The Stratigraphic Distribution of the Bedded Cupriferous Pyrite Deposits and Manganese Deposits in Taiwan*

by T. P. Yen**

I. Introduction.

It has long been known that several bedded cupriferous pyrite deposits and manganese deposits occur in the crystalline schists outcropping on the eastern slope of the Central Range of Taiwan***. Between 1916 and 1923 several deposits were prospected by the Japanese mining companies and three of them were operated on a small scale. All the prospected and operated ore bodies are so small and so variable in thickness, pitch length, and breadth that all the prospects and operations were soon abandoned. Between 1935 and 1938 the second systematic prospects were carried out on the main deposits in six areas, but no workable large ore bodies were found. Several years ago the old prospecting adits in two areas were reopened by Chinese, but soon the work was given up because no workable ores are remained. The areas in which the deposits occur are covered by thick jungles and most of the old adits and roads to the deposits have been destroyed due to collapse of rocks and landsliding. Today, therefore, it is not easy even to approach the deposits and it is almost impossible to study these deposits in detail without reopening of the old prospecting adits or new prospecting work.

The purpose of this paper is to discuss the stratigraphic distribution of the bedded cupriferous pyrite deposits and manganese deposits in Taiwan on the basis of the writer’s work on the metamorphic terrain and of the occasional observations on the deposits. In the past the writer has never had an opportunity to investigate these deposits in detail; for the detailed description on the mode of occurrence, ore bodies, and genesis of these deposits the readers are referred to the reports and papers which have already been published (HATTORI, et al., 1933; ICHIMURA, 1939; OGASAWARA, 1933; OGASAWARA and KIMURA, 1939).

II. Bedded cupriferous pyrite deposits.

On the eastern slope of the Central Range of Taiwan there have been known more than ten areas in which bedded cupriferous pyrite deposits are developed. The main ones are as follows:

<table>
<thead>
<tr>
<th>Area</th>
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<tbody>
<tr>
<td>Buta</td>
<td>Tungao</td>
<td>Ilan-hsien.</td>
</tr>
<tr>
<td>Tapaihan</td>
<td>Tungaochi</td>
<td></td>
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<tr>
<td>Tabilayan</td>
<td>Nanso-hsia,</td>
<td></td>
</tr>
<tr>
<td>Tausai</td>
<td>Hsinchung-hsia,</td>
<td>Hualien-hsia,</td>
</tr>
<tr>
<td>Tabito</td>
<td>Tungmen</td>
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</tr>
<tr>
<td>Tungwian</td>
<td>Liyutang</td>
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<tr>
<td>Hongyehchi</td>
<td>Pengling-hsia,</td>
<td></td>
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<tr>
<td>Tse (Warabi)</td>
<td>Chochi-hsia,</td>
<td></td>
</tr>
</tbody>
</table>

* Received June 14, 1958. ** Geological Survey of Taiwan. *** 台湾中央山脉
1. 五（拓武） 5. 太白山 9. 塔瓦伊（頂峰） 13. 精文 17. 鳳林
2. 東澳村 6. 東澳溪 10. 新城鄉 14. 精文 18. 島
3. 宜蘭県 7. 桑新村 11. 花蓮県 15. 異魚潭 19. 島
4. 東澳 8. 島澳鄉 12. 桑新（大長溪） 16. 異魚 茵
Buta deposit. The deposit was first prospected by the Fujitagumi Co.\(^1\) between 1917 and 1920, and about 1,200 metric tons of ore (containing 5\% Cu and 28.9\% S) were produced. The Nippon Mining Co.\(^2\) prospected the deposit again between 1936 and 1938. Graphite schist, quartz schist, and chlorite schist are the predominant rock types in this area. The main deposit occurs along the foliation planes of the quartz schist and chlorite schist, showing lenticular form. Rarely cupriferous pyrite veins are found to cut the foliation of the wall rocks ("Hanekomi" vein?). The principal opaque minerals of the ore are pyrite, pyrrhotite, and chalcopyrite.

