SPHALERITE-PYRRHOTITE RELATIONSHIPS AT QUEMONT MINE

FINLEY A. CAMPBELL
University of Alberta, Edmonton, Canada

ABSTRACT

X-ray diffraction techniques were used to analyze 38 sphalerite samples for FeS and 27 pyrrhotite samples for Fe. The samples were selected from throughout the massive sulphides of the Quemont ore zones. The data indicate the average temperature of formation of the sphalerite was 540° C. with a standard deviation of ±72° C. The average temperature of formation of the pyrrhotite was 325° C. with a standard deviation of ±47° C. This discrepancy is explained on the basis of the ore having formed from a sulphide melt with an original sphalerite-pyrrhotite equilibrium at around 540° C., then subsequently the pyrrhotite phase has undergone readjustment in the solid state to form a more iron-rich pyrrhotite plus pyrite. This readjustment was completed at around 325° C.

General Geology

Quemont Mine is located at Noranda in northwestern Quebec, approximately 60 miles east of Kirkland Lake, Ontario (Fig. 1). It is 4 miles north of the Cadillac-Bouzan fault zone and some 16 miles south of the Porcupine Destor fault zone.

The geological setting of Quemont has been described by Taylor (1953, 1957), Ballachey *et al.* (1952) and Scott (1948). The ore occurs in non-porphyritic rhyolite. The major structural control appears to be fractures within a westerly plunging anticline. The plunge of this anticline is practically flat to reversed in the upper portion of the mine to produce a dome-like capping of porphyritic rhyolite over the ore zones. The local geology and the relationship of Quemont to the Horne Mine is shown in Fig. 2.

The distribution of the Quemont ore within the anticline is shown in Fig. 3. This figure shows the structural contours for the footwall of the porphyritic rhyolite, and clearly illustrates how the anticline is truncated by the Horne Creek fault.

The Ore

The ore at Quemont is of two types; massive sulphides and disseminated sulphides in highly chloritized zones. The iron sulphides, pyrite and pyrrhotite, constitute about 87 per cent by weight of the ore minerals and the remaining 13 per cent is sphalerite and chalcopyrite (McLachlan, *et al.*, 1954). Like the other typical massive sulphide bodies of the Shield, this deposit consists mainly of iron and sulphur with, in places, sufficient

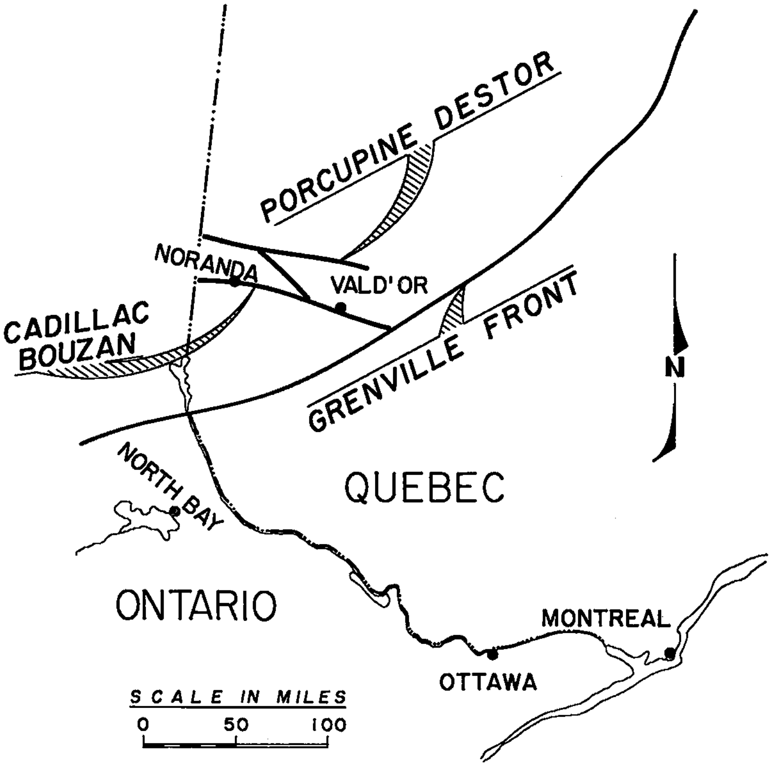

FIG. 1. Location of Quemont Mine at Noranda, Quebec.

copper, zinc, gold and silver to make ore grade. A study of polished sections indicates that the normal paragenetic sequence of pyrite, pyrrhotite, sphalerite, and chalcopyrite obtains.

