

Supergene Alteration of Norwegian Sulphide deposits — a query.

by

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In the previous NGU year book H. Bjørlykke (1960) gave some interesting facts regarding the diminution of copper content with depth in certain Norwegian Caledonian massive sulphide deposits. Bjørlykke cited rather limited data for six of these deposits, which purport to show that this diminution with depth is a general feature of such deposits.

As Bjørlykke states, the copper content in Norwegian massive sulphide ore bodies is always present as chalcopyrite. Copper minerals other than chalcopyrite, sometimes with some exsolved cubanite, are lacking in these pyrite-(pyrrhotite)-bearing ores. In a previous paper (Vokes, 1957) the present writer showed that certain copper ores in Precambrian areas in northern Norway showed two distinct parageneses, which he termed respectively the pyritic paragenesis (pyrite-pyrrhotite-chalcopyrite) and the copper paragenesis (chalcopyrite-bornite-digenite). Pyrite is lacking or present as trace amounts in ores showing the second paragenesis. The similarity between Precambrian ores of the second paragenesis and the normal massive Caledonian pyritic ores was pointed out. In the present context the most important point of similarity is the absence of copper minerals other than chalcopyrite. So far ores of the copper paragenesis type have only been reported from one area in the Caledonian metallogenetic province in Norway, (Foslie, 1941, pp. 205—216). This author describes supergene covellite and, in places, chalcocite, in bornite-rich ores in the Tysfjord area. Gjelsvik (1956) has described supergene phenomena of apparently pre-glacial age in similar ores from Finnmarksvidda. Here such acceptably supergene minerals as chalcocite, covellite, malachite and chrysocolla occur in the oxidation and cementation zones of the chalcopyrite-bornite ores.

Bjørlykke's suggestion is that the higher copper values, due solely to chalcopyrite, in the upper parts of the massive pyritic ores cited by him, may be due to supergene enrichment related to now eroded weathering zones of pre-Pleistocene age.

The present writer feels that this suggestion is so unusual and contrary to what is usually held to be the case that it should be examined in some detail.

In a recent contribution to the problem of supergene alteration of copper ore deposits, Anderson (1955), following Garrels (1954) summarizes the processes taking place as follows:

"At or near the surface in the zone of oxidation, metal and sulfate ions are freed by the oxidation of sulphide minerals. The metal ions may be reprecipitated by reaction with carbonate, hydroxyl, silicate, sulfate or sulfide ions. Copper ions in particular may travel downwards to precipitate as copper, forming secondarily enriched bodies."

Anderson goes on to state that probably the best evidence for secondary copper sulphide enrichment is the presence of an uppermost low-grade leached zone, containing only oxidized copper minerals, overlying a higher grade *chalcocite* or *covellite* ore zone that is in turn *rather sharply* separated from an underlying lowgrade *chalcopyrite* zone (protore). (Present writer's italics).

Anderson summarizes the views of various other authorities regarding criteria for the recognition of a supergene enriched copper zone. Common to all of these is the idea that *chalcocite* or *covellite* must be present, but even this criterion must be used with caution since hypogene *chalcocite* is known from Butte, Kennecott and other localities. Bateman's view (1950, p. 285) is that sooty *chalcocite* is the only mineral absolutely diagnostic of supergene enrichment.

It is a common feature of all these discussions that *chalcopyrite* is implicitly or explicitly regarded as a *primary* sulphide of copper. The appearance of this mineral along with the other (supergene) sulphides of copper is regarded as of minor importance.

Lindgren (1933, p. 831) states that "bornite and *chalcopyrite* are rarely supergene"; further, (p. 834) "occasionally secondary *chalcopyrite* or bornite will appear . . ." along with the other, supergene, sulphides, especially *chalcocite*.

Garrels (1954) in a recent discussion of the chemistry of oxidation of copper, lead and zinc deposits places *chalcopyrite*, along with *galena* and *sphalerite* in the category of primary minerals (p. 154). In the

discussion of the fields of stability of copper minerals, chalcopyrite is not mentioned as one of those found in the zones of oxidation and secondary enrichment.

Ramdohr (1950, p. 370), in a discussion of chalcopyrite in the zone of secondary enrichment, has the following remarks:

“In nicht so seltenen Fällen kann aber auch einmal ein ‘umgekehrte Cementation’ eintreten, wohl dann, wenn im Verlauf des Prozesses — vielleicht z. B. durch Verwitterung einer grösseren Pyritpartie — die zusetzenden Wasser sehr reich an Eisen, arm an Kupfer sind. Dann findet man feine neugebildete Häutchen von Kupferkies auf Klüften im Bornit u.a. Dahin gehören auch die Kupferkieshäutchen, die auf manchen Covellinen zu finden sind.

Kupferkies findet sich als Produkt der deszendenden Anreicherung auch auf anderen Sulfiden wie Pyrit und Zinkblende, aber ziemlich selten. Meist schlagen sich die Kupfergehalt der lösungen auf diesen Erzen sofort als Kupferglanz oder Kupferindig nieder.

Es ist demnach Kupferkies in den meisten Fällen, jedenfalls in seiner ganz überwiegenden Menge, ein primäres und aszendentes Mineral.

Thus while it seems established that chalcopyrite can, and does, in certain rather unusual circumstances, form as a supergene mineral, there is no evidence that it so forms in such quantities that it alone is responsible for the supergene enrichment of large bodies of massive sulphides. The “feine neugebildete Häutchen” described by Ramdohr are quite a different matter from the solid chalcopyrite which occurs interstitially to the idiomorphic pyrite grains in typical Norwegian massive sulphide deposits. Moreover, in all cases described the supergene chalcopyrite is accompanied by much more abundant, typically supergene, copper minerals, such as chalcocite and covellite, which seem to be singularly lacking from the Norwegian pyritic deposits.

