QUANTITATIVE DETERMINATION OF HEXAGONAL AND MONOCLINIC PYRRHOTITES BY X-RAY DIFFRACTION: A DISCUSSION

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Graham (1969) has proposed a rapid technique for the quantitative determination of the absolute abundances of monoclinic and iron-deficient hexagonal pyrrhotites in ore specimens, which should have wide application to the study of iron sulphide zonation in ore deposits. This approach is, however, subject to one complicating factor which may prove to be generally only a minor nuisance, but could introduce significant error in the examination of certain types of mineralization.

Graham assumes that naturally-occurring monoclinic pyrrhotite will invariably yield two principal reflections ($408 + 228$ and $\bar{4}08 + \bar{2}28$, according to Carpenter & Desborough 1964) having sensibly equal intensity in *x*-ray powder patterns; thus, the difference in intensity of the main reflections contributed by intergrowths of hexagonal and monoclinic pyrrhotites would be a direct function of the proportions of the two phases. This assumption had earlier been made by Arnold (1966), who advanced a similar *x*-ray method for the estimation of the relative proportions of hexagonal and monoclinic pyrrhotites in ores.

It is evident, however, that *apparently* monoclinic pyrrhotite in numerous ore deposits exhibits an asymmetrically-split main doublet, in which the reflection falling at the higher 2θ angle is the *more* intense (*i.e.* $I\,\bar{4}08 + \bar{2}28 > I\,408 + 228$). This relationship is, of course, the reverse of that shown by intergrowths of hexagonal and "normal" monoclinic pyrrhotites. Such "abnormal monoclinic pyrrhotites" (hereinafter "Am-po") were first encountered by the author in 1961 in the course of a study of the iron sulphide assemblages in the Ylöjärvi copper–tungsten deposit, southern Finland. Their presence in considerable amounts (*i.e.* greater than 30% of the total pyrrhotite) in several zones of this deposit effectively prevented the application of a method for the estimation of the relative proportions of hexagonal pyrrhotite, monoclinic pyrrhotite, and troilite, similar to that of Arnold (1966).

Subsequent *x*-ray study of pyrrhotite assemblages from other ore deposits and rocks has demonstrated that Am-po is rather widespread, particularly in environments of general low temperature aspect (Clark 1966). Thus, this pyrrhotite modification has been recognized in moderate to major amounts in specimens of sulphur-bearing marls from Sicily; Pleistocene peri-glacial clays from southeast England; and of greenschistfacies, graphitic phyllites from the Nokia area, southwest Finland; in the Cross Gill and St. John's Mine veins in the Northern Pennine orefield; and in the Colquiri tin deposit, Bolivia. Am-po further constitutes a small proportion (~0.1–5%) of the pyrrhotite in representative ore samples from several base metal, broadly-stratabound deposits (*e.g.* Vihanti, Outokumpu, and Orijärvi, Finland; Bluebell, Quemont, Horne, and Heath Steele, Canada) and from Ni–Cu deposits (Kotalahti, Finland; Pechenga, Russia; Frood, Canada). Apparently similar pyrrhotites have been described from the Cerro de Pasco deposit, Perú (Marco T. Einaudi, personal communication, Dec. 1968), and have been briefly reported from the Cobalt, Ontario silver ores (Taylor 1968), and from the Coronation deposit, Saskatchewan (Arnold & Ferris 1969).

Similarly anomalous monoclinic pyrrhotites have been synthesized under dry conditions in the system Fe–S below 200°C (Clark 1966), and, together with natural Am-po, are consistently more iron-deficient than normal monoclinic pyrrhotite. Both natural and synthetic Am-po exhibits weak, low-angle *x*-ray powder lines conforming closely to those characteristic of the $a = 2B$; $c = 4C$ monoclinic superlattice defined by Bertaut (1953) and Carpenter & Desborough (1964), and this form is regarded as a modification of that structure. It may be distinguished from normal m-po in polished section on the basis of its *weakly-* to *non-magnetic* behaviour under magnetic colloids and by its distinctly lower white-light reflectivity. Am-po may, however, be confused with iron-deficient hexagonal pyrrhotite, and precise *x*-ray control is required for their distinction.

A more comprehensive discussion of the properties and significance of abnormal monoclinic pyrrhotite is in preparation, but the interrelationships of this phase with other pyrrhotite modifications remain incompletely defined. It is clear, however, that considerable care must be taken in the application of any *x*-ray powder diffraction technique for the estimation of the relative amounts of pyrrhotite types in ore samples. The unsuspected occurrence of Am-po would result in under-estimation of the proportion of hexagonal pyrrhotite in an ore specimen, and might, in some instances, lead to the deduction of spurious trends in the iron-deficiency of the pyrrhotite in an ore deposit.

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Manuscript submitted November 1969

SUMMER SCHOOL IN ORE MICROSCOPY

A summer school on modern quantitative methods in ore microscopy was held in the Department of Geology of the University of Toronto from 1st to 5th September. The school was organized jointly by Dr. E. H. Nickel of the Mines Branch of the Department of Energy, Mines and Resources in Ottawa and Professor A. J. Naldrett of the Department of Geology; was sponsored by the Commission on Ore Microscopy of the International Mineralogical Association; and was supported by funds provided by the Mines Branch.

Twenty-eight Canadian scientists drawn from industry, the universities and the federal and provincial governments and coming from as far afield as Labrador and British Columbia were students at the school. They were taught by a team of instructors from Germany, the U.K., the U.S.A. and Canada. Particular emphasis was placed on the theory of reflected light optics and the accurate measurement of spectral reflectivity and micro-indentation hardness. Agents or manufacturers of optical equipment including Walter Carveth Ltd. (E. Leitz), Sargent-Welch Scientific Ltd. (C. Reichert), Vickers Instruments Inc., and Carl Zeiss Ltd. kindly placed their equipment and the services of their technical staffs at the disposal of the school. In this way the students had the opportunity to familiarize themselves with the latest equipment and receive practical instruction from the scientists who, in many cases, had themselves designed the equipment.

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