I feel, however, that this does not represent a sequence of introduction but rather the apparent order of deposition from a melt with a specific bulk composition and undergoing its own particular cooling history. The general paucity of gangue minerals and alteration associated with these massive ore bodies makes transportation by a dilute solution medium untenable. There appears to be no more compelling reason to believe that these sulphides were emplaced by dilute solution than that diabase dikes were emplaced by the same mechanism. If we concede that an immiscible sulphide phase can separate from a differentiating magma, then the movement of this phase is tantamount to the movement of any magma and subject to the same structural controls.

The intimate association of cubic pyrite crystals distributed throughout

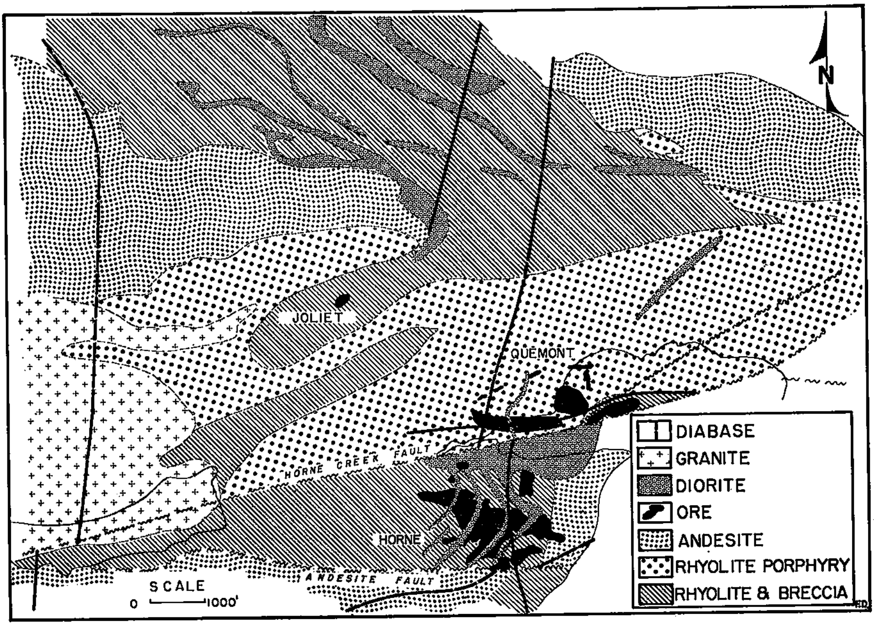

FIG. 2. Generalized geology adjacent to Quemont.

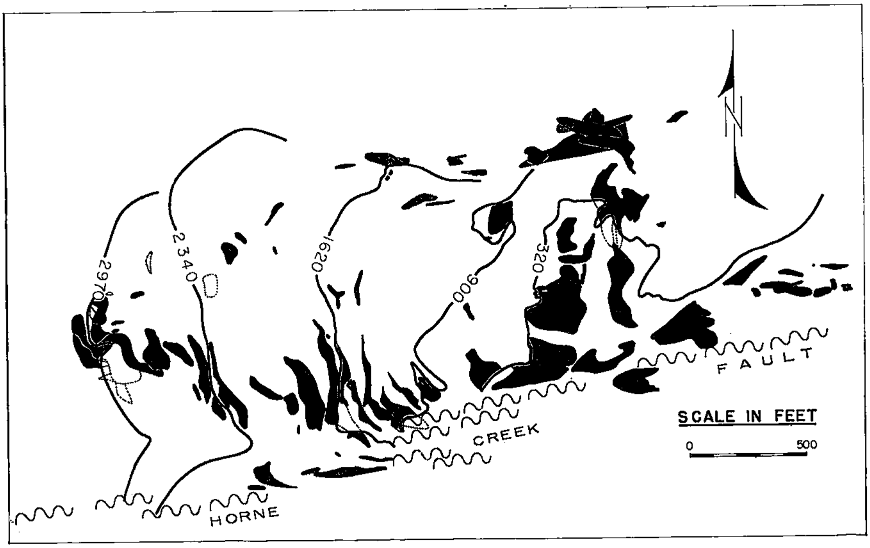

FIG. 3. Relationship of the ore (black) to the articlinal structure and the Horne Creek fault. Contours show footwall of porphyritic rhyolite.

massive pyrrhotite suggested to me that the two phases had been coprecipitated and thus the iron content of the pyrrhotite might be used to determine the temperature of formation of the pyrrhotite (Arnold, 1956, 1958, 1962).