Tungao deposit. This deposit was found by Y. HAENO\(^3\) in 1913. Between 1917 and 1927 the Tanaka Mining Co.\(^4\) prospected and operated the deposit, and about 14,500 metric tons of ore were produced and smelted. The deposit was again prospected by the Nippon Mining Co. between 1938 and 1940. The main rock types in this area are represented by chlorite schist, amphibolite, sericite-graphite schist, quartz schist, and crystalline limestone. Among them the crystalline limestone still contains some remains of fusulines. The deposit shows vein-form with an average thickness of 20-30 cm (the thickest part attains 160 cm), and occurs along the foliation planes of the crystalline limestone and chlorite schist. The opaque minerals of the ore consist mainly of pyrrhotite, pyrite, and chalcopyrite accompanied by a small amount of galena and sphalerite.

Tapaishan deposit. The deposit was prospected by M. IGASAKI\(^5\) between 1935 and 1938. Sericite-quartz schist, quartz schist, graphite schist, chlorite schist, and amphibolite are the main rock types in this area. The deposit occurs along the foliation planes of the quartz schist and amphibolite, consisting of lenticular and bedded bodies. An average thickness of the ore bodies ranges from 30 to 40 cm (the thickest part is 120 cm). Pyrite, pyrrhotite, and chalcopyrite are the principal opaque minerals of the ore.

Tungmen deposit. The deposit was found in 1914 and prospected and operated by the Fujitagumi Co. between 1916 and 1920. About 1,500 metric tons of copper matt were produced. Between 1938 and 1940 the deposit was again prospected by the Nippon Mining Co. The rocks in this area are represented by graphite schist, quartz schist, sericite-quartz schist, chlorite schist, and meta-diabase. The lenticular ore bodies are found along the foliation planes of the graphite schist, sericite-quartz schist, and chlorite schist. The opaque minerals of the ore are pyrite, chalcopyrite, and galena (very little).

Hongyehchi deposit. The deposit has ever been prospected several times. Sericite-graphite-quartz schist, chlorite schist, and amphibole schist are the principal rocks in this area. The deposit occurs along the foliation planes of the chlorite schist and amphibole schist, showing bedded and lenticular forms with an average thickness ranging from 30 to 50 cm. The ore consists chiefly of pyrite accompanied by a small amount of chalcopyrite.

Tse (Warabi) deposit. The deposit was prospected by the Nippon Mining Co. between 1935 and 1938. Crystalline limestone, amphibole schist, chlorite schist, and quartz schist are the main rock types in this area. The deposit is found along the foliation planes of the amphibole schist and crystalline limestone, consisting of lenticular bodies and pyrite-chalcopyrite-impregnating green schist. Pyrite, and chalcopyrite are the main opaque minerals of the ore.

The general features of the bedded cupriferous pyrite deposits of Taiwan may be summarized as follows:

1. Most of the deposits occur along the foliation planes of the crystalline schists as crystalline limestone, chlorite schist, amphibole schist, quartz schist, and graphite schist, showing lenticular, bedded, or massive forms. Some consist of pyrite-impregnating rocks or of veins cutting the foliation

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1. 髙田組, 2. 日本鉱業株式会社, 3. 瓊江邦夫太郎, 4. 田中鉱業株式会社, 5. 伊賀崎基陽
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planes of the wall rocks. It is worthy of notice that most of the deposits have a very intimate relationship with the green schists in the mode of occurrence.

2. All the ore bodies known up to the present are small in scale and very variable in thickness, pitch length, and breadth.

3. The opaque minerals of the ore are represented mainly by pyrite, pyrrhotite, and chalcopyrite. A small amount of galena and sphalerite is rarely found in some deposits. Pyrrhotite is common in the deposits in the northern part (Buta, Tungao, Tapaishan, etc.).

4. All the ore bodies together with their wall rocks were subjected to a regional metamorphism.

5. The mineralization might have taken place chiefly before the metamorphism and in a small part during or after it.

III. Bedded manganese deposit.

Shimaoshan deposit. Up to the present only one area in which bedded manganese deposit is exposed has been known (Shimaoshan, Tungao-hsiang, Ilan-hsien). The deposit was described in detail by OGASAWARA (1933, 1934, 1935) and OGASAWARA and KIMURA (1939). Here only an outline of the deposit is given. The deposit was found in 1932 and prospected between 1938 and 1940 and in 1945. Chlorite schist, crystalline limestone, and quartz schist are the principal rock types in this area. The ore body consists mainly of rhodonite, being intercalated in the quartz schist. The bedded rhodonite-rich part, which has a thickness ranging from 40 to 170cm and a breadth (strike length) of about 700m, gradually passes into manganese quartz schist or quartz schist on both hanging and foot walls. The ore body at and near the surface is subjected to oxidation and most of it was altered to black.

