ORE DEPOSITS OF CHINCHUANTANG, CHENHSIEN, HUNAN

BY Y. T. NAI (南延宗)
(National Geological Survey of China)

I. INTRODUCTION

The ore deposits of Chinchuautang were known to geologists since the publication of the report by Mr. H. C. Wang¹ and others in the year of 1930. In this region, a great number of different ores including zinc, lead, arsenic, sulphur, manganese, tungsten and bismuth have been mined by several companies such as Paosiang Co. in Chinchuautang proper, Chiyuan and Fukang Co. in Chaihan, Tachern Co. in Shihchu-yuan and Tafu Co. in Shuihui. The area of the mineralized region is about 3,400,000 sq. m. In the winter of 1931, while investigating the pyrite reserve in S. Hunan, Mr. H. S. Wang and the writer went to Chinchuautang to see these deposits. With Mr. H. C. Wang's report and geological map at our disposal, we had more time to study the genesis of the ore deposits, particularly on the relationships of the tungsten ore in Shuihui with greisenization that have not hitherto been emphasized by the previous workers.

The writer wishes to acknowledge Prof. C. Y. Hsieh, Prof. H. H. Cheng and Mr. H. J. Chu for their direction and encouragement in preparing this report. To Mr. H. S. Wang he is deeply indebted for his guidance during the field work.

II. GENERAL GEOLOGY

The geology of Chinchuautang and its neighboring regions is rather simple; it is composed of granite with some pegmatitic or quartz veins intruding through a limestone formation. The latter partly shows the roof-pendent structure enclosed in the granite.

¹ Received for publication, November 1935.

The limestone may be reasonably correlated with the so-called Shihlantze limestone of Lower Carboniferous age near the Chenhualing city. It is dark gray in color and contains usually cherty nodules. In most cases, it is metamorphosed into marble and disturbed by the igneous intrusion, so that fossils are not found.

The granite shows in general a more or less porphyritic texture consisting mainly of orthoclase, plagioclase, hornblende, actinolite and biotite, their relative proportion varies from place to place. Orthoclase is the most abundant mineral among them and shows a tabular form ranging from 1 to 24 mm in width. It is often intergrown with quartz forming the typical micrographic (or eutectoid) texture which is clearly shown in the thin sections. Plagioclase determined to be an oligoclase occurs in small quantity and exhibits occasionally zonal structure. Both orthoclase and plagioclase are partly converted to sericite and kaolin and sometimes the plagioclase may also be changed to epidote. The color of the granite varies in different localities due chiefly to the content of orthoclase. It is reddish in Chaishan, pinkish red to white in Chunhuantang proper (including Tachuling), reddish white in Shiuhiuli, and greenish white in Shihchuyuan, in the last case the color is evidently resulted from the absence or rarity of the orthoclase. Quartz is present in euhedral grains and occasionally in corroded crystals varying from half a millimeter to 8 mm in diameter. It is vitreous and colorless differing from that found in pegmatitic veins which is of milky white appearance. Hornblende and actinolite are sparingly distributed in the granite, with the former comparatively more abundant than the latter. Biotite shows brownish black crystals with good basal cleavage. In Shihchuyuan, it is preponderant over the hornblende and actinolite and in others they are in reverse proportion. All these dark minerals in granite are mostly altered to chlorite. Muscovite in irregular flakes and patches is very rarely present in the granite but common in the pegmatitic or quartz veins. Occasionally, there are some bluish black crystals of tourmaline cutting through the quartz and feldspar crystals in granite; they evidently come from the last emanation of the magmatic solution. Magnetite, pyrite, apatite and zircon occur sparingly as the accessory constituents of the granite.
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The pegmatitic or quartz veins are found in or adjacent to the granite. They are more abundant in Shuihuli and occur subordinately in Chaishan and Chinchuantang proper. They are irregularly intersected and are composed almost entirely of quartz with minor amount of associated minerals.

Although the granite is found here to have intruded into the Carboniferous limestone only, but when comparing the granite intrusion in other parts of Hunan, it is evident that the age of intrusion should be extended up to early Cretaceous or still later; the intrusion probably took place during or after the Yenshanian movement of Dr. W. H. Wong.