In the case cited by Bjørlykke of the Rio Tinto ore deposits, the enrichment, as he states explicitly, is due to chalcocite. Since the Rio Tinto deposits are in many ways analogous with the Norwegian massive sulphide deposits, it would seem logical to expect that a supergene enrichment zone, in the case of the latter, would also contain much chalcocite. The fact that well-authenticated supergene parageneses have so far not been reported from the Norwegian massive sulphide deposits must mean that either, (a) the zones of oxidation and cementation have been totally removed by erosion, presumably by the Pleistocene ice,

and have not been re-established since then, (b) such were never formed, or (c) the chemistry and mineralogy of the ores, possibly taken together with the prevailing climatic conditions, have been such that supergene enrichment has taken an entirely different course from that normal in copper sulphide deposits.

Just which of these three possibilities is actually the case will only be determined after detailed mineralogical work has been carried out on those deposits which do show weathering zones, which for some reason or other escaped the eroding action of the Pleistocene ice. Three such deposits cited by Bjørlykke (op. cit. p. 5) are Rauhammeren, Bjørkåsen and Skorovass mines.

So far no detailed mineralogical description of the first two deposits has appeared, but Gjelsvik (1960) has recently given an account of the chemistry and mineralogy of the Skorovass deposit. This is a fairly flat-lying ore body in which the higher copper values lie in the centre towards the southern end, i. e., away from the outcrop. No typical supergene copper minerals have been identified in the Skorovass ore, even though Foslie (1926) mentions that it showed the largest gossan ever to be found above a Norwegian sulphide deposit¹⁾ and was of the opinion that considerable leaching of the ore near the outcrop had taken place.

Gjelsvik, however, states (op. cit. p. 63 and personal communication) that the ore at present outcrop was originally poor in copper; furthermore, it shows no structures or textures that can be ascribed to the alleged leaching.

At Bleikvassli mine in Nordland an apparently pre-glacial weathering zone is preserved along parts of the outcrop. Here the massive, porous, cinder-like gossan consists of granular quartz and other resistant minerals, which originally formed the gangue to the sulphides, cemented by brown to black, botryoidal goethite. There is a transition zone not more than 20 to 30 cm deep between this gossan and apparently unaffected primary massive sulphides. The detailed investigation of specimens taken from this ore is proceeding and it is hoped that the results will throw some light on this problem of the supergene alteration of massive sulphide deposits in Norway.

¹⁾ This gossan lies on the "crag-side" of the hill in a position which would have met the full force of the ice erosion. The question thus arises as to whether this gossan is therefore of post-glacial origin. Whether this is so or not, there is at any rate no supergene cementation zone beneath the gossan.

Sammendrag.

Supergen omvandling av norske sulfidmalmer.

Forfatteren diskuterer en tidligere avhandling av Bjørlykke som behandler spørsmålet om supergene anrikninger i norske kisforekomster. Bjørlykkes forslag er at anrikninger av kobber, utelukkende som kobberkis (kalkopyrit), i de øverste deler av visse norske kisforekomster i Kaledonidene, kan skyldes supergene prosesser. Forfatteren peker på at kalkopyrit er høyst usedvanlig som et supergent mineral og at, i de tilfelle hvor det er kjent, forekommer det utelukkende i små mengder og ledsaget av større mengder av typisk supergene kobber sulfider som, f. eks., chalcosit og covellin. Disse mineraler er ikke beskrevet fra norske kisforekomster og, så vidt man vet, er de ikke til stede. Dette må bety enten at de supergent anrikete soner på norske kisforekomster er blitt vekkerodert under istiden og at de rikere partier i de øvre delene skyldes andre prosesser, eller at supergen anrikning i norske kisforekomster foregår på en meget usedvanlig måte, kanskje p. g. a. klimatiske og kjemisk-mineralogiske faktorer.

Videre, detaljerte mineralogisk-geokjemiske studier er nødvendige før man kommer med bestemte konklusjoner angående dette problem.

References.

- Anderson, C. A.*, 1955. Oxidation of copper sulphides and secondary sulphide enrichment. *Econ Geol.*, 50th anniv. Vol., 324—340.
- Bateman, A. M.*, 1950. *Economic Mineral Deposits*, Second edition. John Wiley and Sons.
- Bjørlykke, H.*, 1960. Supergene anrikninger av kopper i våre kisforekomster. *Norges geol. unders.*, 211 (Årbok 1959), 5—7.
- Foslie, S.*, 1926. Norges svovelkis forekomster. *Norges geol. unders.*, 127.
— 1941. Tysfjords geologi. *Norges geol. unders.*, 149.
- Garrels, R. M.*, 1954. Mineral species as functions of pH and oxidation-reduction potentials, with special reference to the zone of oxidation and secondary enrichment of sulphide ore deposits. *Ceochim. et Cosmochim. Acta.* 5, 153—168.
- Gjelsvik, T.*, 1956. Pre-glasiale forvittringsfenomener i kopper forekomster i den sydvestlige del av Finnmarksvidda. *Geol. För Förhandl.*, 78, 4, 659—665.
— 1960. The Skorovass pyrite deposit, Grong, area, Norway. *Int. Geol. Congress*, XXI Session, Proc. pt. XVI, 54—66.
- Lindgren, W.*, 1933. *Mineral Deposits*. Third edition. McGraw Hill.
- Ramdobr, P.*, 1950. *Die Erzminerale und ihre Verwachsungen*. Akademie Verlag, Berlin.
- Vokes, F. M.*, 1957. Some copper sulphide parageneses from the Raipas formation of Northern Norway. *Norges geol. unders.*, 200, 74—111.