Although the sphalerite cuts the pyrrhotite and pyrite, exsolution of pyrrhotite from sphalerite and the complete enclosure of the sphalerite in millions of tons of iron sulphides suggests that equilibrium of sphalerite and pyrrhotite was probably attained. For this reason it is felt the FeS content of the sphalerite will indicate its temperature of formation (Kullerud, 1953).

Sphalerite Temperatures

Samples were chosen from throughout the mine in such a way as to represent ore from different parts of the anticline. The sphalerite was removed from clean cleavage surfaces by means of a drill. The cell edge was calculated and the FeS content determined using the graph published by Skinner, Barton & Kullerud (1959). A sample was chemically analyzed for FeS and gave 16.5 mole per cent FeS and the results agreed well with the composition of 16 per cent determined by the diffraction method. The temperature of formation was determined by using the solvus curve published by Sims & Barton (1961). Figure 4 shows the distribution of temperatures determined from 38 samples from throughout the Quemont mine. No regular variation with depth or laterally can be

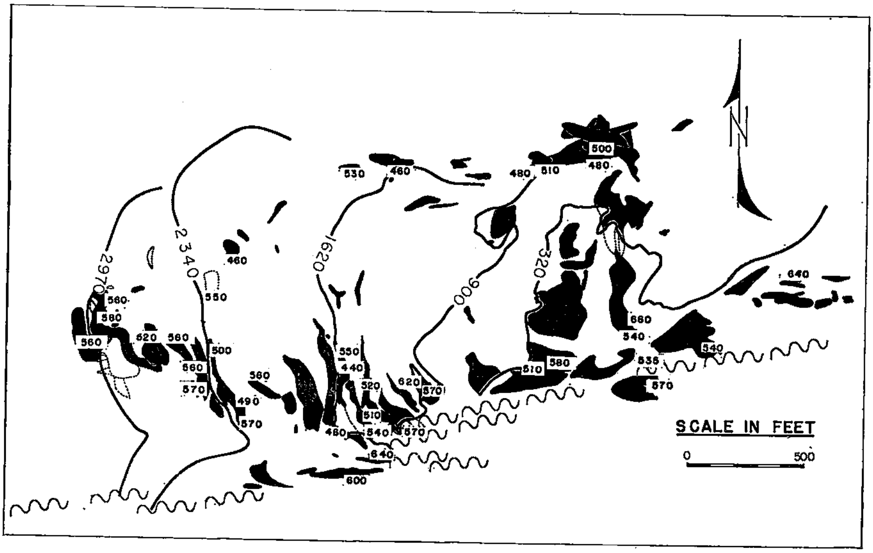

FIG. 4. Temperatures determined from the sphalerite.

recognized in these data. The average temperature of formation is 540° C. with a standard deviation of ±72° C. The variation in apparent temperature of formation can be due to either a real variation in temperature or a variation in the sulphur pressure or both.

Pyrrhotite Temperatures

The iron content of 27 pyrrhotite samples was determined by the diffraction method described by Arnold (1956). One sample of pyrrhotite containing minor copper and zinc was chemically analyzed and gave 46.86 atomic per cent Fe. The *x*-ray diffraction data for pure pyrrhotite from this sample gave 47 atomic per cent Fe. The lower figure in the chemical analysis is considered due to dilution by chalcopyrite, pyrite and sphalerite which are difficult to remove completely when a large sample is being prepared. Recent work by Arnold (1962) tends to support his original suggestion that as long as the pyrrhotite is hexagonal the *x*-ray diffraction method can be used to measure the metal content of pyrrhotite. The temperature of formation, assuming equilibrium with pyrite, can be determined from the solvus curve published by Arnold (1958). The temperatures thus determined are shown in Fig. 5. Once more there seems to be no systematic variation of the temperatures within the ore structure. Furthermore, the temperatures are markedly lower than those found for the formation of sphalerite. This fact is emphasized by the average of the pyrrhotite temperatures which is 325° C. with a standard deviation of ±47° C.