III. DISTRIBUTION OF THE ORE DEPOSITS

The ore deposits in this region are in various forms of chimneys, pockets, veins, etc. All of them are commonly found near the contact zone between granite and limestone, less frequently they are found also in the granite or in the limestone. An individual description of different parts of the deposits is given as follows:

(1) Tachiling.—This region is situated about 22 km SE of Chenshien city. The ore body occurs in limestone showing chimney structure with an average diameter of 12 m. and an approximate vertical extension of about 220 m. An interesting feature is that the deposit shows a vertical variation of mineral constituents in such a way that galena and sphalerite are characteristic of upper zone, while pyrrhotite, pyrite and arsenopyrite become more and more abundant in depth. The primary minerals are arsenopyrite, pyrite, pyrrhotite, sphalerite, tetrahedrite, talc and epidote. At the lowest part of the ore body, there is a garnet zone containing garnet, epidote, feldspar, quartz, calcite with scattered pyrite, arsenopyrite and pyrrhotite grains.

In the east of the Paosiang Co., there is the Mn-deposit of Wuleishiku; the ore occurs in laminated form and is composed of palomeline, pyrolusite and wad. The origin of this deposit is not certain; most probably it is of residual origin, being formed from weathering and decomposition of a preexisting manganese sulphide to be described in
detail in the following paragraphs. Further east of the Mn-deposit, small and thin wolframite-quartz vein was also found, but it is of economic value.

(2) Chaishan:—Chaishan is situated about one and half km S of the Chinchuantang proper. It is essentially a pyrite deposit with minor amount of arsenopyrite, sphalerite and galena. The ore body assumes the shape of a vertical chimney with the same width and extension as that of Tachiling deposit, but here the ore is almost exclusively confined to the limestone portion. The pyrite body is generally penetrated by purple fluorite veinlets.

Near the top of Chaishan, a deposit of pyrite and bismuthinite with gangues of calcite, quartz, and fluorite was found. This mine was abandoned at the time of our visit, so detailed description cannot be given.

On the SE or along the lower slope of Chaishan for about half a kilometer in distance, there is a thin pegmatitic vein composed of quartz, topaz, epidote, sericite, fluorite and pyrite in small amount.

(3) Shihchuyuan:—This deposit is located about 2 to 2.5 km east of Chinchuantang proper. It occurs as pocket and veins in the limestone and consists mainly of pyrite and subordinately of arsenopyrite both being associated with gangues of calcite and quartz.

(4) Shuihuli:—Shuihuli is about one and half km N W of Chinchuantang proper and is about 20 km away from the city of Chensien. The deposit is characterized by rather considerable amount of wolframite and cassiterite occurring in a number of quartz veins and greisen rocks. The wolframite and cassiterite veins are rather regular in shape being more or less parallel to each other and extend in a direction of N 30° E dipping 60° toward NW. Among the different veins, there are two principal ones each measuring about half a meter in thickness and 95 m in length.

The walls immediate to these two principal quartz veins are highly altered by the process of greisenization. The altered rocks are com-
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foamed mainly of topaz, muscovite, tourmaline, and garnet, and subordinately of chlorite, fluorite, sericite, calcite, epidote and spinel. All of these minerals occur in massive form or in a series of zonial arrangement. The greisen carries a minor amount of ore minerals, such as cassiterite, arsenopyrite, pyrrhotite, pyrite, sphalerite, tetrahedrite, chalcopyrite, bornite, stannite, galena, and also wolframite.

Besides these two principal veins, there are a great number of smaller ones intersecting irregularly and carrying as a rule a little amount of wolframite and cassiterite. Although such veins are small and narrow but on account of their greater number, they are still of considerable economic importance.

(5) Manoshan:—This is located about one km W of Shuihuli and 3 km NW of Chinchuantang proper. It is chiefly a manganese-on deposit containing magnetite, pyrrhotite, arsenopyrite, alabandite in the lower part, and the oxidized products of the above minerals, such as stilomelane, pyrolusite, limonite, and wad in the upper. Unfortunately we are not able to make personal inspection of the underground working for the shaft was full of water during our visit.

