Molybdenum Deposit of the Yang-chia-chang-tzu Mine, Manchuria

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I. Location and Transportation

The Yang-chia-chang-tzu Mine is situated 32 km west of Chin-hsi, a station on the Shan-Feng Railway line which runs from Shang-hai-kuan to Feng-tien via Chin-chou. As the mine is connected to Chin-hsi by a branch railway and a truck road, transportation is very good.

The molybdenum deposit is to the west of the lead-zinc deposit (Nishizawa and Tatsumi, 1953).

II. History

It is said that several hundred years ago in the Kao-chu-li period pyrite in this area was mined as a source of sulphur. Afterwards the lead-zinc deposit was worked on a small scale for lead, and in 1933 the deposit was equipped with machinery by a Japanese miner and the lower part of the old lead ore body was worked. In the course of the mining, prospecting was very actively undertaken for unknown deposits in the neighboring area but without success. In 1940 a prospect tunnel was opened on the western side of the Ta-pei-ling saddle and the molybdenum deposit was discovered. At that time the lead deposit was about to be exhausted and continuation of the mining seemed difficult, so mining of this newly discovered molybdenum deposit was started at once.

III. Topography

The upper reaches of the Nu-erh-ho, which flows into Po Hai via Chin-hsi, runs from southwest to northeast, i.e., parallel to the Sinian Trend. The Yang-chia-chang-tzu Mine is situated in the mountainous district between the upper reaches of this stream and the sea. In this mountainous district are developed low undulating hills, 50 to 100 m above sea level, and some monadnocks, 400 to 500 m in height; the former are considered to correspond to the Kuan-tung Paneplain because of the topographic similarity to that of Kuan-tung province.

The mine is located among the monadnocks. Ta-pei-ling, a granite mountain with an elevation of 500 m, lies to the north, and to the south there is a group of several steep sandstone mountains, the Pi-chia-shan Mountains, whose highest peak is 560 m above sea level.

IV. Stratigraphy

The stratigraphic sequence of the mine area is as follows:

A. Cenozoic era
   Quaternary (sand, gravel, and loess)

B. Mesozoic era
   Cretaceous (pyroclastic rocks)
   Triassic (shale, sandstone, and conglomerate; 340 m thick)

C. Paleozoic era
   Permo-Carboniferous (shale, sandstone, and conglomerate, intercalated with coal; 120 m thick)
   Cambro-Ordovician (limestone, dolomitic limestone, shale, and quartzite; 600 m thick)

D. Proterozoic era
   Upper Sinian (cherty limestone and slate; 400 m thick)

E. Igneous rocks
   Granites intrude the strata ranging from the Sinian to the Triassic, and are covered by the Cretaceous pyroclastics.

A. Cenozoic Era

The Quaternary system consists of loess (20 to 30 m thick) deposited at the foot of the mountains, and sand, gravel and clay along the rivers. These sediments are not related to the ore deposit.

B. Mesozoic Era

The Cretaceous system, consisting of andesitic pyroclastic rocks, unconformably overlies Triassic sedimentary rocks and is overlain by loess. It is distributed in the eastern part of the mine area but is not directly related to the ore deposit.

The Triassic system is 340 m thick. Since no fossils were found, the exact age of the strata remains undetermined. Some geologists assigned them to the Permo-Triassic age but, for the sake of convenience, I am assuming that they are Triassic. They unconformably overlie the Permo-Carboniferous system and consist mainly of alternating conglomerates and sandstones. The strata are generally reddish. The base is a compact, white, siliceous sandstone on which lies an alternation of multi-colored (reddish purple, brown, grayish green, yellow, etc.) shales and sandstones. The pebbles in the conglomerates are mainly water-worn pebbles of quartzite and flint; no limestone pebbles are found. Some pebbles are deformed and cracked due to the effect of compression, which may suggest that the conglomerates suffered orogenic movements.

In the upper part there are thick sandstones colored grayish green, yellowish gray, dark gray, etc.

