A Discussion. Geology of the Kvikne Mines with Special Reference to the Sulphide Ore Mineralization

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Vokes, F. M. & Morton, R. D.: A discussion. Geology of the Kvikne mines with special reference to the sulphide ore mineralization. *Norsk Geologisk Tidsskrift*, Vol. 53, pp. 333–336. Oslo 1973.

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The description of the geology and sulphide deposits of the Kvikne mining district by Nilsen & Mukherjee (1972) constitutes the third in a series of publications resulting from the 'Røros project' currently being worked on in the University of Oslo. As long-standing students of Norwegian geology, especially of ore petrology and mineralogy, these publications are of great interest to us and we would like to express our opinions on the paper, and, incidentally, upon the ore geological thinking as expressed in the Røros project papers so far published.

Nilsen & Mukherjee's paper provides an extensive account of the distribution, mineralogy and mineral geochemistry of the sulphide deposits of the Kvikne area. It is of interest as being the first modern account of a mining field within the Norwegian Caledonides where the ores are spatially related to a volcanic unit other than that of the main Lower Ordovician Støren group. The authors make a point of the stratabound nature of the sulphides and the fact that cross-cutting features are never met within the field. They emphasize the close relationships to zones of amphibolites, which are regarded as being the metamorphic equivalents of the 'Gula Greenstone' (Cambrian) volcanic unit.

In addition, the metamorphic nature of the sulphide deposits is recognized, and the admittedly rather cursory sulphide geothermometric evidence is shown to be consistent with the ores having been subjected to the staurolite-almandine subfacies metamorphism which the area as a whole has undergone. Comparatively little textural evidence for the metamorphism is advanced, though it is shown that the pyrite and pyrrhotite have suffered deformation during the course of the orogeny.

Yet, despite this documentation of the stratabound, volcanic-associated, preorogenic nature of the sulphide deposits and regardless of current world trends of geological thought regarding sulphide deposits of just this type, the authors do not appear to entertain even the *possibility* of the Kvikne deposits being of an originally volcanogene or synvolcanic nature.

Instead they forward, more or less as an aside on p. 190, line 22, the opinion that the ore formation was of an 'epigenetic nature', based upon considerations of the Co:Ni ratios in the sulphides present. Of course, one could enter into a discussion of the meaning of the term 'epigenetic nature', which the authors do not enlarge upon. In previous literature on the Norwegian Caledonian sulphide ores the term has usually been used to denote a late or post-orogenic, hydrothermal replacement origin. Nilsen himself (1971) has recently used the term in this sense for the origin of the Rødhammeren deposit, located in the same general district as the Kvikne mines, in the first of the Røros project publications. Nilsen's conclusions with respect to Rødhammeren have already been commented upon by one of us (Morton 1972) but one is in addition tempted to enquire as to why the Rødhammeren ore is an exception to the rest of the Caledonian sulphide deposits in not being of a 'metamorphosed nature' (Nilsen & Mukherjee 1972, p. 188).

It is patently clear that at Rødhammeren as well as at Kvikne one is dealing with preorogenic (geosynclinal), regionally metamorphosed ores. One can discern in Nilsen & Mukherjee's paper a weakening of the rigid, late orogenic, epigenetic view held regarding Rødhammeren. One looks forward to the next publication in the series when, it is to be hoped, the 'conversion' will be complete. For, if one examines the evidence for retaining the epigenetic hypothesis in the case of Kvikne, one finds it consists of nothing more than a 'constant prevalence' of Co over Ni in the pyrites from the deposits. This is not at all unusual in massive sulphides of this general type, some of which indeed, are worked as cobalt ores, e.g. Kilembe, Uganda. In Norway one can cite, for example, the cobaltiferous pyrite of the Fosdalen metamorphosed volcanic-exhalative, magnetite-pyrite-deposit (H. Carstens 1955) and others. The myth that predominance of Co over Ni signifies 'epigenetic' as against 'syngenetic' formation is one which builds upon a false misconception of the true nature of the volcanogene ores. These are just as much of a hydrothermal origin (whatever one may choose to read into this term) as 'conventional' epigenetic ores. The ore forming fluids will have had the same ultimate origin and same geochemical characters in both cases. It is only in the *loci of deposition* that differences occur. Indeed most volcanogene deposits consist of both an epigenetic and a syngenetic component, deposited by the same surge or surges of 'ore forming fluid' (cf. Gale & Vokes 1972). Thus the use of geochemical characteristics to differentiate between 'epigenetic' and 'non-epigenetic' massive sulphides is without foundation.