IV. MINERALOGY

A. ORE MINERALS

1. Magnetite:—Magnetite with arsenopyrite and pyrrhotite occurs as irregular grains at the bottom of the Tachiling mine; near the limestone side of the greisen in Shuihuli; and with alabandite in Manoshan. It is obviously the earliest mineral, in these deposits. Hematite and limonite veinlets are occasionally seen to cut through the veins.

2. Arsenopyrite:—Arsenopyrite occurs hypidiomorphically as plate to the magnetite, but idiomorphically to the pyrite and pyrrhotite. It is also present in Shuihuli as euhedral grains associated with pyrite and pyrrhotite in the veins and in the greisen. The size of grains varies from 2-15 mm across.
3. Pyrite:—At Shuihuli pyrite occurs generally in fine euhedral crystals in the greisen near the limestone portion. At Tachiling and Shishchuyuan, it forms large masses at the lower part of the ore body and is more or less replaced by sphalerite and galena. At Chaishan, it is the most important ore mineral and is generally cut by fluorite veins.

4. Cassiterite:—This mineral is almost entirely restricted to the Shuihuli quartz veins and their greisen. The large crystals are found in association with quartz and wolframite in the quartz veins; while the fine aggregate of cassiterite usually forms crusts surrounding the muscovite in the greisen and at the same time is enclosed or penetrated by the fluorite.

5. Wolframite:—Wolframite is dark brown to black in color and occurs in long prismatic form, being found both in the quartz veins and in the greisen rock itself at Shuihuli. The crystals of wolframite are found to penetrate through both quartz and arsenopyrite grains indicating therefore a definitely later age of deposition. Wherever the wolframite occurs in the greisen, it is usually accompanied by fluorite, sericite, and a little or no quartz. Part of it has been changed to limonite and tungstite on the weathered surfaces of the specimens.

6. Pyrrhotite:—Pyrrhotite is found at both Tachiling and Shuihuli to replace pyrite, magnetite and arsenopyrite; sometimes it is irregularly disseminated in the andradite grains. At Manacahan some fine grains of pyrrhotite are enclosed in the alabandite in such a way as to resemble somewhat the phenomenon of 'unmixing'.

7. Sphalerite and Smithsonite:—Sphalerite is rather abundant in Tachiling and rare in other localities. It is usually associated with pyrite, pyrrhotite and galena. Generally it includes small dots and rods of chalcopyrite forming a grating texture. In the greisen of Shuihuli, smithsonite in stalactitic forms is found to coat the sphalerite and quartz crystals.

8. Tetrahedrite:—Tetrahedrite occurs in small amount but is rather common in Tachiling and Shishchuyuan. It is gray in color and
under the microscope it is evidently earlier than bornite and later than sphalerite.

9. Stannite:—Few grains of it with steel-gray color are recognized in intergrowth with sphalerite, cassiterite, and arsenopyrite in Shuihuli greisen rock. It is probable that the latter three minerals have been replaced by stannite.

10. Bornite:—Bornite in Shuihuli shows the mutual intergrowth with tetrahedrite and chalcopyrite and they are probably to be regarded as of contemporaneous deposition.

11. Chalcopyrite:—Chalcopyrite occurs together with pyrite in small amount in the deposits of Tachiling and Shuihuli and usually forms fine to medium disseminated grains in the chimney of Tachiling and the greisen rock of Shuihuli. It replaces arsenopyrite, pyrite and tetrahedrite. Small grains or rods of chalcopyrite are sometime intergrown in sphalerite forming thus a typical unmixed texture.

12. Galena and anglesite:—Galena is the chief ore mineral in the Tachiling deposits, but rarely in other localities. It occurs more abundantly in the upper part of the ore body and gradually decreases in amount with depth. On its weathered surfaces some anglesite may be recognized.

13. Bismuthinite:—It is found near the top of Chaishan being adjacent to the granite; it appears to replace pyrite, quartz, fluorite, and calcite.

14. Alabandite:—At Manaoshan there are found some manganese minerals, one of which with gray color and green internal reflection is identified to be alabandite. Chemical analysis has confirmed the presence of manganese and sulphur. It includes more or less along its crystallographic direction many fine rods and spots of pyrrhotite.

