SHORTER COMMUNICATIONS

SOME OBSERVATIONS ON THE MINERALOGY AND METAMORPHISM OF THE Zn-Pb-Cu ORES FROM DERI-AMBAJI AREA, BANASKANTHA DISTRICT, GUJARAT

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The lithology of the area between Deri and Ambaji (24°23′; 24°20′; 72°51′; 72°52′) along Rajasthan-Gujarat border comprises metamorphosed pelites, amphibolites and marbles of the Ajabgarh series—the upper division of the Delhi system, and the Erinpura granite intrusive into it (Coulson, 1933; Heron & Ghosh, 1938). The area holds much promise as many small and discontinuous, but rather rich polymetallic (Zn-Pb-Cu) ore bodies are huddled together in a narrow zone of feldspathic arenaceous metasediments with pockets of talc-tremolite schists. The mineralization in the form of patches and lenses is most preferentially concentrated in the talc-tremolite schists. According to a recent work (Shekar *et al*, 1968), the ore mineralization took place by replacement under mesothermal conditions along a series of reverse strike faults traversing the western limb of a cross-folded syncline at Ambaji. The main host rocks, the talc schists, are considered to be the metamorphosed product of pre-Erinpura basic/ultrabasic intrusions.

Preliminary observations on the mineralogy of these ores from samples collected systematically from five bore-holes in the area, have revealed certain remarkable features of the highly metamorphosed nature of these ores. The purpose of the present communication is to place on record these new observations which strongly indicate the necessity to substantially modify the existing concept on ore genesis in the area as well as the petrogenesis of the host rocks.

Major minerals and their textures: Sphalerite is by far the most common sulphide in most of the ore bodies. It is followed in abundance by galena, chalcopyrite, pyrite and magnetite. The last two minerals though occurring mainly as disseminations are also, at times, concentrated in patches and bands. These major minerals display many interesting textural relationships amongst themselves; but most of the vital features go unnoticed unless the polished sections are etched with the appropriate reagents.

Where galena is a minor phase in a two phase aggregate of sphalerite and galena, it forms wispy concave masses often linked up to form a network around the grains of sphalerite; on the other hand either sphalerite or pyrite in a galena matrix invariably display convex grain boundaries and occur as isolated rounded bodies. Such textural features, liable to be interpreted as indicating replacement, are actually the result of dihedral angles determined by the phase boundary-grain boundary free energy ratios in the two concerned phases (Stanton, 1964). An HI-etch clearly reveals that the cusps or rounded bodies of the minor phase meet the grain boundaries of the matrix producing a series of triple junction points. Where the dihedral angle (θ) at these triple points is large, as when pyrite or sphalerite (galena/sphalerite $\theta = 134°$, cf. Stanton *op. cit*) is involved as the minor phase, the latter appears as spherical or equant grains in the matrix. In contrast the wisps and intergranular films of galena develop in a sphalerite matrix due to low dihedral angle, i.e. low phase boundary-grain boundary free-energy ratio between the phases. Identical relationships are also displayed by chalcopyrite occurring as a minor phase in a polycrystalline aggregate of sphalerite. Besides when chalcopyrite blebs and galena wisps occur within sphalerite grains, the requirements of minimum interfacial free-energy is satisfied by their restriction along the annealing twin-boundaries of the host mineral (Stanton & Gorman, 1968).

In monomineralic aggregates of galena, sphalerite and chalcopyrite, the presence of foam-structure is revealed on etching with the appropriate reagents. The meeting of typical polyhedral grains at triple junctions with angles approximating 120° is indicative of a matured structure produced by annealing. Where this textural maturity is not very well marked, subgrains in galena still bear evidence to the stages of annealing. However, the presence of evenly spaced, straight sided and coherent twin lamellae in grains of sphalerite and chalcopyrite producing the foam structure lends further credence to the degree and completeness of the annealing process. The

