THE TEMPERATURE OF DEPOSITION OF SPHALERITE-BEARING ORES IN THE CALEDONIDES OF NORTHERN NORWAY

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The sulphide ores in the Caledonides of northern Norway commonly occur as flat tabular bodies in the allochthonous schists of the eastern or marginal zone (as opposed to the central zone) of the Caledonides. Some are thick and extensive enough to be exploited commercially as in the mines of the Sulitjelma region (e.g. Jakobsbakken). They frequently occur in planes of shear and always seem to be later in age than the regional metamorphism.

The assemblage of ore minerals and the mode of occurrence of the ore bodies suggest a uniform temperature of mineralization in the Caledonide schists of northern Norway. The present work was undertaken in order to test the validity of this assumption.

The chief ore minerals are pyrrhotite, pyrite, chalcopyrite and sphalerite. The proportion of each varies but the sphalerite usually is less abundant than the other minerals. The texture of the ores indicates that in most cases the sulphide minerals were formed during one epoch of mineralization.

In a recent publication one of us (KULLERUD, 1953) has demonstrated the value of the FeS-ZnS system as a geological thermometer.

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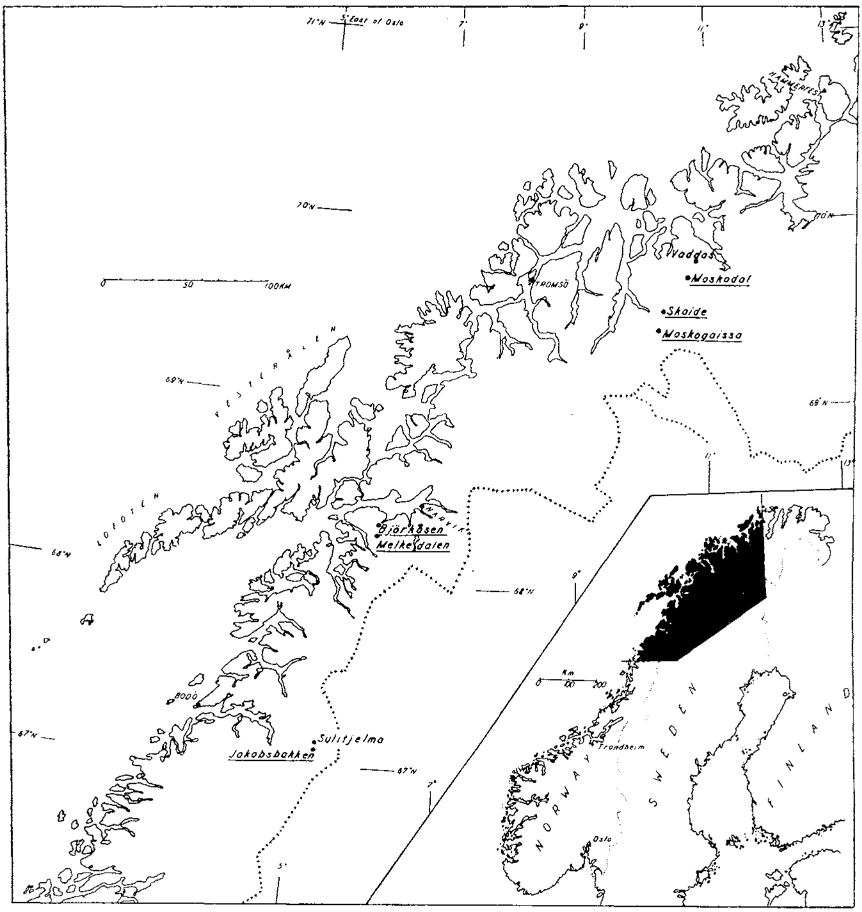

Fig. 1. Map of part of northern Norway showing location of sulphidic ore bodies referred to in the text; sphalerite samples were obtained from those underlined. Inset map shows location of the area in Scandinavia.

It was shown how the (Fe,Zn)S mix-crystal composition under equilibrium conditions varies as a function of temperature. Samples of sphalerite from various parts of the world and from different geological environments were chemically analyzed for FeS and their temperatures of formation determined from the FeS-ZnS equilibrium diagram (op. cit., fig. 1.) after correcting for the influence of Mn, Cd and pressure.

The texture of the ores indicates that excess iron sulphide was present in most cases. The previous work has shown that under these circumstances the composition of the (Fe,Zn)S mix-crystals is a measure of the P, T conditions existing during the formation of the ore bodies as a whole.

Locations of sphalerite samples considered in this paper are shown on the accompanying map (text-fig. 1).

Description of localities.