15. Psilomelane and pyrolusite:—Psilomelane occurs as stalactitic masses with concentric layers at Manaoshan and Wuleichihku. It is commonly associated with pyrolusite, the latter occurs in reniform shape forming alternating layers with psilomelane. These are evidently oxidation products of the primary manganese minerals.
B. GANGUE MINERALS

1. Spinel:—Spinel of a dark green variety occurs side by side with fluorite and garnet grains in Shuihuli. Occasionally it is penetrated by the topaz grains and enclosed by sericite shreds.

2. Garnet:—Two varieties of garnet have been determined in the greisen of Shuihuli and the lowest part of Tachiling ore body. One being found both at Shuihuli and Tachiling is a flesh red or deep red colored andradite, and the other only seen in Shuihuli is a grossularite with brownish-yellow color. The former is intimately associated with fluorite and pyrrhotite and the latter with cassiterite, fluorite, and sericite. Alteration of andradite to chlorite has been noticed in the greisen of Shuihuli.

3. Quartz:—Quartz is the commonest gangue mineral in the deposits. It occurs in two forms, massive and granular. The massive quartz usually showing a milky white appearance is found only in the vein of Shuihuli. The granular transparent quartz occurs more commonly in all of the other deposits. Its range of deposition seems to be quite long, being started from the end of the deposition of garnet till the end of wolframite, for quartz at one place is seen to be replaced by most oxides and sulphides while at others it replaces them. In Chaishan it seems to be contemporaneous with calcite and definitely prior to the purple fluorite.

4. Topaz:—It is only found in the quartz veins of Shuihuli and SE of Chaishan. It shows fine aggregate with individual crystals frequently penetrated by streaks and patches of sericite and tourmaline. Most probably it is formed by reaction between orthoclase and a predominately fluorine-bearing solutions during the process of greisenization as shown by the following chemical equation:

\[ 2KAlSi_3O_8 + 2F = [Al(O_2F_2)_2]AlSiO_4 + K_2O + 6SiO_2 \]  
(orthoclase)  
(Topaz)

5. Muscovite:—This mineral is present chiefly in the quartz vein and rarely in the greisen rock. It is in large white plate with greenish tint and elastic foliation.
6. Tourmaline:—Tourmaline occurs more abundantly in the veins and the greisen of Shuibiuli and rarely in the granite of Chinchuantang proper. At Shuibiuli, there are two varieties of tourmaline; one is the black variety restricted to the limestone side in occasional association with grossularite and green fluorite and the other is a green one confined to the aggregate of topaz, quartz, muscovite and fluorite. The black one frequently forms parallel veinlets while the green one as isolated crystals of radiated aggregates. In Chinchuantang proper there are many small stringers of bluish black tourmaline embedded in the quartz crystals of the granite.

7. Epidote:—It occurs in brownish green, fine-grained aggregates in the fluorite veinlets or in association with garnet, calcite, sericite and fluorite masses near the quartz veins of Shuibiuli and Chaishan. At Tuchiling, it is closely associated with garnet, sericite, calcite and quartz in the lower wall of the ore body.

8. Fluorite:—The color of fluorite varies from purple to green. The green fluorite occurs throughout the greisen as isolated crystals or rarely in veinlets with cassiterite, wolframite, arsenopyrite and chalcopyrite. It replaces both quartz and topaz, therefore its development is definitely later than the process of greisenization. It is also found in the lower part of the Tuchiling ore body accompanying pyrite and galena. The purple fluorite on the other hand is found only at Chaishan, being intimately associated with pyrite, quartz, calcite and tourmaline. Besides fine disseminations, the fluorite may also occur in connecting veinlets of lenticular form in limestone.

9. Sericite:—This mineral is seen in the greisen of Shuibiuli megascopically and is cotton-white in color forming zonal arrangement parallel with black tourmaline bands. Under the microscope, a number of minute flakes or scales of sericite firmly aggregated together and sometimes cut by the fluorite veinlets are found.
10. Chlorite:—It has been previously mentioned that considerable amount of ferromagnesian silicates, as biotite and hornblende in granite and garnet in greisen, were mostly altered to chlorite. In Chaisun, some veinlets of penninite are also seen in association with pyrite, quartz, and fluorite crystals.