Fig. 1: Geologic sketch map of the northeastern part of the Central Range of Taiwan with distribution of the cupriferous pyrite deposits and manganese deposit.

A ...... Yuli formation.
B1 ...... Tungao facies of the Tailuko formation.
B2 ...... Tachinshui facies of the Tailuko formation.
C ...... Kanagan formation.
D ...... Sanchan formation.
E ...... Bedded cupriferous pyrite deposit.
F ...... Bedded manganese deposit.
G ...... Ridge of the Central Range of Taiwan.
1. Buta 2. Tungao 3. Tapaishan
4. Tungaochi 5. Tabiyahan 6. Tausai

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1) 西帽山，2) 小笠原兼津雄，3) 木村正
manganese ore composed mainly of manganese oxides (psilomelane).

Some black manganese ore boulders have ever been found by Kōno\(^5\) (1930, 1931) in the mouth of the Takkirichi,\(^3\) and the writer also has picked up several boulders from the river beds of the San-
chanchi\(^3\) and Takkirichi. Although the sources of these boulders have not yet been found, they may have been derived from the bedded manganese deposits similar to that at Shimaoshan as inferred from the stratigraphic and petrologic investigations on the crystalline schists outcropping along the rivers.

IV. The stratigraphy of the original sediments of the Tananao schist.\(^4\)

Based on the geologic and petrologic studies on the Tananao schist, the original sediments of it are inferred and tentatively classified as Table 1.

<table>
<thead>
<tr>
<th>Upper Permian and/or lower Triassic?</th>
<th>Yüli formation(^2)</th>
<th>Sandstone with shale, basic tuff, and serpentinite. 2,000 m thick.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle Permian and lower Permian?</td>
<td>Tailuko formation(^3)</td>
<td>Tungao facies(^4)</td>
</tr>
<tr>
<td>Permian and Carboniferous?</td>
<td>Kanegan formation(^6)</td>
<td>Tachinshui facies(^4)</td>
</tr>
<tr>
<td></td>
<td>Sanchui formation(^7)</td>
<td>Gong facies(^9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Raushi facies(^9)</td>
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</tbody>
</table>

This stratigraphic classification of the Tananao group\(^5\) (the original sediments of the Tananao schist) is tentative because some criteria, on which the classification is partly based, are still speculative. The criteria of the stratigraphic classification will be discussed in other paper (YEN: The Tananao group, unpublished).

From the middle part of the Tailuko formation\(^6\) (Tungao facies\(^7\)) such fusulina as Neoschwagerina (?), Schwagerina (?), Parafusulina (?), Neoschwagerinidae, and Schwagerinidae were found (Neoschwagerina zone ?), and from the upper part of the formation (Tachinshui facies\(^8\)) Waagenophyllum (? indicum) and larger fusulina were detected (Yabeina zone ?) (YEN, 1953, 1954 b; YEN et al., 1952). These fossils indicate that the Tailuko formation may be middle Permian (and early Permian ?) in age. It is possible, as deduced from the lithologic characters, that the Sanchui formation\(^9\) is equivalent to part of the Tailuko formation; however, no paleontologic and other evidences have been found to support this view. Therefore, the Sanchui formation is tentatively introduced here to separate it from the Tailuko formation. From the distribution of the green schists in the Tananao schist (YEN, 1954 a), it can be learned that the most conspicuous geosynclinal volcanism took place during the sedimentation of the Tailuko formation.

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1. 大南澳群 2. 玉里層 3. 太魯閣層 4. 東澳相 5. 大湖水相
6. 阿南層 7. 三錐層 8. ゴン相 9. ラウシ相

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V. The stratigraphic distribution of the bedded cupriferous pyrite deposits and manganese deposits.

