asbestos mine lies southwest of Wang-t'ai. Parallel thin veins of tremolite-asbestos are found in a crystalline dolomite which has been contact-metamorphosed by granite magma. It was worked by small open pits during World War II.

Iron

Deposits of banded magnetite-hematite ore of the Wutai system are found within the complex of schist and gneiss in the vicinity of Tai-pao-chuang station. The deposits are not promising in either quality or reserves.

Graphite

Graphite ore deposits are found in the Wutai system southwest of Wang-t'ai. Enriched parts of graphite schist were mined by small open pits at Ta-ch'ang-pa [大張八] and Sung-chia-tun [宋家屯].

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