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NATIVE COPPER AND SILVER ORE DEPOSITS IN DALANE, NORWAY

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With 4 figures in the text.

Geologic description of the area. The area consists of folded and metamorphosed rocks of pre-Cambrian age, greenstones, quartz porphyries, quartzites, and conglomerates.

The greenstones and the quartz porphyries were in turn erupted as respectively basic and acid lavas. In the intervals between the eruptions of the various lavas sandstones and conglomerates were deposited. To some extent, e. g. at Årdalen, the sandstones have been broken up and intruded by the basic rocks, see map fig. 2, but the predominating part of the erupting magma has flowed and covered the older rocks as lavas.

The rocks have been deposited in a shallow sea of great dimensions. This may be gathered from the fact that in the greenstones are constantly found thin strata of quartzite or slate; these strata sometimes have a very limited extension. Further the conditions of deposition must account for the frequent occurrence of conglomerates, as well as for the fact that pebbles occur dispersed within the quartzites. — Finally ripple marks are very common, and current bedding is known from several localities.

The described series of rocks has later been folded. In the area in question the trend of the folding axes is NE—SW, with dip to SW. There are every indication of a steep dip, but this cannot be decided with certainty, all the rocks showing a tectonically conditioned schistosity which is almost vertical. The primary structure of the strata is to all evidence everywhere extinct.

As has been already shown by C. Bugge[1] the degree of metamorphosis of the rocks depends on the distance which separates

[1] C. Bugge: Geologiske undersøkelser i Telemark. Norsk geol. tidsskr. 12, 1932, p. 149.

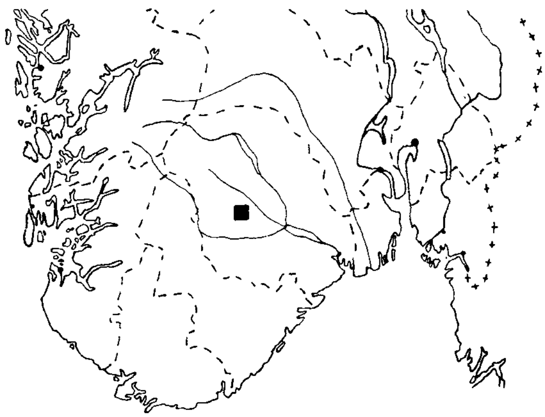

Fig. 1. Key map showing location of Dalane.

them from the Telemark gneiss. The greenstones which at a large distance from the gneiss largely consist of epidote and highly altered plagioclase, with some chlorite, amphibole and calcite, has at a shorter distance from the gneiss been developed as amphibolites or hornblende schists.

These rocks will be more thoroughly described in a following paper.

The folding as well as the metamorphosis appears to have taken place contemporaneously with, and must be ascribed to the same causes as the extensive granitization which caused the formation of the Telemark gneiss (the Telemark granite), which constitutes the bed rock all over a greater part of Southern Norway.

Deposits of native copper and silver. On the border between an older quartzite and a younger greenstone native copper and native silver occur as impregnation in the quartzite.[1] The zone of impregnation usually extends 1—2 dm from the border between the two rocks into the quartzite; sometimes, but very seldom, this zone may be up to two meters wide, but it may also be limited to some few centimeters. In the greenstone I have never found native copper or silver. The zone of impregnation is 1 1/2 kilometers long, extending from 100—150 m north of the river SE Landsverk to Kjerrstaul outfarm (sr.). The border of the rocks, and thus also the impregnation zone strikes N 60° E and dips 85°—90° SE.

[1] The occurrence has been earlier dealt with by C. Bugge, Op. cit. p. 165.

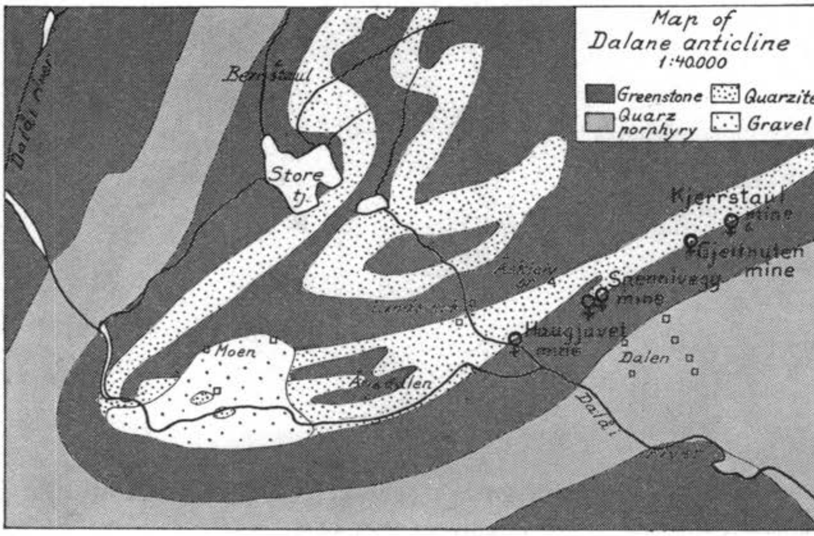

Fig. 2. Geological map of Dalane anticline.