Jakobsbakken, Sulitjelma. The mine is one of several belonging to the Sulitjelma group. The sphalerite is commonly associated with pyrite and appears to be interstitial to the latter. It is locally present in more conspicuous amounts and the sample analyzed was obtained from one such occurrence (level 7-½). The other minerals present include pyrrhotite and chalcopyrite in the main and these possibly belong to another and later period of mineralization.

Melkedalen, Ofoten. The ore occurs in a shear zone in a bed of meta-limestone (FOSLIE, 1946). The chief ore minerals are pyrite, chalcopyrite, pyrrhotite and sphalerite.

Bjørkåsen, Ofoten. Here the ore occurs as a thin layer in hornblende-schist (FOSLIE, 1926). Pyrite is the most common sulphide with a little sphalerite and chalcopyrite. Pyrrhotite occurs in very minor quantities.

Birtavarre district. Several small mines were worked in this area on either side of Kåfjorddalen during the years 1900—1919. The mining operations appear to have been based on separate small, lens-like bodies. The area is at present being investigated by the Geological Survey of Norway and more complete reports are in preparation.

a. M o s k o g a i s s a . Three small abandoned mines lie on the plateau south-west of Kåfjorddalen. Specimens of sulphides from the mine dumps and from drill cores showed mainly chalcopyrite and pyrrhotite. Megascopically visible sphalerite was found, however, at a small prospect pit, one kilometer north of the old mine of Moskogaissa 117, and on the same «ore horizon». Associated sulphides were chalcopyrite and a little pyrrhotite, the proportion of the latter being much lower than seems to be normal for the area.

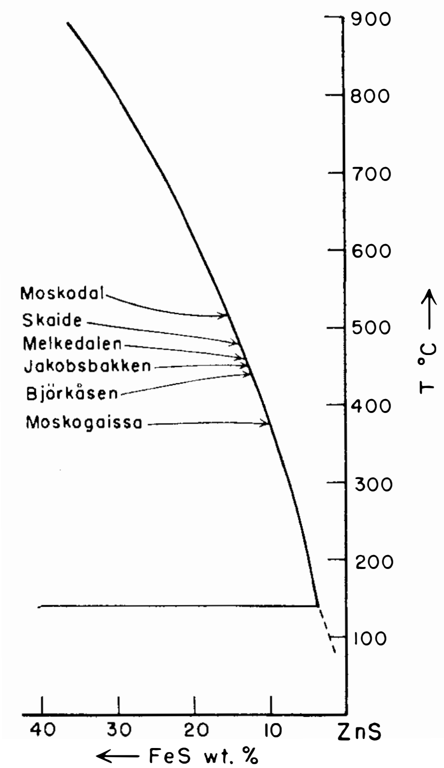

Fig. 2. Diagram showing temperatures of deposition of the ores from wt % data.

b. Skaide. The small mine at Skaide lies 10 km NE of the Moskogaissa workings. The chief ore minerals are pyrrhotite and chalcopyrite. Sphalerite occurs in megascopic amounts.

Moskodal, Troms. A small mine situated in the upper part of a valley of the same name. The chief ore minerals include chalcopyrite and pyrrhotite with small amounts of visible sphalerite. The ore strongly resembles that at Skaide both in the minerals present and in texture. It also seems to belong to the same stratigraphical formation.

It should also be pointed out that other sulphide ore bodies occur in northern Norway but not all contain visible sphalerite. The zinc content as revealed by chemical and spectrographic analyses is often less than 1 per cent. (e.g. Vaddas).

Below are listed the results of chemical analyses on FeS, MnS and CdS of the sphalerite samples and the deduced temperatures of formation, uncorrected for the influence of pressure. The limit of analytical error of the FeS content was about 2.5 per cent. The amounts of CdS and MnS in the samples were in all cases too low to influence the solubility of FeS in ZnS (See KULLERUD, op. cit. p. 119).

Great care was taken to obtain pure samples of sphalerite for analyses. Both a Frantz Isodynamic Separator and heavy liquids were employed to separate out the sphalerite and the final concentrate was carefully hand-picked under a binocular microscope. (The authors are very grateful for the assistance of Mrs. B. Nilssen of the Geologisk Museum, Oslo, in this work.)

The temperatures of deposition of the ores can be obtained from text-fig. 2 which was drawn from the weight per cent data given on p. 98 and p. 100 in the earlier paper by KULLERUD (op. cit. 1953). As chemical analyses normally are given in weight per cent, it is more practical to use the weight per cent diagram for temperature determinations than the mol per cent diagram earlier published by KULLERUD.