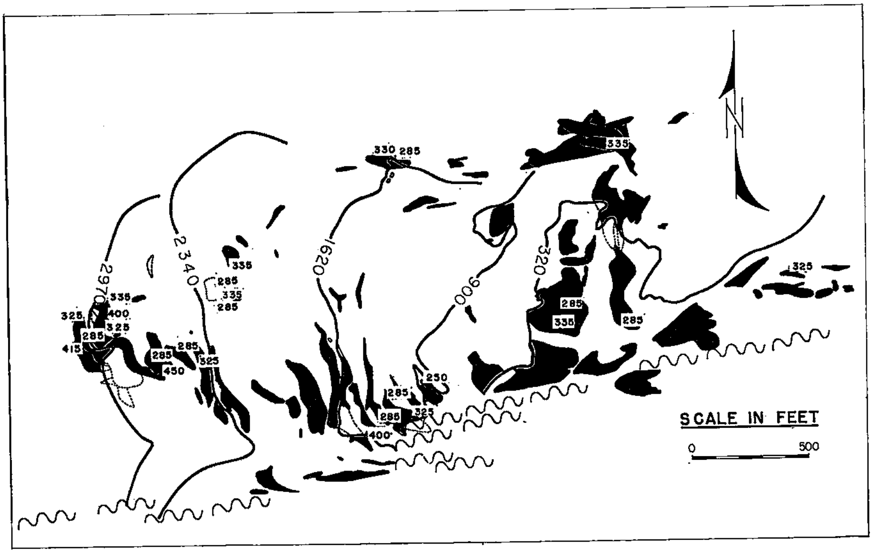

FIG. 5. Temperatures determined for the formation of the pyrrhotite.

Discussion of Results

How sphalerite which apparently formed later than the pyrrhotite can have formed at a higher temperature poses a problem. I feel that the data indicate that the sphalerite solidified at around 540° C. and was generally formed in equilibrium with pyrrhotite. Subsequently, as cooling took place the pyrrhotite phase has undergone readjustment to form a more iron-rich pyrrhotite plus pyrite. The readjustment seems to have been completed by 325° C. This modification of an iron-poor pyrrhotite to give pyrrhotite plus pyrite has been observed in experiments and described by Kullerud & Yoder (1959). Figure 6 shows a plate taken from their paper which clearly shows the pyrite crystals that developed from the pyrrhotite during quenching.

In order to consider the reaction in a semi-quantitative way part of the system Fe-S at about 10 bars is shown in Fig. 7. The bulk composition of the ore in terms of the iron sulphides recalculated to 100 per cent is 44 mole per cent pyrite and 56 mole per cent pyrrhotite. This composition is plotted on the diagram and a cooling history for the iron sulphides postulated. At a temperature of 540° C. the system would consist of 40 per cent pyrite and 60 per cent pyrrhotite as shown by the relative lengths of AB and BC respectively. The pyrrhotite in equilibrium with pyrite at this temperature would contain 46.4 atomic per cent iron. As the temperature drops from 540° C. to 325° C. the pyrrhotite changes in

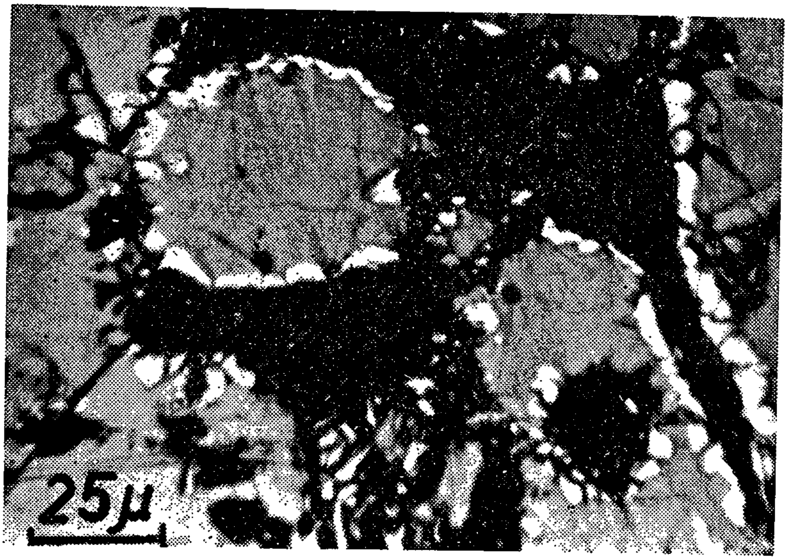

FIG. 6. Photomicrograph from Kullerud & Yoder (1959) showing pyrrhotite (grey) with the pyrite (white) that developed during quenching.