11. Kaolin:—Kaolin occurs as fine, amorphous aggregate upon the weathered surface of the country rock and igneous body.

12. Calcite:—It is limited to the limestone side of both the greisen and the ore bodies. Calcite in the ore body sometimes includes pyrite grains.

13. Apatite:—It is present in minute slender crystals sparingly distributed throughout the country rocks and the greisen.

V. GENESIS AND PARAGENESIS

Although the different ore deposits herein described were formed under almost identical genetic conditions and belonging evidently to the same metallogenetic type, they differ however, slightly in their mineral compositions as well as paragenetic relationships; accordingly they may be described separately as follows:

1. Tachiling:—From the presence of high-temperature minerals, such as magnetite, arsenopyrite, pyrrhotite, garnet, biotite, epidote, and fluorite, it is concluded that the Tachiling chimney-like deposit in limestone may belong to the hypothermal type. Though tourmaline is probably absent in this deposit but a small amount of it has been found in the granite near ore body. The tungsten-quartz vein at the Wulechihku north of Tachiling may be considered as a pneumatolytic deposit. The paragenetic sequence of the different minerals in the Tachiling deposit is shown in the following table:
2. Chaishan deposits:—This deposit is characterized by the presence of arsenopyrite, bismuthinite, fluorite and large amount of pyrite and belongs therefore to hypothermal type. The paragenetic sequence may be determined as follows: Garnet, quartz, calcite, pyrite, arsenopyrite, bismuthinite, fluorite, sphalerite, chalcopyrite, and galena.

3. Shihchuyuan deposits:—The Shihchuyuan deposit characterized by the presence of arsenopyrite, pyrite, sphalerite, chalcopyrite, tetrahedrite and galena with gangues of calcite and little quartz is evidently of hypothermal to mesothermal origin. The order of crystallization is: Garnet, quartz, arsenopyrite, calcite, pyrite, sphalerite, chalcopyrite, tetrahedrite, and galena.
4. Manacoshan deposit:—This deposit contains abundant magnetite, arsenopyrite, pyrite, pyrrhotite, stelbanite and galena. The only associated gangue is quartz. It may be said to be a deposit of hypothermal to mesothermal in origin. Pyrosluite, psilomelane, and wad are the oxidized and enriched products of the Mn-bearing minerals.

5. Shuihuli deposits:—The minerals introduced into the greisen made their way by replacement along the minute fractures in almost parallel direction. In the greisen and the ore body the minerals are: pyrite, fluorite, cassiterite, andradite, sericite, tourmaline, topaz, spinel, chalcopyrite, arsenopyrite, pyrrhotite, stannite, sphalerite, galena, prismatic wolframite or columnar wolframite and quartz. The two kinds of garnet are separated from each other by black tourmaline and sericite bands in the greisen, and are characterized by two different types of mineral assemblage. The minerals commonly associated with grossularite are cassiterite, fluorite, sericite and pyrite; those with andradite are chlorite, epidote, fluorite, and pyrrhotite. While topaz, spinal, chalcopyrite, arsenopyrite, sphalerite, stannite, galena and wolframite are minerals not found in association with garnet in our collected suite of specimens. Judging from their mode of occurrence and their associated minerals the wolframite-cassiterite ore bodies may be taken as pneumatolytic to hypothermal in origin and obviously related to the mother granite. When the granitic magma came in contact with the limestone, the contact silicates and oxides as spinel, garnet, epidote, and rarely magnetite were first formed in succession. Fractures and cracks due to marginal cooling stresses of the magma were developed along contact zone; an ascent of a residual solution or siliceous ichor of the granitic magma ensued them with a number of mineralizers as boron, chlorine, fluoride and possibly water, acting on the wall rock and transforming it to greisen, and then ore minerals as pyrite, arsenopyrite, and wolframite, pyrrhotite, sphalerite, stannite, tetrahedrite, bornite, chalcopyrite, and galena. were deposited in succession. These minerals appeared in normal sequence following the lowering of the temperature-gradient with some of them showing however partial overlapping crystallization. As to the gangue, the minerals, spinel, garnet and epidote, named in their orders of formation
and an early appearance as previously mentioned. They were followed by topaz, muscovite, sericite and tourmaline which were developed, presumably before the interior of the granite was fully crystallized. Fluorite of irregular patches, streaks and wavy veinlets might have been introduced at the time of injection of the quartz veins by solutions carrying an appreciable amount of tin and tungsten. The paragenetic sequence of all these minerals in these deposits may be summarized in the following table (see p. 404).