Locality	Wt % FeS	Wt % MnS	Wt % CdS	Temp. °C	Temp. °C after pressure correction
Jakobsbakken[1]	12.70	0.24	< 0.5	450	487 ± 25
Melkedalen[2] ..	13.10	0.28	0.13	460	497 ± 25
Bjørkåsen[2]	12.32	nd	nd	440	477 ± 25
Moskogaissa[1] ..	9.99	0.02	< 0.5	375	412 ± 25
Skaide[1]	13.63	0.37	tr	480	517 ± 25
Moskodal[1]	15.18	0.04	< 0.01	515	552 ± 25

[1] Analyses carried out in the laboratory of the Geological Survey of Norway by Miss Erna Christensen.

[2] Analyses carried out by Dr. H. B. Wiik, Helsingfors, Finland.

The Influence of Pressure.

Little is known of the rock pressures operating during deposition of these sulphide ores. It is shown experimentally, however, (KULLERUD, op. cit., pp. 105-7) that the (Fe,Zn)S mix-crystal composition is affected by pressure to some extent. Thus an increase in pressure of 1000 atmospheres decreases the solubility of FeS in the mix-crystals corresponding to a temperature difference of 25° C. The ore bodies all belong to the same geological environment, namely regionally metamorphosed rocks in the epidote-amphibolite or low amphibolite facies. It seems, therefore reasonable to assume that ore formation probably took place at depths of less than 10 km. The confining pressure should thus not have succeeded 2,500 atmospheres. A pres-

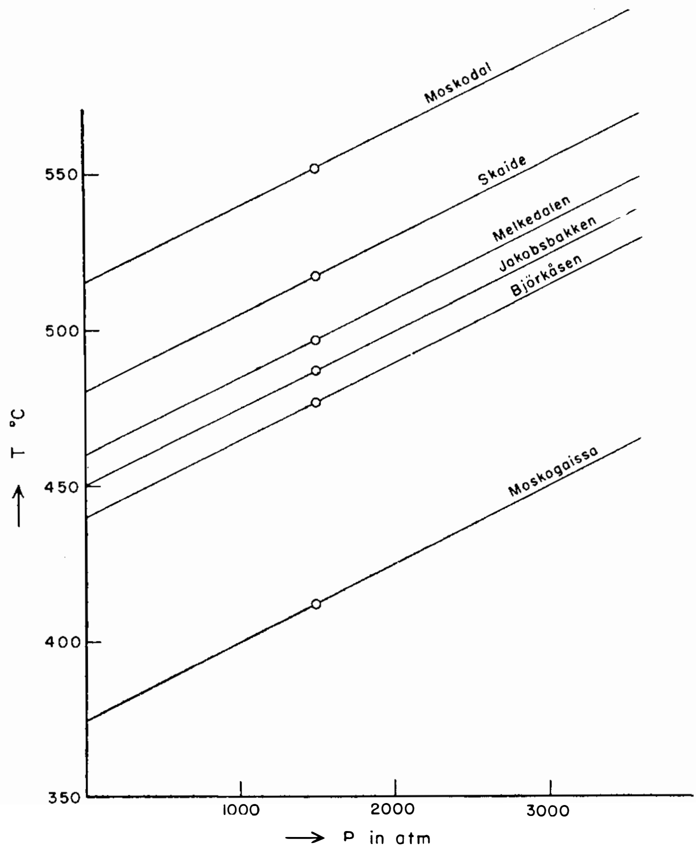

Fig. 3. Diagram showing the influence of pressure on the temperature of depos ition of the ores.

sure of 1,500 ± 1,000 atmospheres should cover the possible range of pressure and will give a possible temperature variation of ± 25° C. A graph (text-fig. 3) demonstrates the effect of pressure on the temperature of formation of the (Fe,Zn)S mix-crystals. From this the temperatures of formation of the sphalerite in the 6 cases investigated are as shown in table above.

The temperature at Jakobsbakken is an interesting check on a previous determination by KULLERUD (op. cit., 1953, p. 130) when the temperature was deduced from unit cell data of an X-ray powder diagram.

Of the above results the temperature deduced for Moskogaissa is lower than for the other deposits. There seems no reason to suppose that the geological environments differed greatly, though an explanation may lie in the exceptionally low pyrrhotite content of the deposit. Thus it may well be that an iron deficiency existed locally during the formation of the Moskogaissa ore deposit such that (Fe,Zn)S mix-crystals with an iron content corresponding to the equilibrium composition at the prevailing P,T conditions were not formed.

Conclusion.

The temperatures of formation of these scattered ore deposits in northern Norway all lie within a rather narrow range (550 ± 40° C, excluding Moskogaissa). This supports the idea of a uniform mineralization in the Caledonide schists of northern Norway as deduced from the assemblage of ore minerals and from the mode of occurrence of the ore bodies.

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