

Cupriferous sericite from the Sar Cheshmeh porphyry copper ore, Kerman Province, Iran

COPPER-BEARING halloysite and montmorillonite (medmontite) have been recorded from the oxidized zone of the Ray porphyry copper deposit in Arizona (Stephens and Metz, 1967) and copper vermiculite has been reported from the **Zambian Copper Belt** (Bassett, 1958). In addition, Clement (1968) has described the occurrence of chrysocolla and copper-bearing halloysite within altered plagioclase phenocrysts of the **Copper Canyon porphyry, Battle Mountain, Nevada**. The copper contents of the halloysite, montmorillonite, and vermiculite in the above examples vary between 0.3 and 16.4 % Cu, and the fixation of Cu^{2+} in the mineral lattices is consistent with the good cation exchange capacities of the minerals. The present note describes the occurrence of a cupriferous sericite, which was discovered during a mineralogical investigation of drill-core and dump samples of the Sar Cheshmeh porphyry copper ore, Kerman Province, Iran. The mineralogical investigation was undertaken in an attempt to discover the cause of low recoveries of 'oxide' copper (i.e. copper that is soluble in cold 3 % SO_2 solution) obtained during beneficiation testwork on the ore.

The geology of the Kerman Province has recently been described by Bazin and Hübner (1969), who showed that the Sar Cheshmeh copper deposit is located in a complex of Tertiary volcanic rocks that extends intermittently from Turkey to **Baluchistan**. The protore is a porphyritic granodiorite containing finely disseminated chalcopyrite and pyrite; the granodiorite contains coarse quartz and sericitized potash and plagioclase feldspars in a fine-grained quartzo-feldspathic groundmass. Supergene enrichment has taken place in the upper part of the ore body with the alteration of the primary chalcopyrite and pyrite to secondary digenite, chalcosine, covelline, and bornite. Subsequent to the supergene enrichment some oxidation of the copper sulphides has occurred, with the formation of minor amounts of malachite, brochantite, diopside, cuprite, azurite, and delafossite.

It was initially thought that these non-sulphide minerals accounted for all the 'oxide' copper contents of the samples (mostly 0.05–0.4 %) but detailed modal analyses carried out by various techniques, including point-counting, grain-counting, and mineral separation, showed that these minerals accounted for less than about 15 % of the 'oxide' copper present.

To confirm that the 3 % SO_2 solution used to determine 'oxide' copper was not also leaching part of the copper sulphides, pure samples of chalcopyrite, chalcosine, covelline, and bornite were analysed for 'oxide' copper in the normal way. The results of these check tests confirmed that only negligible quantities of the sulphides were being dissolved by the sulphurous acid, the apparent 'oxide' copper contents

being: chalcopyrite 0.13 %, bornite 0.26 %, covellite 0.57 %, and chalcocine 0.86 %. Since the copper sulphides constituted less than 3–4 % of the ore samples examined, it was evident that only a negligible part of the 'oxide' copper analyses of the ore samples (less than 10 %) was due to leaching of the sulphides. Thus, taking into account the observable non-sulphide copper minerals, 80–90 % of the total 'oxide' copper was still unaccounted for.

Analysis for 'oxide' copper of different heavy liquid separation products of various size fractions of the ore showed that a considerable proportion of the 'oxide' copper at all sizes was associated with the products with specific gravity between 2.7 and 3.0. Optical examination indicated that these products consisted almost entirely of sericite, and X-ray diffraction showed the mineral to have a 10 Å basal spacing. Differential thermal analysis gave a trace, with endotherms in the 100–200° range, at 540 °, and at 900 °C, which was more characteristic of illite than muscovite.

