SHORTER COMMUNICATIONS

SULPHIDE GOLD-QUARTZ VEINS IN THE PRECAMBRIAN OF KOLAR

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Introduction: The Kolar amphibolite series in which gold-quartz veins occur has a unique N–S regional trend unlike the Western and Eastern ghat trends of the Precambrian formations of South India. The other formations of this unique trend are the Closepet belt in the west and the gneissic complex between the Kolar and the Closepet belt. Generally the gold-quartz veins occurring in the more metamorphosed Dharwar bands of the Precambrian of Mysore are richer in gold than those that occur in less metamorphosed bands in the N-W of Mysore State. In Gadag, Ramagiri and Kolar, quartz veins occur along the crests of the refolds of the synclinal belts, formed towards the waning stages of the Dharwar orogeny. This refolding date is 2000 million years. Depletion and migration of the ore constituents from high pressure flanks to the low pressure crests of the refolds took place, and gold-quartz veins were formed (Iyer and Murthy, 1967).

Of the numerous gold-quartz veins occurring in the amphibolite series in Kolar, only the Champion reef system and the West reef system are of economic importance. Quartz, calcite, pyrrhotite-arsenopyrite, galena, chalcopyrite and pyrite occur in the gold-quartz veins. The West reefs are richer in sulphides and poorer in gold than the Champion reef system. Tourmaline, chlorite, sericite, albite, muscovite and other silicate minerals also occur in the veins.

In the ore zones, we find ductless pegmatitic bodies as dislocated and tectonically deformed structures. They present a bewildering variety of shapes and sizes and vary from the merest thread up to a bar of 1600 feet along the strike of the lode, with a thickness of 80 to 100 feet. We find albites at the altered ore-pegmatite contacts in the underground workings. K-feldspars and the albites occurring in altered zones are used for determining the formation temperatures of the veins.

Intensive investigations have been carried out in the last decade on the Fe-S and Fe-As-S systems. Interplanar distances d_{102}, in pyrrhotite was used to determine the atomic percentages of iron, d_{131} to determine the As/S ratios in the arsenopyrite minerals. The experimental investigations have helped to construct P_{S_2}-T-X diagrams for studying the sulphide stabilities and the large response of arsenopyrite to increased confining pressures suggested its use as a 'geobarometer' in situations where the formation temperature may be approximated by an independent means. (Barton and Skinner, 1967; Clark, 1960).

In the present communication the geology of the area is described and the techniques employed to analyse and fix the temperature of formation are indicated.

Geology of the area: Field evidence suggests that the Dharwar schists, composed of meta-volcanics and sediments, were deposited on the crystalline gneissic basement in this area. They were later infolded to form the present synclinal belt. This belt is 6 to 7 km wide and extends for a distance of 60–70 km. The low lying area on either side of the belt forms the Champion series. It is chiefly composed of quartz, mica and feldspar rocks and can be considered as an integral part of the Dharwar schists. Next to the low lying area of Champion series are the outcrops of the recrystallised basement gneisses. All these rock formations have the same N–S regional strike. Towards the waning stages of the Dharwar metamorphism, the meta-volcanics were refolded; gold-quartz veins were formed along the crests of the refolds. The Rb/Sr ages of the minerals from the rock formations and the whole rock age determinations reveal that Dharwars were deposited on the older basement gneiss and later got recrystallised and metamorphosed. The Patna granite is as old as the basement gneiss. The whole rock ages confirm the field evidence that the underlying gneisses are older than the infolded schists.

Rock	Whole rock age	Mineral age, Rb/Sr (Mica)
Dharwars	2480	2440
Basement gneiss	2850	2000

Experimental work: Mineral separation: Feldspars from the ore-pegmatite contact were handpicked and were examined under polarising microscope for phase purity. Pyrrhotite and arsenopyrite were handpicked from the crushed ore. They were examined for phase purity under reflected polarised light.

X-ray analysis: Rich Seifert X-ray unit and copper K-α radiation for feldspars and iron K-α radiation for sulphides were employed. The patterns were taken with Straumanis mounting a 114.6 mm Phillips Powder Camera. The powder patterns were measured with a Carl Zeiss Jena Glass Scale and distances were estimated correct to 0.05 mm.

I. R. Spectra: The infrared spectra of the feldspars were taken on Carl Zeiss UR–10 double beam instrument with potassium bromide, sodium chloride and lithium fluoride prism optics. The I. R. spectra of the feldspars in the range 400–1800 cm^{-1} were recorded. Alkali halide pellet (KCl) technique was employed. (Fig. 1).

Chemical analysis: Albite and microclines were analysed for potassium using the EEL Flame Photometer. The actual K-feldspar contents of albite and microcline were calculated from the data. Both pyrrhotite and arsenopyrite were analysed for iron by complexometry, the sulphur of pyrrhotite was determined by iodimetry, and that of arsenopyrite by gravimetry.

Results and discussion: The triclinicity values of microclines 12.5 [d_{131}–$d_{1\bar{3}1}$], 0.92 and 0.97 and the I. R. spectra of albites suggest that the feldspars are of low temperature form (Layes and Hafner, 1962). The K-feldspar content of albite (1.48%) and that of microcline (86.4%) indicate a temperature formation of 430°C (Barth, 1962).