On the other hand the barren pyrrhotitic mineralizations, showing a consistent dominance of Ni over Co, would seem to be of a non-hydrothermal type, i.e. derived from weathering and sedimentation without a magmatic addition. We would suggest that these are metamorphosed equivalents of the so-called 'vasskis'-type of sedimentary sulphides first described by C. W. Carstens (1931). The general Ni-dominance of these deposits is characteristic of their purely sedimentary origin; they were probably laid down at the termination of, or during a break in, the volcanic activity represented by the Gula Greenstone unit.

On the basis of the above arguments the present writers feel that the evidence from Kvikne – as presented by Nilsen & Mukherjee – shows that the sulphide deposits *do* conform to the majority of the massive sulphides of the Caledonides, whose origin is *far from* being 'unknown' as Nilsen & Mukherjee would have it (1972, p. 187). We also suggest that a greater awareness and consideration of the current literature on volcanogene/metamorphosed ores from other places in the Caledonides as well as analogous areas in other parts of the world would have brought the authors to the same conclusion and avoided the necessity of this contribution.

We would also respectfully submit that a closer refereeing prior to publication would have avoided these and the other weaknesses of the paper, some of which are mentioned below:

The general absence of structural symbols on the geological maps, Figs. 1, 2 and 3, which might be used by readers to draw their own conclusions regarding the areas covered.

The poor quality of, especially, Figs. 8 and 13, which demonstrate mainly the low standard of polishing accepted.

The absence of any information in the texts to Figs. 6A to 15B inclusive which might tell the reader where the specimen was collected.

Errors of calculation in the tables, e.g. Tables 7 and 8 where many of the distribution ratios are incorrect.

The reporting of microprobe analyses of cubanite and mackinawite without any details of analysis conditions, standards used or output correction programmes followed.

The introduction of the unusual, to say the least, term 'hydrothermal quartzite' without any discussion to justify its use. The mention on p. 171 that these 'quartzites' carry in places 'a heavy magnetite impregnation . . . as dusty banded aggregates', as well as the conclusion that they 'seem to be contemporaneous with the emplacement of the pyrite ores', would strongly suggest that they represent metamorphosed cherty iron oxide facies of the volcanic deposition ('oxide exhalites' after Ridler 1971).

December 1972

REFERENCES

Carstens, C. W. 1931: Die Kiesvorkommen in Porsangergebiet. *Norsk geol. tidsskr. 12,* 171–177.

Carstens, H. 1955: Jernmalmene i det vestlige Trondheimsfeltet og forholdene til kisforekomstene. *Norsk geol. tidsskr. 35,* 211–221.

Gale, G. H. & Vokes, F. M. 1972: Norwegian Paleozoic volcanogene sulphide deposits in the light of plate tectonics. Paper deliv. at: *Norwegian Geotraverse Meeting, Trondheim,* April 1972. In press. *Norsk geol. tidsskr.*

Morton, R. D. 1972: A discussion. Sulphide mineralization and wall-rock alteration at Rødhammeren mine, Sør-Trøndelag, Norway. *Norsk geol. tidsskr. 52,* 313–315.

Nilsen, O. 1971: Sulphide mineralization and wall rock alteration at Rødhammeren mine, Sør Trøndelag, Norway. *Norsk geol. tidsskr. 51,* 329–354.
Nilsen, O. & Mukherjee, A. S. 1972: Geology of the Kvikne mines with special reference to the sulphide ore mineralization. *Norsk geol. tidsskr. 52,* 151–192.
Ridler, R. H. 1971: Analysis of Archean volcanic basins in the Canadian Shield using the exhalite concept. Paper pres. to: *Can. Inst. Min. Met., Ann. Western Meeting, Vancouver, B.C.* Oct. 1971. Abs. publ. in: C.I.M.M. Bull. Oct. 1971.