

PRELIMINARY STUDY ON HALOGEN ELEMENTS OF THE OK TEDI PORPHYRY COPPER DEPOSIT, PAPUA NEW GUINEA

Munetomo NEDACHI and Salam MALAGUN

Introduction

Ok Tedi ore deposit is epicontinental porphyry copper system in Papua New Guinea. By comparison with the hydrothermal mineralization in island arc systems, the behaviour of halogens in the Ok Tedi porphyry mineralization is considered, based on the chemical compositions of some hydrous rock-forming minerals and fluid inclusions.

Ok Tedi porphyry copper ore deposit is located in the Star mountain region near the frontier with Irian Jaya, which is in the most continental side in the boundary zone between the Australian plate and the Pacific Ocean plate. The basement rocks in this district are Paleozoic metamorphic rocks and granites. The Leru formation and the Darai limestone, Mesozoic to Cenozoic shelf sediments, unconformably cover the basements, and are intruded by Ok Tedi complex of calc-alkaline rock series of Upper Miocene to Pleistocene (ARNOLD & GRIFFIN, 1978). In the mining area, the Ok Tedi complex is mainly composed of two intrusive bodies: Sydney monzodiorite and Fubilan monzonite porphyry. Hydrothermal alteration and copper mineralization are intense in the Fubilan monzonite porphyry. A silicified and/or quartz stockwork zone, called "Quartz Core", is located in the center of the Fubilan monzonite porphyry.

Samples and Hydrous Rock-forming Minerals

The locality of samples examined in this study and the occurrences of hydrous rock-forming minerals are as follows.

Biotite hornfels (No. 320-10): The rock is a contact metamorphosed siltstone of the Leru formation from the depth of 385.9 m of drill hole No. 320. The sample is situated very close to the contact with the Fubilan monzonite porphyry. The sample contains small grains of anhedral pale brown biotite, and also contains a small amount of fine subhedral apatite from 1 to 10 micron in diameter.

Sydney monzodiorite (No. 319-2): The sample of Sydney monzodiorite was collected from the depth of 18.0 m of drill hole No. 319. Amphibole occurs as primary euhedral phenocryst, but no biotite is observed in this sample. Apatite frequently occurs as euhedral crystal from 10 to 100 microns, mainly in amphibole phenocrysts.

Hydrothermally altered Fubilan monzonite porphyry (No. 334-4): Varying degree of hydrothermal alteration is predominant all over the Fubilan monzonite porphyry, and biotites are disseminated in rather weakly altered rock. The examined sample was collected from the depth of 261.3 m of drill hole No. 334. The biotite occurs as euhedral crystal, and the grain size is 20

×100 micron in average, with reddish brown color. The phosphate mineral in the sample is monazite; no apatite is observed.

Hydrothermal biotite vein (No. 3-4): Biotite–quartz–apatite veins are frequently observed in the Fubilan monzonite porphyry. The sample in present study was collected from the site of 315198mE–424223mN on the surface of the Fubilan open pit. Biotite is pale brownish euhedral crystal with the grain size upto 2 cm. Apatite coexists with biotite and as large euhedral quartz grain from 0.1 to 1 mm in diameter. The veining might have postdated the dissemination of biotite, and have preceded the introduction of “Quartz Core” and copper mineralization.

Massive quartz (No. 6-2): The sample is from the “Quartz Core”, located in 315198mE–42423mN on the surface of the Fubilan open pit, which is composed of equigranular quartz of 100 micron in diameter. No hydrous minerals are observed, and the sample was examined only for fluid inclusions.

Chemical Composition of Hydrous Rock-forming Minerals

Biotite: Fig. 1 illustrates the major compositions in biotite quadrangular diagram. The chemical features of biotite in hornfels, disseminated biotite and vein biotite might reflect the host-rock compositions and the environment of biotitization (MOORE & CZAMANSKE, 1973; FORD, 1978). As magnetite is common in all samples, the chemical compositions of biotite might suggest that the oxygen fugacity of biotitization was rather high in the intrusive body, and increased with advancing alteration and mineralization.