C. Paleozoic Era

The Permo-Carboniferous system is a 120 m thick coal-bearing formation. It disconformably overlies the Ordovician limestone and consists of conglomerate, sandstone, and shale. The basal bed is white conglomerate or sandstone. The sandstones are yellow or white and the shales are multi-colored. The formation is intercalated with 50 cm to 1.5 m thick coal seams, which are mined on a small scale at Hei-yu-kou and Fu-erh-kou. There are three seams of coal, the total thickness attaining 2.5 m in places.

The formation contains plant fossils, such as *Lepidodendron* sp., *Tingia* sp., *Pecopteris* sp., *Stigmaria* sp., *Cordaites* sp., and rarely limestone lenses. The Permo-Carboniferous beds are thinner here than in North China and the other regions of South Manchuria. In the lower part of the basal conglomerate, there is a layer of alumina shale about 1 m thick.

The Cambro-Ordovician system disconformably overlies the Sinian system and consists mainly of limestones and dolomitic limestones with some intercalations of shales. The total thickness is estimated at 600 to 800 m. The strike is generally E-W and the dip is 40°S. At Lien-hua-shan, about 3 km south of the mine, the total thickness may be as much as 800 to 1,000 m and the stratigraphic sequence is as follows:

(1) Black dolomitic limestone; marly in part.
(2) Conglomerate; calcareous matrix with chert pebbles.
(3) Dolomitic limestone, dark gray, partially reddish and shaly.
(4) Flinty limestone; light gray, intercalated with green shale.
(5) Gray laminated limestone.
(6) Alternation of dolomitic limestone and shale, intercalated with micaceous shale.
(7) Laminated dolomitic limestone.
(8) Alternation of dolomitic limestone and sandy shale (each layer is 30–40 cm thick).
(9) Dolomitic limestone, intercalated with several beds of shale.
(10) Oolitic limestone; black and massive.
(11) Gray dolomitic limestone.
(12) Gray limestone; contains *Girvanella manchurica*.
(13) Gray oolitic limestone.
(14) Red and purple shale.
(15) White limestone.
(16) Quartzite.

The white basal quartzite, (16), is highly resistive to weathering and characteristically forms cliffs. It is often brecciated. The quartzite was once considered to be Sinian by some geologists, but later other geologists, during their survey of the lead-zinc deposit, identified this quartzite as the base of the Cambrian system, for the reason that the quartzite disconformably overlies the Sinian limestone and is conformably overlain by the Cambrian limestone. The thickness of the quartzite is 100 to 150 m.

The gray limestone, (12), contains fossils of brachiopods and trilobites in addition to *Girvanella*. The country rocks of the molybedenum and the lead-zinc deposits are generally limestones of this systym. In the 90 m pit, the 120 m pit and in the Ta-pei-ling pit on the mountain sides some of the shales were altered to cordierite-hornfels or biotite-hornfels by the intrusion of the Ta-pei-ling granite.

D. Sinian System

The strata deposited in the Sinian period are exposed near Ta-pei-ling and Lung-wang-miao. They consist mainly of siliceous limestones, often intercalated with chert, and locally slaty limestone and shale. Total thickness is about 400 m.

E. Igneous Rocks

Granitic rocks occur as loccoliths in the area north of Yang-chia-chang-tzu. They affected sedimentary rocks with contact-metamorphism. In the west of Ta-pei-ling pass, the width of the contact-metamorphosed zone reaches several hundred meters, and molybdenite-bearing garnet-skarn is found there.

The granite in the vicinity of Ta-pei-ling is coarse- to medium-grained and pinkish. Under a microscope the rock is found to consist of phenocrystic quartz, orthoclase and biotite, occasionally with a small amount of hematite.

The marginal part of the granite laccoliths is monzonitic, more or less greenish, consisting of orthoclase and green biotite, but no quartz.

Many dikes extend from the laccolith; they are generally quartz porphyry or monzonite porphyry.