6. The other deposits:—The Mihuli and Husyuanli Pb-Zn deposits in limestones are located W of Paosiang Co.; the former one containing arsenopyrite, pyrite, sphalerite and galena with gangues of quartz, calcite and fluorite; and the latter containing pyrite, sphalerite, and galena with small amount of pyrrhotite. According to their mineral composition and mode of occurrence, they appear to belong to the mesothermal type.

Conclusively, the deposits in this region have probably been formed during one general period of mineralization and have had a common relation with the mother granite. The difference in the character of the ores is probably due to difference in the physical conditions under which they were formed and possibly also due to slight difference in stage of formation during the general period of the ore deposition.

The events that led to the mineralization were recognized to have assumed the following general order:

(1) The intrusion of the granitic magma and the accompanying fracturing and fissuring of both the granite body and the adjacent sediments.

(2) The passage, along the fissures or cracks, of solutions of deep-seated origin that resulted in the formation of greisens and other alterations of the wall rocks.

(3) Deposition of pneumatolytic ore minerals succeeded by

(4) Hydrothermal mineralization. Highly heated solution deposited the iron sulphides as in Tachiling. When the temperature and possibly the pressure were reduced, lead-zinc ores were deposited.

(5) Finally the ores were oxidized and partly enriched by surface waters.
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Explanation of

Plate II
PLATE II

Fig. 1 A Greisen rock aside the wolframite-cassiterite vein consists of spinel (1), topaz (2), garnet (3), epidote (4), and disseminated ore minerals of pyrite (5), arsenopyrite (8) and pyrrhotite (7), cut through by tourmaline (8), sericite (9), and fluorite (10) veinlets. The upper part is the limestone side. Polished section × $\frac{4}{5}$. Shuishuli.

Fig. 2 Wolframite (1)-quartz (2) vein in contact with topaz greisen (3) which contains topaz, muscovite and some arsenopyrite grains (natural size). Shuishuli.
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Plate II
Explanation of

Plate III
PLATE III

Fig. 1. Greisen showing banded structure contains tourmaline, sericite, fluorite, epidote, quartz and some ore minerals (black). Thin section, ×10. Shuihuli.

Fig. 2. Green tourmaline embedded in the topaz-greisen rock. Thin section, ×15. Shuihuli.

Fig. 3. Arsenopyrite crystals (opaque) in the greisen of topaz and muscovite. Thin section, ×10. Shuihuli.

Fig. 4. Spinel (dark) replaced and brashed by garnet and fluorite. Thin section, ×10. Shuihuli.

Fig. 5. Greisen rock with topaz (high relief), quartz and fragments of hornblende. Thin section, ×10. Shuihuli.

Fig. 6. Alabandite with pyrrhotite inclusion replaces magnetite. Polished section, ×45. Manaoshan.

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Explanation of

Plate IV
PLATE IV

Fig. 1 Bismuthinite replacing pyrite. Polished section, $\times 45$. Chaishan.

Fig. 2 Arsenopyrite with little pyrrhotite replaced by quartz gangue. Polished section, $\times 45$. Tachiling or Chingchuangtang proper.

Fig. 3 Stannite (gray) replacing arsenopyrite (white). Polished section, $\times 90$. Tachiling.

Fig. 4 Crystals of pyrite enclosed by sphalerite which contains chalcopyrite dots. Polished section, $\times 45$. Tachiling.

Fig. 5 Tetrahedrite (light gray) and bornite (gray) replaced by chalcopyrite (white). The former two are in contemporaneous relation. Polished section, $\times 300$. Tachiling.

Fig. 6 Galena with triangular pits replacing pyrite and sphalerite (Unmixing). Polished section, $\times 45$. Tachiling.
Plate IV

Nan.—Ore Deposits of Chinchuangtang, Hunan