The stratigraphic distribution of the bedded cupriferous pyrite deposits is shown on Table 2.

Table 2: Stratigraphic distribution of the bedded cupriferous pyrite deposits of Taiwan.

<table>
<thead>
<tr>
<th>Yuli formation</th>
<th>Liyutang, Hongyehchi</th>
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<tbody>
<tr>
<td>Tungao facies</td>
<td>Buta, Tungao, Tapaishan, Tungsochi, Tabiyahan, Tausai</td>
</tr>
<tr>
<td>Tachinshui facies</td>
<td>Tungmen, Tungwenluan, Tse (Warabi)</td>
</tr>
</tbody>
</table>

Most of the deposits hitherto known are found mainly in the green schist-rich parts of the Tungao and Tachinshui facies of the Tailuko formation, and rarely in the green schists of the Yuli formation. Therefore, it can be mentioned that the majority of the cupriferous pyrite deposits in Taiwan are distributed in the same stratigraphic formation (middle Permian and early Permian?).

The bedded manganese deposit of Shimaoshan occurs in quartz schist of the Tungao facies of the Tailuko formation. The quartz schist containing the deposit is stratigraphically very close to the crystalline limestone and chlorite schist in which the Tungao cupriferous pyrite deposit is intercalated.

VI. Conclusion

Most of the bedded cupriferous pyrite deposits and manganese deposits in Taiwan are found in the same stratigraphic formation, and have a close relationship with green schists (derived from basic rocks) quartz schist (probably mainly from chert), and crystalline limestone (from coralline and fusuline limestone) in the mode of occurrence. The deposits together with their wall rocks were subjected to a regional metamorphism. These facts are worthy of notice in consideration on the genesis of the deposits.

The bedded cupriferous pyrite deposits in Taiwan very resemble those in Japan in such respects as the stratigraphic distribution, mode of occurrence, and genesis (KOJIMA, et al., 1956; WATANABE, 1957).

References

KOJIMA, G., HIDE, K. and YOSHINO, G. (1956): The stratigraphic position of "kieslagers" in the 1. 王畏柳


台湾層状含銅硫化鉄鉱鉱床および渋亜鉱鉱床の層位学的分布

（摘）

台湾中央山脈東斜面に露出する大南澳片岩（主として上部古生層から変成したもの）中に層状含銅硫化鉄鉱床および渋亜鉱鉱床が発達している。それら鉱床の一般性質としてつぎの事があげられる：（1）多分の鉱床は結晶石灰岩、角閃片岩、石英片岩および石英片岩などの結晶片岩の片理面に沿って発達し、レンズ状、扇状または塊状をなす。とくに褐色片岩と密接に伴って出現する傾向がある。（2）現に特に判明した鉱体はいずれも小規模でかつその形や大きさは変化しやすい。（3）鉱床鉱物として黄鉄鉱、磁鉄鉱鉱および黄 правилоがあり、このほかに少量の方鉄鉱や閃緑鉱鉱を伴う鉱床もある。磁鉄鉱鉱は北部の鉱床に比較的多い。（4）鉱体はその母岩と共に広域変成作用を受けている。（5）鉱化作用は主として広域変成作用前に行われ、1部ではその役中あるいはその後に行われた。

大南澳片岩の原岩（大南澳群）はつぎのごとくに分けられうるが、これは暫定的なものである。とくに地層の上下関係は目下なお研究中で決定的なものではない。

玉里層（上部二億紀或および下部三億紀？）
大南澳群
太魯閣層 中部二億紀（および下部三億紀？）
開南同層（二億紀および石炭紀？）
三稚層

大南澳群のおもな岩石は砂岩、頁岩、巖性砕岩および碎屑岩、チャート、石灰岩、アルコースなどである。地向斜内基性火山活動が最も盛んでかつ普遍的なのは太魯閣層の沈降期中である。

台湾の層状含銅硫化鉄鉱鉱床の大多数および渋亜鉱鉱床が太魯閣層中の灰色岩に富んだ部分に発生する。すなわち層位学的見て同一地層内に分布しているといえる。

【本文の発表について東大渡辺武男教授および編集委員会の諸氏から多くの御教示を頂いた。厚く感謝の意を表します。】