V. Ore Deposits

The ore deposits of the Yang-chia-chang-tzu mine have been formed by mineralization in the contact zone of the granite and limestone. The deposits are of four types according to the grade of mineralization: (a) Molybdenite deposit; (b) Magnetite deposit; (c) Copper deposit; and (d) Lead-zinc deposit. Type (d) is further subdivided into (d–i) the Yang-chia-chang-tzu type (low temperature replacement); (d–ii) the Shang-pien type (high temperature vein); and (d–iii) the Sung-shu-wu type (low temperature vein). In this report only the molybdenite deposit will be discussed.

The molybdenite deposit occurs in a body of skarn formed by the strong contact-metamorphism which is known as the Ssu-chien type metamorphism. The skarn is in the folded part of the Cambro-Ordovician limestone along the western

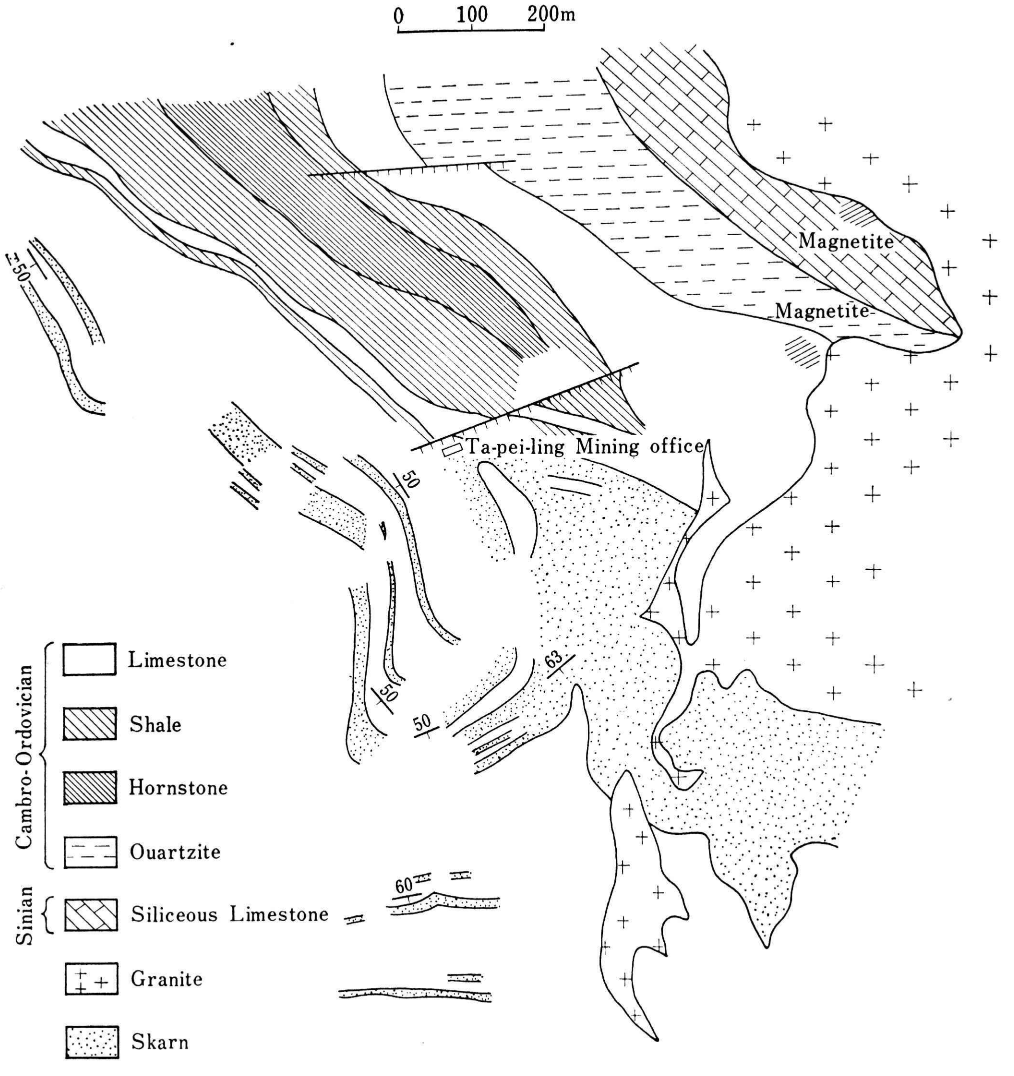

Fig. 1. Geological map of the Yang-chia-chang-tzu molybdenum deposit.

contact of the granite which extends like a tongue in the area between Ta-pei-ling and Ssu-chien.

The skarn is dark brown, brown, light brown, green or yellowish brown, and is crossed by quartz and calcite veins parallel or oblique to the bedding plane. The brown part consists almost entirely of aggregates of garnet crystals some of which are as large as a finger tip. Diopside is also abundant, filling the interspaces of garnet. In addition, there are mica, hornblende, augite, vesuvianite, epidote and calcite. Molybdenite occurs as veins, impregnations and lumps in this skarn.