Further information was obtained by an electron-microprobe study of one of the 2.7–3.0 specific gravity products. The product, which assayed 0.30 % 'oxide' copper, was briquetted in cold-setting resin, polished and scanned for Cu, Al, Si, K, and S. This indicated that some of the sericite grains contained noticeable quantities of non-sulphide copper. A scan was then carried out across several grains of sericite, using the Al-K α radiation to monitor the location of the individual grains. The results showed that many of the sericite grains contained small quantities of copper, and point-analyses of ten grains confirmed this conclusively. Two or three points were analysed for copper on each of these grains and, although many of the grains appeared to be fairly homogeneous, some were inhomogeneous. The mean Cu contents of the ten grains analysed were: 0.07 %, 0.11 %, 0.13 %, 0.14 %, 0.42 %, 0.50 %, 0.51 %, 0.53 %, 0.58 %, and 1.13 %, the average of the ten being 0.41 % Cu, not significantly different from the bulk 'oxide' copper content of the sericite.

Although the electron microprobe data proved the intimate association of 'oxide' copper with the sericite the location of the copper is not known with certainty. It is clear, however, that the copper is dispersed throughout the sericite on a submicro-metre scale, either as discrete intergrowths of a non-sulphide copper mineral such as malachite, or as Cu²⁺ substituted in the sericite lattice.

Acknowledgements. My thanks are due to Miss J. Richardson and Miss D. A. Poynter for carrying out the analytical work, to Dr. R. C. Mackenzie and Mr. L. D. Muller for critically reading the manuscript, and to Kerman Copper Industries for permission to publish this note.

*Warren Spring Laboratory
Gunnels Wood Road
Stevenage, Hertfordshire¹*

K. J. HENLEY

REFERENCES

- BASSETT (W. A.), 1958. Copper vermiculites from Northern Rhodesia. *Amer. Min.* **43**, 1112–33.
BAZIN (D.) and HÜBNER (H.), 1969. La région cuprifère à gisements porphyriques de Kerman (Iran). *Min. Deposita*, **4**, 200–12.

¹ Present address: The Australian Mineral Development Laboratories, Conyngham Street, Frewville, South Australia 5063.

- CLEMENT (S. C.), 1968. Supergene copper concentration in altered plagioclase feldspar, Copper Canyon, Nevada. *Econ. Geol.* **63**, 401-8.
- STEPHENS (J. D.) and METZ (R. A.), 1967. The occurrence of copper-bearing clay minerals in oxidized portions of the disseminated copper deposit at Ray, Arizona. *Progr. Abstr. Geol. Soc. Am. Ann. Meeting (New Orleans)*, 213.

[Manuscript received 17 November 1969]

MINERALOGICAL MAGAZINE, DECEMBER 1970, VOL. 37, NO. 292

Barian muscovite from the Jhabua manganese belt, Madhya Pradesh, India¹

A GROUP of interesting silicate minerals associated with manganese ores occurring in the Jhabua manganese belt were described by Fermor (1909), but no further work has been done on the mineralogy of this belt except by Nayak (1963). During the course of detailed geological mapping of this belt Das Gupta (1959, also Venkatesh *et al.*, 1958) collected a number of mineral samples in which pink barian muscovite has been recorded for the first time. The mode of occurrence, mineralogy, and composition of this rare type of mica are little known apart from the data of Bauer and Berman (1933), Heinrich and Levinson (1955), and Hirowatari (1957). Therefore an attempt is made in this note to present the geological setting and mineralogy of the barian muscovite occurring in the Kajlidongri mines of the Jhabua manganese belt of Madhya Pradesh.

Geologically the terrain belongs to the southern continuation of the Precambrian Aravalli system (Gupta and Mukherjee, 1938) of Rajasthan. The area around Kajlidongri (22° 57' N; 74° 31' E.) consists predominantly of various types of phyllites interbanded with either massive quartzites rich in conglomerates and pebble beds or calcareous phyllites and dolomitic marbles. Regionally the rocks trend N.-S. to NNW.-SSE. with dips ranging between 35° and 75° mainly to the west. The dominant structural patterns in the rocks, which have been strongly deformed, are folds the axes of which run parallel to the regional trend. Granites of different periods are noted and one that has been paratectonically intruded into the piles of metasediments in the western parts of the Kajlidongri mines is accompanied by widespread feldspathization. A number of thin manganeseiferous quartzites and cherts, which carry manganese

¹ Published with the kind permission of the Director-General, Geological Survey of India.