Resume of a report on the geology of the cupriferous pyrite deposits in the crystalline schists of the northern part of Awa and the northwestern part of Iyo in the Island of Shikoku.

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Résumé of a report on the geology of the cupriferous pyrite deposits in the crystalline schists of the northern part of Awa and the northwestern part of Iyo in the Island of Shikoku.

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The cupriferous pyrite deposits in crystalline schists form important sources of the present supply of copper and sulphur ores in Japan. The crystalline schists, predominantly metamorphosed sediments, consisting of graphite-schist, chlorite and amphibole-schists, mica-schists and phyllites with intercalating thin layers of quartzose sericite-, piedmontite-, and glaucophane-schists and limestone, stretch through the northern portion of the Island of Shikoku from the northwestern part of the province of Iyo in the west to the northern part of the province of Awa in the east. The present paper deals with two small areas, rich in mines of cupriferous pyrite. They lie near the two ends of the zone of crystalline schists, and are separated from each other by the tract of high mountain ridges in which lies the copper mine of Besshi with the most extensive deposit of cupriferous pyrite in Japan.

In Awa the larger number of the pyrite deposits are found in the formation of chlorite-schist and quartzose piedmontite-schist. The chlorite-schist shows microscopically in most cases, epidote and abundant glaucophane needles. Here also are found a glaucophane rock with a massive structure and a black glaucophane-schist, resembling the Swedish occurrence, both rocks being as yet known only in Japan. In the southern portion of the area in Awa, and in the metalliferous portion in question in Iyo, the rocks show the weaker metamorphism and instead of chlorite-schist amphibole-pyroxene-schist predominates. In Iyo especially the schistose structure is far less pronounced, and there are found intrusive pyroxenite and massive gabbro and diabase together with the green schists.

The mines described number thirty of which fifteen belong to Iyo. None but the Mochibe Mine in Awa, which produced 14,041 metric tons of ore in 1908, are at present large producers. But lying as they do clustered in small areas, they afford good opportunities for the comparative study of the nature of the geologica occurrences. In all cases, without exception, the mother-rocks of the ore deposits are green schists, namely, chlorite-schist and amphibole-pyroxene-schist. Outside of the districts here described are found in rare instances cupriferous pyrite deposits which are contained in graphite-schist or in a formation consisting of black phyllite and limestone. But so far as I know no instance has yet been observed in the workable deposits of a like nature in the crystalline schists in Japan, where no green schist, however insignificant in thickness, has been found to occur in direct contact with the deposits.

As a common feature connected with the deposits under consideration the fact that in all cases the pyrite deposits are accompanied by shear-zones deserves special attention.

The shearing of the green schists is shown not by the brecciated structure, but by a loss of schistosity and an appearance like irregular bundles of fibres, or by an excessive crumpling of schistose planes, and always by a darker colouring of the whole mass. It is very common that a thin layer of pyritic ore is found on each side of a shear-zone on both the hanging and the foot walls; nevertheless one or more pyritic layers often occur in the middle of a shear-zone.

Shear-zones, together with pyrite beds, follow in the main the schistosity of the rocks(compare fig. 1 and 2).

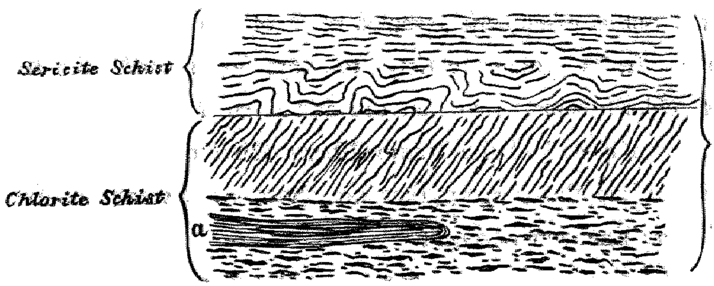

Fig. 1.- Shear-zone at Kawatayama Mine
a. not sheared

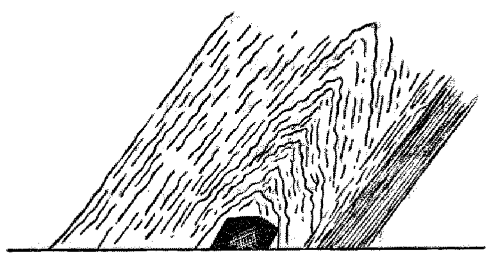

Fig. 2.- Shear-zone at mouth of the Adit of the Kawatayama Mine

The chief ore is pyrite with a grayish, very finely granular aspect, usually with 2—5 % copper and a small quantity of silica. Poorer pyrite is sold only for its sulphur. In Awa are found besides the pyrite ore, ores of copperpyrites and bornite.