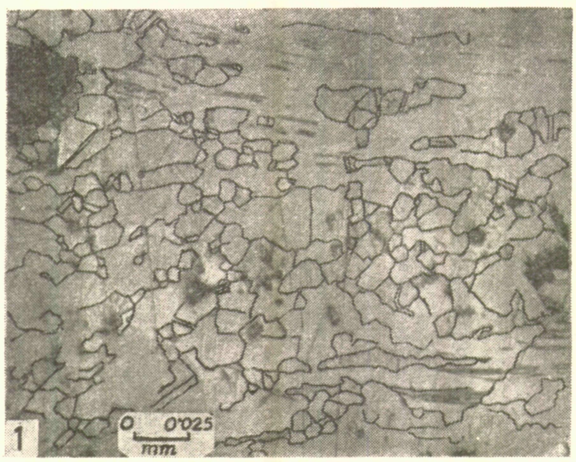

Figure 1. Polycrystalline chalcopyrite showing foam-structure and flattened grains defining a rough schistosity. Etched with sat. chromic acid.

occasional bending of these annealing-twin lamellae may be taken to suggest that deformation broadly outlasted normal grain growth during recrystallization of the sulphides. The distortion of the foam structure in polycrystalline chalcopyrite with flattened chalcopyrite grains defining a rough schistosity (Fig. 1) may support this contention. Such schistose structure nevertheless, could also result from preferred orientation of the grains during annealing (Stanton, 1972).

Besides the annealing twins, chalcopyrite and sphalerite occasionally show incoherent, tapering twin lamellae in more than one crystallographic direction. These are interpreted as deformation twins, bearing conclusive evidence to the fact, as noted above, that deformation broadly outlasted the process of recrystallization in these ores. These twins are often found to be bent themselves. Irregular lattice bending is also indicated by sharp bending of cleavages in some galena grains.

Fine irregular to mostly rounded blebs of an unidentified phase have been noted to be uniformly distributed in certain annealed polycrystalline aggregates of sphalerite. The blebs, revealed after an HI-etch, have identical optical characters as the host, except for a distinctly higher relief. Their distribution is often controlled by grain boundaries and annealing twin boundaries in sphalerite. They could possibly have formed by the unmixing of certain minor elements in the host sphalerite during metamorphism and recrystallization.

Pyrite often occurs megascopically in alternate bands of uniform thickness in massive sphalerite ore—a feature strongly reminiscent of primary compositional banding. Under the microscope, in such bands (Fig. 2), pyrite is found to be present as idiomorphic grains of widely varying sizes showing well developed triple-junctions. The intergranular space is generally filled up by cusps of chalcopyrite and galena, or even shreds of magnetite. Frequently, various sulphide matrices are found studded with subrounded to idiomorphic poikiloblasts of pyrite. Augens and strings of granules of sphalerite along with laths of tremolite have been observed to flow out in sheared galena mass to define a distinct schistosity which bulges around coarse rounded poikiloblasts of pyrite showing sieve texture with the same matrix-minerals

Figure 2. Bands of pyrite, made up of idiomorphic grains of varying sizes, alternating with silicate gangue. Shreds of magnetite concentrated in the silicate band.

(Fig. 3). This suggests that schistosity-formation outlasted crystallization/recrystallization of ore minerals. Certain other poikiloblasts are suspected to have rotated during growth as suggested by the rough trails of internal inclusions. Besides parallelism of internal schistosity (Si) defined by tremolite laths with the similar external schistosity (Se) in the surrounding gangue is a frequently noted feature.

Elongated pyrite grains are quite common where the ore has a conspicuous directional fabric produced primarily by sheaves of chalcopyrite in between tremolite blades, along with elongated grains of pyrite and magnetite showing cross fractures. While some of these are definitely aggregate grains juxtaposed in a parallel orientation (as shown by etching with zinc dust + HCl), others are suspected to have been stretched in the plane of schistosity. Even some hook shaped single pyrite grains are present in a particular section in which the orthogonal fractures are healed up by softer matrix sulphides like chalcopyrite and sphalerite.

Magnetite either occurs intimately associated with groundmass silicates as fine shreds or more commonly, as coarse poikiloblast in chalcopyrite matrix.

Textural relationships between the gangue silicates and the ore minerals are also interesting. Chalcopyrite, galena and sphalerite closely intergrown with sheaves of tremolite, biotite and chlorite, together with elongated grains of pyrite and magnetite very often define a well developed schistosity in the ore. Where such schistosity has been involved in folding, the softer sulphides, especially chalcopyrite, have accumulated in the pressure shadow zones of distorted magnetite porphyroblasts. At places, streaks and triangles of chalcopyrite and galena in between disoriented aggregates of tremolite and biotite describe a typical decussate texture. Besides, coarse blades of tremolite have been found to contain elongated grains of pyrite and magnetite as well as shreds of chalcopyrite and galena along the cleavage directions. Rarely fine specks of chalcopyrite also produce a rough trail within coarse tremolite plates.