In addition to quartz, feldspar and sericite, which are found everywhere in the quartzite, the impregnation zone also offers calcite, native copper and native silver, and besides also cuprite which is without doubt a later deposition. Sulphides I have never found in the ores. They are to all evidence not to be found in the paragenesis. Fig. 3 clearly shows how the native metals have replaced the minerals of the quartzite. Silver is found in the middle of the portions of copper as well as along their borders. The borders between silver and copper are smooth, and no indications of unmixing structures are found. The smooth borders are not straight. Thus neither of the metals are limited by crystal faces. The relative ages of the metals are very difficult to decide, but the structural conditions described above might indicate a contemporaneous deposition.

Megascopically the metals are seen as flakes, lumps and small threads. An attempt to crack a piece of ore will show that this is not easily done. Even if the piece cracks, the portions do not fall from each other. The rock is as if it were sewn together by threads of copper.

The relative quantities of silver and copper are found to vary from mine to mine and from place to place in the same mine. O. Dalen, M. E., has kindly supplied me with some data: Analysis of crude ore, which was earlier sold to England and Germany, show

Fig. 3. Native copper (light grey) replacing quartzite (dark grey to black). Smaller portions of native silver (lighter grey) together with native copper.

× 6 2/3.

variations of at least 2.6 to 6.7 parts of Ag per 100 parts of Cu, estimated according to weight. Residue at the mine from handpicked ore offers 0.76 Ag per 100 Cu, and products from laboratory tests on flotation show 0.74—1.78 Ag per 100 Cu. — Besides the copper contains traces of gold.

Cuprite is seen in the microscope as thin coatings on native copper. Fig. 4. This mineral is to all probability much younger than the others, and is due to oxidation of the ore.

Genesis. The above described geological observations and mineralogical data gathered in the field can only be explained by supposing the occurrences to have been formed by the basic lava after overflowing the younger sandstone having impregnated the latter with native copper and silver. Occurrences deposited in this way are known from several places, f. ex. in connection with the triassic trapp rocks in New Jersey, Pennsylvania, and Virginia. Usually, and in contrast to the conditions at Dalane, the metals are found not only in the underlying rocks but also in the basic lava itself. In most ore deposits of this type native copper is even only found in vacuoles or fractures in the lava. In this connection some interest may attach

Fig. 4. Quartzite (black) replaced by native copper (grey) and native silver (light grey) within a thin coating of cuprite (dark grey). The borders between copper and silver are smooth, but no crystal faces are seen.

$\times 100$.

to the fact that there is found no indication at all of amygdaloidal structure in the greenstone along the zone of impregnation, and it must probably be concluded that the zone has offered no vacuoles and blowholes in which the metals might have been deposited. (That contingent vacuoles should have become extinct by the following folding and metamorphosis is not probable, fine amygdaloids having been preserved elsewhere in the area.)

Investigations on the interesting deposition of native copper from natural ascending solutions have been made by R. C. Wells.[1] He has shown that when solutions of copper are treated with a suitable oxidating reagent, he himself used Fe_2O_8, the following processes will take place:

1. $Cu_2S + 5\,Fe_2O_8 + 11\,H_2SO_4 = 10\,FeSO_4 + 2\,CuSO_4 + 11\,H_2O$
2. $Cu_2S + 8\,CuSO_4 + 4\,H_2O = 5\,Cu_2SO_4 + 4\,H_2SO_4$
3. $Cu_2SO_4\,(+\,aq.) = CuSO_4 + Cu$

   or by a combination of these three processes:

4. $Cu_2S + 3\,Fe_2O_8 + 5\,H_2SO_4 = 2\,Cu + 6\,FeSO_4 + 5\,H_2O$

or in other words: When copper sulphide-bearing solutions are flowing

[1] R. C. Wells: Chemistry of deposition of native copper from ascending solutions, U. S. G. S. Bulletin 778 (1925).

into oxidating surroundings the sulphide ions will be oxidized to sulphate ions, whereas the copper ions at the same time will be reduced to metallic copper.

In the case under discussion this process must have been completed, the occurrence being, as mentioned above, completely void of sulphides.

That the silver ions present in the solution must necessarily be deposited as native silver is obvious, considering the impossibility of silver ions existing side by side with native copper, because of the relative position of the metals in the electromotive force series.

The above-mentioned smooth borders between silver and copper and the absence of unmixing structures indicate that the temperature cannot have been very high when the system was last in equilibrium, as at a high temperature the metals would have been alloyed. However, we cannot on these indications conclude that they have originally been deposited at a low temperature, as we cannot exclude the possibility of the present structure being due to the subsequent folding and metamorphosis. It is, however, commonly supposed that occurrences of this type have been deposited at a low temperature.

History and mining. The occurrences must have been known at an early date. This appears from the fact that at Øvre Spennivegg a driftway is found, which has been worked by burning wood. Later they have been forgotten and rediscovered in the eighties of the last century by Aslak Dalen. From that time up to the present efforts at mining have been done by one Norwegian, two English and two French companies. The mines were lastly worked for two years from 1916 by a French company. Since then the mines have not been worked.

Along the impregnation zone there are found no less than seven mines and mining claims, of which four are of a considerable size, i. e. from West to East Haugjuvet, Spennivegg, Geitnuten and Kjerrstaul.

The fact that the occurrence is situated in a very steep and almost impassable landscape, makes the exploitation difficult.

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