Bornite forms an important ore only in a few cases, but copperpyrites are found in most mines in the chlorite-schist in Awa and is in some mines a more important ore than the cupriferous pyrite. In the Mochibe Mine there is found a small quantity of copperpyrites ore which represents a greatly enriched portion of pyrite ore, but commonly this kind of rich ore does not occur in sufficient quantity to be important.

The other kind of copperpyrites ore always contains more or less fragments of chlorite-schist and grains of pyrite (Plate I). This ore represents partly the filling of small interstices and fissures in the sheared rock, but is essentially a replacement of chlorite-schist in the sheared zone. In its poorer variety the ore looks more like the rubbish of chlorite-schist than an ore and in such cases compares well with the "Kniest" of the Rammelsberg Mine in Germany. In the Mochibe Mine the copperpyrites ore shows an average copper content of more than ten per cent.

The copperpyrites and bornite ores do not occur as continuous veins or beds; they generally form local patches outside of the main pyritic ore-bodies and often ramify in very irregular ways in the shear-zones. It may be here noticed with interest that it was this kind of ore that made the Besshi Mine the largest of the copper mines in Japan for hundreds of years, while the thick poorer pyrite beds on both sides of the copperpyrites ore were left untouched in the mine till recent years.

The pyrite and copperpyrites ores contain, usually in minute quantities, silver, zinc and gold, and in some cases lead.

Microscopically pyrite ore invariably contains more or less small interstices which are commonly filled with quartz, and in some cases with white mica. Chlorite and glaucophane have been also found in pyrite. Pyrite shows square crystal outlines against the interstices. The metallographic examination of the pyrite ore reveals the fact that in the ores utilized for their copper, copperpyrites exist as a material filling the narrow spaces between pyrite granules or in richer varieties completely enveloping pyrite granules (Plate I, Fig. 4); and we can, from the mode of the relation of the two minerals, infer that the essential portion of copperpyrites in those ores came after the pyrite which they more or less replaced.

Only a small amount of gangue minerals is found as is usual with deposits of this nature. Quartz always occurs in shear-zones and is especially abundant in those parts rich in copperpyrites and bornite. Calcite has been only rarely observed. Of the metallic minerals found occurring together with the pyrite ore magnetite, pyrrhotite, and probably some hematite are contemporary with the pyrite. Magnetite occurs in intimate banding with pyrite. Hematite is also seen where the pyrite has suffered excessive shearing. Zincblende which was microscopically detected in the pyrite ore from only one locality seems to be contemporary with copperpyrites of a later mineralisation. Native copper is known only as a rare occurrence. Crystals of chalcosite have been found in a small druse together with bornite.

The forms of the pyrite masses are platy beds, lenticular masses, or long rods with transverse sections of various descriptions. Platy types are observed in the deposits of Awa but they are seldom uniform in thickness and the economically workable parts in them form in many cases parallel shoots, of lenticular transverse sections, which pitch usually with gentle inclinations. In the Mochibe Mine are found both forms of the platy regular bed and the irregular rod-shaped deposits; the mineralogical characters and copper contents of the two show no important differences.

The deposits of the latter form are found in the hanging wall of the former, and their transverse sections are by no means always lenticular, but show forms of every conceivable variety (Plates III and IV), In the northwestern part of Iyo deposits of the rod-shaped type are conspicuously prevalent. There, only one case of a thick lenticular mass is known, and none of the platy type. Ore bodies, in a single rod or in two or three parallel rods, pitch usually with angles from of fifteen to twenty degrees. The direction of the pitch is usually W. S. W. and it coincides in the main with the direction of the minute wrinkles observable in the sheen, cleaved faces of the schists. The neighbouring ore-rods do not always lie on the same planes transversely and longitudinally, but in some cases are arranged in the form of steps (Plate VI).

The never-failing accompanyment of shear-zones, the irregular forms of the ore bodies, the abutting of ore beds against the schistosity of the rock which is observed especially distinctly in slender pyrite seams, the step-formed occurrence of ore-rods—all these preclude the notion of the sedimentary formation of these pyritic deposits. The deposits are best explained by the infiltration and mineralisation, firstly of essentially pyritic solutions in fissures formed in and along the shear-zones with a certain impregnation and metasomatosis on the walls of the fissures, and secondly of solutions rich in copper that reacted upon the pyrite previously formed and caused also metasomatosis by copper sulphides upon the rocks of the shear-zones, thus forming, besides pyrite rich in copper, the ores of copperpyrites and bornite.

As the districts lie in a region of steep topography, the actions of percolating waters on the uppermost parts of the deposits have not been considerable. Only in a few cases, under the limonitic covering were found enriched zones, consisting chiefly of covelline and copper carbonates together with partly limonitized pyrite. This kind of enrichment above and directly under the ground-water level, usually known by American geologists by the name of secondary sulphide enrichment, should in my opinion be carefully distinguished from the enrichment by copperpyrites as previously described which shows no relation to the ground-water level and must be attributed to the action of hot solutions in the deeper regions of the earth.