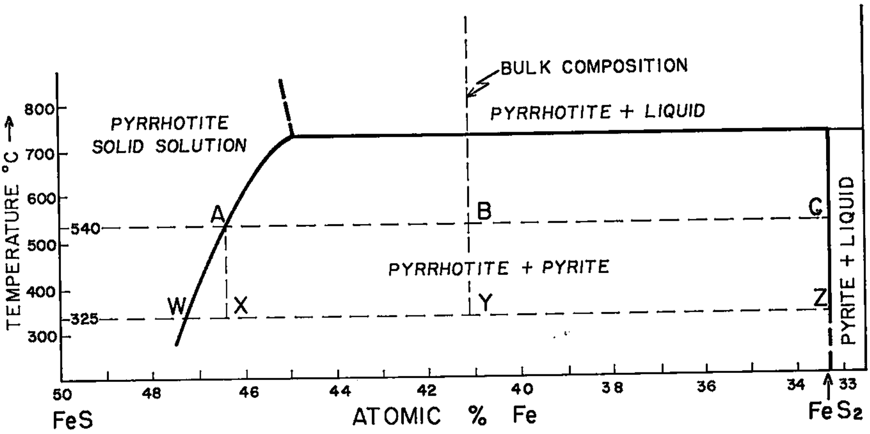

FIG. 7. Part of the system Fe-S at about 10 bars, showing the approximate bulk composition of the Quemont ores and the postulated phase adjustments with decreasing temperature.

composition until at 325° C. it would contain about 47.2 atomic per cent iron. At 325° C. the ore would consist of 44 per cent pyrite and 56 per cent pyrrhotite which is the assemblage as we now see it in the deposit. It will be noted that during this drop in temperature there has been a relative increase in pyrite and a decrease in pyrrhotite.

Why has this readjustment taken place? The obvious possibility is that it has resulted from the normal cooling sequence after the sulphides were emplaced. Another suggestion and one which I feel is not frequently enough considered, in regions with a complex history, is the possibility that these are metamorphic temperatures that resulted from the raising of the temperature of the region during the emplacement of the granites.

ACKNOWLEDGMENTS

I would like to thank A. G. Ballachey for the opportunity of studying the Quemont mine. B. Taylor, mine geologist and his staff were most helpful in discussion and sample collection. Although I gratefully acknowledge this assistance, I take full personal responsibility for the opinions expressed. Financial assistance was received from a University of Alberta research grant.

REFERENCES

ARNOLD, R. G. (1956): The pyrrhotite-pyrite relationship: *Carnegie Inst. Wash. Year Book*, **55**, *Ann. Rept. Dir. Geophys. Lab.*, pp. 177–178.

——— (1958): The Fe-S System: *Carnegie Inst. Wash. Year Book*, **57**, *Ann. Rept. Dir. Geophys. Lab.*, pp. 218–222.

——— & REICHEN, L. E. (1962): Measurement of the metal content of naturally occurring, metal-deficient, hexagonal pyrrhotite by an *x*-ray spacing method: *Am. Mineral.*, **47**, 105–111.

BALLACHEY, A. G., JAMIESON, W. D., & HAMBLETON, J. R. (1952): Mining at Quemont: *C.I.M.*, *Trans.* **55**, 47–58.

KULLERUD, G. (1953): The FeS-ZnS system, a geological thermometer: *Norsk. Geol. Tidssk.*, **32**, 61–147.

——— & YODER, H. S. (1959): Pyrite stability relations in the Fe-S system: *Econ. Geol.*, **54**, 533–572.

McLACHLAN, C. G., BENNETT, M. J. S., & COLEMAN, R. L. (1954): The Quemont milling operation: *C.I.M. Trans.*, **57**, 230–245.

SCOTT, J. S. (1948): Quemont mine; *Structural geology of Canadian ore deposits*, p. 778, Geology Division, C.I.M.

SIMS, P. K. & BARTON, P. B., JR. (1961): Some aspects of the geochemistry of sphalerite: *Econ. Geol.*, **56**, 1211–1237.

SKINNER, B. J., BARTON, P. B., JR., & KULLERUD, G. (1959): Effect of FeS on the unit cell edge of sphalerite. A revision: *Econ. Geol.*, **54**, 1040–1046.

TAYLOR, B. (1957): Quemont mine. *Structural geology of Canadian ore deposits*; vol. 2, pp. 405–412, Geology Division, C.I.M.

——— (1953): Geology of Quemont Mining Corporation, Limited: Geology and mineral deposits of northwestern Quebec, *Guidebook Field Trip, no. 10,* p. 15, Annual Meeting, G.S.A. and G.A.C., November.

Manuscript received October 29, 1962