The ore body, which was encountered in No. 8 Ta-pei-ling shaft, is parallel to the bedding plane of the limestone. It strikes NNW-SSE and dips 55°W. In the southern part, this body makes a large turn as shown in Fig. 2. Its total extension is more than 300 m, including four parallel ore shoots. Width of the ore shoots increases downward, or eastward, locally exceeding 30 m. The second to fourth ore shoots are 2 to 5 m wide, partially swelling. The molybdenite grains are generally 0.3 mm in size, occurring as impregnations often parallel to the bedding plane of the country rock. In some cases, small flakes or fine grains of molybdenite fill the fissures which obliquely intersect the bedding plane.

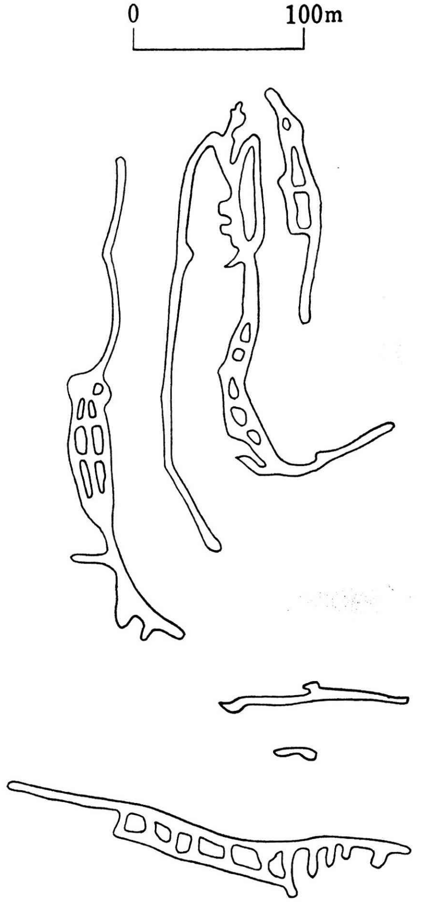

Fig. 2. Sketch of tunnel in Ta-pei-ling ore body.

According to the results of analysis, the average MoS_2 content reaches 1% to 5% in the high-grade portion and about 0.55% in the 5 to 10 m wide low-grade portion. After the completion of the sorting plant, mining was carried out setting the standard grade of crude ore at 0.65% MoS_2.

As the mineral assemblage of the ore is simple, the sorting was not considered to be difficult, but the results of the sorting were not good because of lack of investigation and of much mechanical trouble owing to the forced production increase during the war. Although the deposit remained undiscovered for a long time, the mine was required to produce considerable amounts of refined ore. Under these conditions, prospecting and equipment necessary for sorting were not always sufficient.

