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論 說 及 報 文

The Types of Copper Ore Deposits of Japan¹⁾

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All the copper ore deposits found in Japan are connected genetically with igneous activity in one of the four distinct metallogenic epochs, (1) pre-Cambrian (?), (2) late Paleozoic, (3) late Mesozoic—early Tertiary and (4) late Tertiary.²⁾

They may be classified into four types, viz. 1) pyrometasomatic deposits, 2) veins, 3) hydrothermal replacement deposits and 4) bedded deposits of cupriferous pyrite.

1) This paper was presented before the Fifth Pacific Science Congress held in Canada last year. The Executive Committee of the Congress has decided to exclude all the papers on the copper resources of the Pacific from the Proceedings, because the International Geological Congress held in Washington in the same year has undertaken the publication of a monograph on the copper resources of the world in which the copper resources of Japan will be fully treated. This is why this paper is published in this journal.

2) T. Kato: The period of igneous activity in Japan, with special reference to metallogeny, *Proc. Pan-Pacific Science Congress*, Australia, 1923, pp. 806–815.

: A revised summary of the metallogenetic epochs of Japan, including Korea, with special reference to the periods of orogeny and igneous activity, *Proc. III. Pan-Pacific Sci. Congress*, Tokyo, pp. 581–588, 1926.

1) Pyrometasomatic deposits

Contact metamorphic or pyrometasomatic deposits of copper ore are very common in Japan. In Japan proper, they are mostly found at or near the contacts between the Permo-Carboniferous limestones belonging to the Chichibu system and the late Mesozoic, chiefly post-Jurassic, granites, those worked in the Yakuki mine in north Japan being the largest of this type. They consist usually of skarn minerals such as hedenbergite and andradite accompanied by varying amounts of wollastonite, ilvaite, epidote, scapolite and others, with chalcopyrite as the chief ore mineral in association with arsenopyrite, pyrrhotite, pyrite, small quantities of galena, zincblende, bismuth ores, scheelite, magnetite and specularite, etc. Most of the sulphide ores, especially chalcopyrite, belong to a stage of deposition later than the skarn minerals, iron ores and a small quantity of sulphides, i.e. in the hydrothermal stage.

The famous gold-copper deposits of the Sûan mine in central Korea also belong to this category. They are developed in pre-Cambrian dolomitic limestone in contact with late Mesozoic (?) granites, being characterized by the occurrence of magnesian skarn minerals such as phlogopite, diopside, tremolite and others, associated with scapolite, humite, ludwigite, etc. with predominant auriferous chalcopyrite and bornite as ore minerals. A characteristic lattice intergrowth of chalcopyrite and bornite is observed in polished specimens under the ore microscope, which disappears on heating to about 500°C, suggesting that the structure is due to ex-solution of bornite from a solid solution of chalcopyrite and bornite formed at a high temperature. Mineralization in the hydrothermal stage is also recognized in the Sûan deposits.

2) Veins

Tourmaline copper veins, representing products of the pneumatolytic stage, are found in the Yakuôji mine in the province of Nagato in western Japan. They are developed chiefly in a boss of grano-diorite near the contact with the Paleozoic formation, and

contain tourmaline and quartz as the principal gangue minerals, and chalcopyrite as the chief ore mineral, associated with arsenopyrite, pyrite, bismuth ores, scheelite, and abundant chlorite. The abundance of chlorite and partially chloritized tourmaline needles in the veins, and the intense chloritization of the wall rock, grano-diorite, suggests that mineralization continued from the pneumatolytic stage to the hydrothermal. Similar tourmaline copper veins are found in the Kanan mine in southern Korea.

Among hydrothermal veins, those connected genetically with pre-Tertiary plutonic rocks are of rather rare occurrence, whereas those related to late Tertiary (Miocene) volcanic activity play a very important rôle in the Japanese copper industry.

The copper veins of the Yoshioka mine in the province of Bitchû and those of the Obie mine in the province of Bizen in western Japan, neither of which is being worked at present, are connected genetically with late Mesozoic granitic intrusion. The former are characterized by the presence of much amphibole and garnet associated with quartz as the principal gangue minerals, the chief ore minerals being chalcopyrite, pyrite and pyrrhotite, while the latter may be classed as quartzose copper veins with quartz and chalcopyrite as the chief components.