Minor minerals: The minor minerals noted in these ores are molybdenite, cubanite, mackinawite, chalcocite and covellite. Besides, irregular patches of a soft mineral assemblage has often been found along the gangue-chalcopyrite interface.

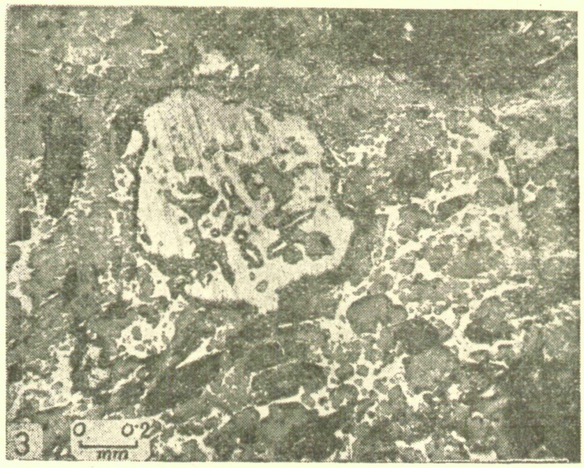

Figure 3. Rounded poikiloblast of pyrite with inclusions of sphalerite, galena and silicates, set in a deformed matrix of galena, in which flowage of augens and granules of sphalerite and laths of tremolite produce a schistosity bulging around the poikiloblast.

Among the four minerals present in this assemblage, three have been provisionally identified as stromeyerite, tenantite and enargite. It must be pointed out here that the identification must be taken as tentative till electron-microprobe data for each of the phases is provided. Work in that direction is in progress.

Flakes of molybdenite are ubiquitous within the gangue silicates. Quite often they assume appreciable dimensions and occur in clusters. Finer flakes are also met with in sphalerite or chalcopyrite matrix. Much of the flakes are kinked and show strong undulose extinction while a few others display sharp knee-shaped twinning.

Cubanite needles, blades and even discrete grains are present in a few sections, occurring within or in intimate association with chalcopyrite grains. The blades are commonly located along two or three crystallographic directions of chalcopyrite and some are even deformed and bent.

Fine needles, or irregular worm-like grains of mackinawite are frequently found dispersed within chalcopyrite grains. They have also been noted to project into fractures in the associated cubanite blades.

Chalcocite, associated with minor amounts of covellite, has formed along cracks and fractures of chalcopyrite, as a secondary product.

Conclusion: This account of the textural features of the various minerals in the Deri-Ambaji ores, clearly indicates that the ore minerals and the gangue silicates in the enclosing host rocks were together involved in a metamorphic episode (cf. Vokes, 1969)—a vital fact overlooked in the previous studies. This, combined with the relict banding of the ore minerals, suggests a possibility of syngenetic origin of the ores with subsequent modification during metamorphism. The different aspects of this problem are being worked out so that a viable conclusion may be reached.

Acknowledgements: The author is grateful to Shri S. P. Nautiyal for providing facilities for field work and to Shri N. C. Shekhar for his warm hospitality at Ambaji. Thanks are also due to Dr. S. C. Sarkar, Jadavpur University and Dr. S. Varadarajan, Delhi University, for critically reading the manuscript and offering valuable suggestions.

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PETROCHEMISTRY AND STUDY OF THE THERMAL METAMORPHIC PROCESSES IN THE CALCAREOUS ROCKS AROUND KODAG, DISTRICT PALAMAU, BIHAR

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Introduction: The present work deals with the chemical and mineralogical changes involved during the metamorphism of calcareous sediments. Three type localities (Fig. 1: Location map) where calcareous formations of Archaean age are well exposed, were selected for this study. The reason for including these three areas lies in the fact that the changes due to different sets of P-T conditions superimposed on one another could be easily sorted out and the relative role of original composition vis-a-vis the different physico-chemical and geological parameters could be ascertained. These areas viz. Kodag, Demu and Khalari lie in the Palamau and Ranchi districts of Bihar and follow the same stratigraphic continuity though showing differ-