The d_{102} spacing of hexagonal pyrrhotite is a function of its composition and is dependent on the temperature of formation. The measured d_{102} spacings for three hexagonal pyrrhotite samples happen to be 2.0635 Å, 2.0635 Å and 2.0652 Å. The atomic percentage of iron for these samples is 47.2, 47.2 and 47.5% respectively and this is confirmed by chemical analysis of the samples. The temperature of formation of pyrrhotites not associated with pyrite with d_{102} spacing of 2.0635 Å can be between 390°–450°C. (Buseck 1962). The two feldspar geothermometer fixes this to be 430°C. The atomic percentage of iron and the temperature of formation of pyrrhotite indicates a sulphur vapour pressure of 10^{-7} atmospheres (Barton and Skinner, 1967) Fig. 2.

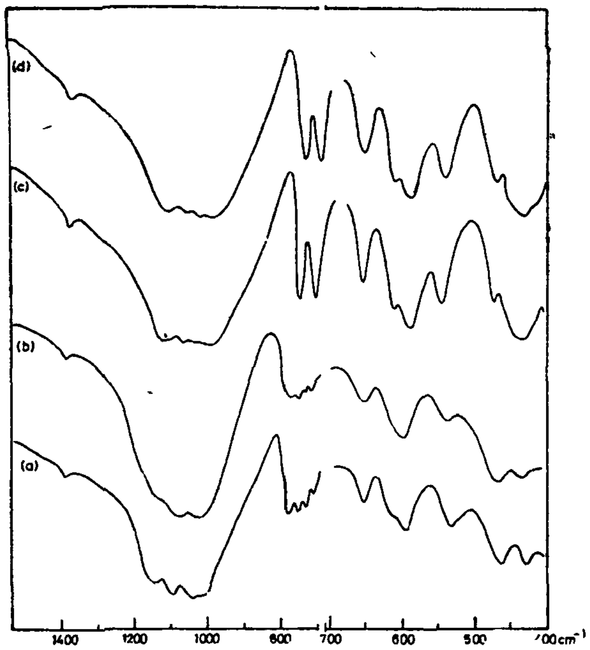

Figure 1. Infra-Red spectra of feldspars. Ore-pegmatite contact. Kolar Gold fields. (a) Albite (low temperature form). (b) Albite heated at 1050°C for 11 days. (c) Microcline (greyish). (d) Microcline (whitish).

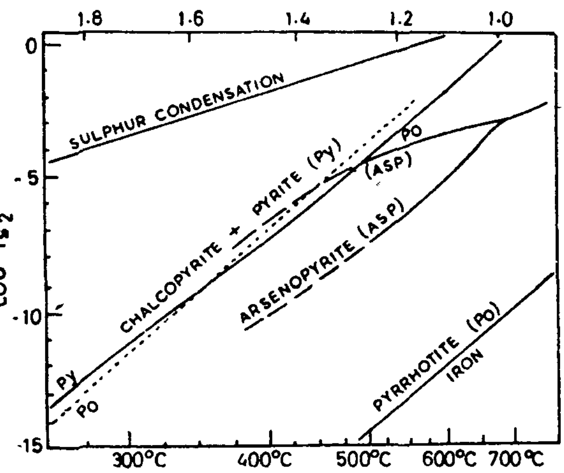

Figure 2. Stability diagram for sulphides of Kolar with temperature and log fs_2 as the defining variables. (Data from Barton and Skinner, 1967)

The composition of arsenopyrite, especially S/As ratios as determined by d_{131} spacing (1.6354 Å) is confirmed by chemical analysis (Fe = 33.6%, As = 47.9%, S = 18.5%). In the Fe-As-S system d_{131} spacing is a measure of S/As ratio of arsenopyrite. The temperature of formation is 430 ± 15°C. This indicates that the confining pressures did not exceed 1 bar (Clark, 1960) in Kolar.

The absence of wollastonite in the gold-quartz veins of Kolar and the presence of calcite-quartz association, formed under middle amphibolite facies conditions, also suggests that carbon dioxide pressure was low during ore formation.

Conclusions: The whole rock ages (isochron) and the mineral ages of the Precambrian formations in the area indicate that the Dharwars were laid down on the basement gneisses, which were recrystallised during the infolding of the belt. The refolding of the belt caused depletion, migration and localization of the ore constituents along the crests following the pressure gradients along the fold. The mineral assemblage studies suggest that they were all formed under low P_{S_2} P_{CO_2} and confining pressures during the middle amphibolite facies conditions.

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THE OCCURRENCE OF ROCKS OF KAKARA (PALEOCENE) AFFINITY IN THE BAKHALAG—BUGHAR BELT, HIMACHAL PRADESH

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Introduction: In the course of mapping of parts of Lower Himalayas in the Himachal Pradesh, the authors found a continuous strip of hitherto unreported fossiliferous limestones and shales of Kakara affinity (Srikantia and Bhargava, 1967), between Bakhalag (31°9′25″ : 76°56′40″) and Bughar (31°17′ : 76°56′40″) in Arki tehsil of Mahasu district. The belt extends over a length of about 14 km in the north-south direction and is about one to two kilometres broad. It is involved in a