The copper veins of late Tertiary age found in the terrain of the Tertiary beds with predominant tuff and tuff-breccia associated with liparitic and andesitic lavas and dykes are characterized by propylitization and silicification of the walls. They are mostly quartzose copper veins, with quartz as the chief gangue and chalcopyrite as the principal ore, as in the veins of the Ashio mine in the province of Shimotsuke, the Osaruzawa and Arakawa mines in the province of Ugo, the Furokura mine in the province of Rikuchû, the Ikuno-Kanagase mine in the province of Tajima and others, but a few of them are characterized by the presence of siderite as the chief gangue, as in the Omori mine in the province of Iwami. Some veins of the Kinkwaseki mine in Formosa are peculiar in containing enargite as the chief ore associated with native gold.

3) Hydrothermal replacement deposits

The characteristic ore deposits of mixed sulphides, called "kuro-mono" or "black ore", which are irregularly massive in form and composed of zincblende, galena, pyrite and chalcopyrite with varying amounts of barite, gypsum and chalcedonic quartz, are widely scattered in the terrain of late Tertiary volcanic rocks throughout Japan, especially in northeastern Japan. They are hydrothermal replacement deposits formed in liparitic and andesitic rocks as well as in associated tuffs and even in the Tertiary shaly rocks, and are successfully mined and smelted as copper ore, notwithstanding that their copper content is very small, ranging usually from 2% to 3% or a little more, on an average. More than 35 deposits of this category have so far been exploited, of which those of the Kosaka mine in the province of Rikuchû and of the Hanaoka mine in the province of Ugo are the largest.

In the Ashio mine, already mentioned, many irregular massive deposits of replacement origin, called "kajika" by miners, are known to exist in the liparite mass forming a volcanic neck, which is the chief country rock of the copper veins, as well as in the surrounding Paleozoic formation. They are usually found at the intersections of small fissures that served as channels for the hydrothermal solutions. The ore of the "kajika" deposits is characterized by the scarcity of gangue minerals and by the presence of high-grade massive chalcopyrite.

4) Bedded deposits of cupriferous pyrite

Bedded deposits of cupriferous pyrite play an important rôle in the mining industry of Japan. They are mostly enclosed in the so-called Sambagawa series, consisting of highly metamorphosed crystalline schists, which is the oldest formation found in Japan proper. The age of this series still remains a topic of controversy among Japanese geologists. Some consider that it is younger than the pre-Cambrian and call it "pre-Carboniferous", while others assign it to the oldest Paleozoic on the assumption that the younger Paleozoic

formation called the Chichibu system, containing beds with Permian and Carboniferous fossils, conformably overlies a series of phyllites and green metamorphic rocks called the Mikabu series, which apparently rests conformably on the Sambagawa series. Others maintain that it is of pre-Cambrian age on the basis that its members are always highly metamorphosed, in contrast with those of the Chichibu system. The Sambagawa series is a characteristic formation developed along the inner border of the outer zone of southwest Japan, which is separated from the inner zone by the prominent tectonic line called the median dislocation line. Throughout this elongated area, innumerable ore deposits of cupriferous pyrite are found, commonly along the plane of schistosity in lenticular or bedded forms. The largest of this category is the deposit of the Besshi mine in Shikoku, which has a length of more than 1,600 meters along the strike, and over 1,300 meters down the dip, and is usually 5 to 10 meters in thickness. It consists of massive pyrite mingled with more or less chalcopyrite and fahlband-like banded ore cut by a pure chalcopyrite vein, and is enclosed in graphite and chlorite schists in close relation to eclogite and amphibolite. It is believed that the deposit was formed through replacement and fissure-filling along the schistosity plane by the hydrothermal solutions genetically connected with basic igneous rocks now metamorphosed into the eclogite and amphibolite. Other large deposits of this type found in the Sambagawa series are those of the Kune mine and the Iimori mine on the Main Island, Shirataki and Higashiyama in Shikoku.

The Hitachi mine in the province of Hitachi also works bedded deposits of cupriferous pyrite, which are enclosed in the highly metamorphosed amphibolite formation belonging to the Mikabu series, or the lower Paleozoic, intruded by granitic and dioritic rocks. The Hitachi deposits were formed by successive mineralizations from the pneumatolytic to the hydrothermal stage, in either the late Paleozoic or the late Mesozoic metallogenic epoch.

The bedded cupriferous pyrite deposits of the Makimine mine in Kyûshû, which are evidently related genetically to the gabbroic

rocks, were formed by hydrothermal replacement and fissure-filling in the late Mesozoic metallogenic epoch.

Thus, of the four largest copper mines of Japan, the Besshi and the Hitachi mines work the deposits of cupriferous pyrite, the Ashio mine veins and replacement deposits, and the Kosaka mine (including the Hanaoka mine) works the deposits of "kuromono" or replacement deposits of mixed sulphides.