The mining has not been flawless, but mining conditions are very good and as it has not been long since mining was started a large part of the deposit is not exploited yet. The net reserves are at least 2,000,000 tons and the probable reserves amount to more than 5,000,000 tons. This molybdenum mine, therefore, is considered to be second in size to the Climax Molybdenum Mine in the United States, in reserves and ore quality. Considering that the Climax Mine started with relatively small probable reserves, 5,000 tons, and afterwards became the largest molybdenum mine in the world, the mining of this deposit should be carried on at a moderate rate—not more than 3,000 to 5,000 tons per month of ores with the MoS_2 content higher than 1%. The mine could then surely have a great expectancy.

After the war, I proposed a plan based on this rate of operation to Nationalist China, but the government set the mining rate at 2,000 tons per day, a figure far larger than mine, so the plan was not realized. The molybdenum deposit is one of the best deposits in the world, and should be mined as soon as possible.

Output of ore since the beginning of mining is as follows:

Year/month	Sorted ore (tons)	Grade of crude ore (MoS_2%)
1940/1–1940/12	9,080	0.69%
1941/1–1942/3	65,961	0.55
1942/4–1943/3	137,611	0.53
1943/4–1944/3	166,429	0.47
1944/4–1944/6	54,045	0.50
Total	533,126 tons	

VI. Mineral Assemblage

Rokuro Shima (1944), in his graduation thesis listed the following mineral assemblages:

(1) Magnetite and molybdenite

At Han-chia-kou, molybdenite fills the interspaces of magnetite. Magnetite is therefore considered to have crystallized before molybdenite.

(2) Molybdenite and pyrite

At Ta-pei-ling, pyrite fills the interspaces of molybdenite. Molybdenite is therefore considered to have crystallized before pyrite.

(3) Molybdenite and lead-zinc ore

Galena and zincblende are also found in the skarn of Ssu-chien, Ta-pei-ling, but no ore shows molybdenite-galena or molybdenite-zincblende paragenesis. But from several facts molybdenite is believed to have crystallized before galena and zincblende.

The mineral assemblages and their paragenetic relations are shown in the following table compiled by Shima.

Paragenesis of Minerals

									Skarn													
		Granite			Monzonite		Q-porphyry		Ta-pei-ling					Central part				Ssu-chien		East wing		Han-chia-kou
Ore	?	○		○													○					
	Magnetite																				○	○
	Molybdenite									○	○		○				○					○
Calcite									○	○		○	○					○		○		
Tremolite																○						
Epidote											○										○	
Vesuvianite										○	○											
Augite															○							
Diopside										○	○	○		○				○	○	○		
Garnet									○	○	○	○	○	○	○		○	○	○	○		
Green hornblende																				○		
Mica	(Mica)									○												
	Muscovite			○																		
	Green biotite				○	○	○															
	Brown biotite	○	○	○	○	○																
Feldspar	Plagioclase									○					○							
	Orthoclase	○	○	○	○	○	○	○	○													
Quartz		○	○	○			○	○	○					○			○					

VII. Summary

The Yang-chia-chang-tzu Mine is connected with Chin-hsi station on the Shan-Feng Railway line by a branch line 32 km long. It started as a lead mine, but just when the lead deposit was almost exhausted the molybdenite deposit was discovered and was at once worked as an important resource for Japanese military operations during World War II.

The molybdenite deposit is a contact deposit resulting from a granite intrusion into the Sinian to Permian strata. The molybdenite deposit in limestone was formed during the period from the later stage of the pneumatolysis to the earlier stage of the hydrothermal process. Molybdenite is partially paragenetic with pyrite of the succeeding stage, but escaped impregnation by galena and zincblende of the later stage.

Possible ore reserves exceed several million tons. When 3,000 to 5,000 tons of sorted ore are to be dealt with monthly, the grade of crude ore should be $MoS_2=1.0\%$, and if the monthly output is increased to 30,000 tons the ore grade must be lowered to $MoS_2=0.6\%$.

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