Fig. 2 illustrates the log (Cl/OH) and log (F/OH) versus mg value (Mg/Mg+Fe+Mn) of

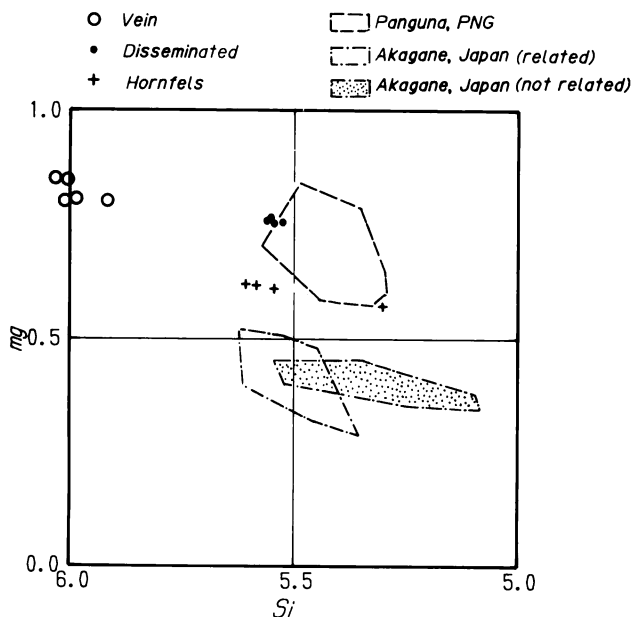


Fig. 1. Chemical compositions of biotite in the Ok Tedi porphyry copper deposit, PNG.

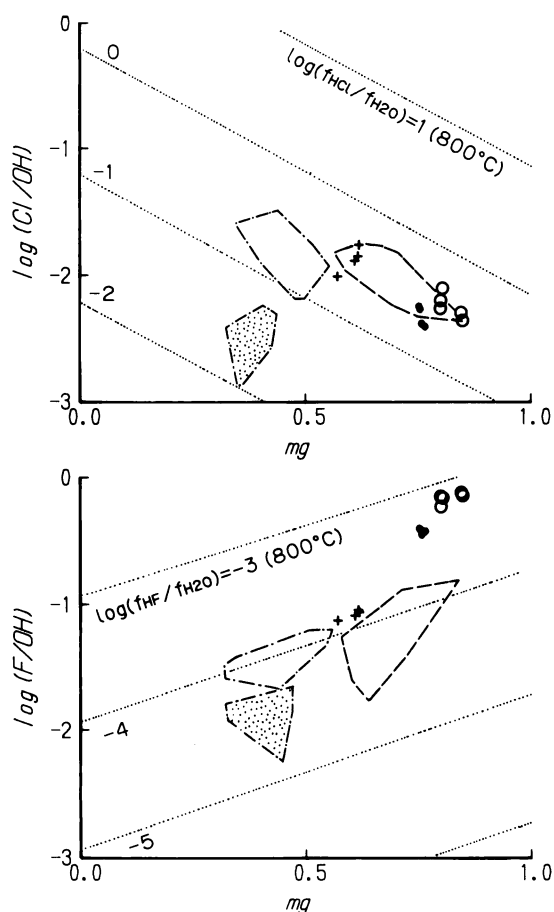


Fig. 2. $\log(\text{Cl}/\text{OH})$ (above) and $\log(\text{F}/\text{OH})$ (below) versus mg value ($\text{Mg}/\text{Mg} + \text{Fe} + \text{Mn}$) of biotite in the Ok Tedi porphyry copper deposit, PNG. The symbols and enclosed lines are same with those in Fig. 1.

biotite. In the figure, the $\text{HCl}/\text{H}_2\text{O}$ fugacity ratios of liquid coexisting with biotite are also drawn after MUNOZ & SWENSON (1981). The fugacity ratio depends on the mg value of biotite. Igneous and hydrothermal biotite in the Panguna ore deposit, Bougainville (NEDACHI, 1988), and igneous biotite in the Akagane ore deposits, Japan, are also plotted. In spite of the low Cl/OH ratio of biotite, the $\text{HCl}/\text{H}_2\text{O}$ fugacity ratio has been high as same as those observed elsewhere related to mineralization.

HF/HCl fugacity ratio also depends on biotite major composition (MUNOZ & LUDINGTON, 1974). As shown in Fig. 2, the $\text{HF}/\text{H}_2\text{O}$ fugacity ratios of liquid coexisting with vein biotite and disseminated biotite are higher than those in hornfels, and also than those elsewhere. MASON & McDONALD (1978) reported that Ok Tedi complex is a high K_2O suite derived by crust contamination. NEDACHI & YAMAMOTO (1990) reported that the $\text{HF}/\text{H}_2\text{O}$ fugacity ratio of the granitic magma with strong contamination with crustal materials was higher than those with weak contamination. Hence, the igneous activity and mineralization in the Ok Tedi ore deposit might be characterized by extreme F concentration in the continental crust.

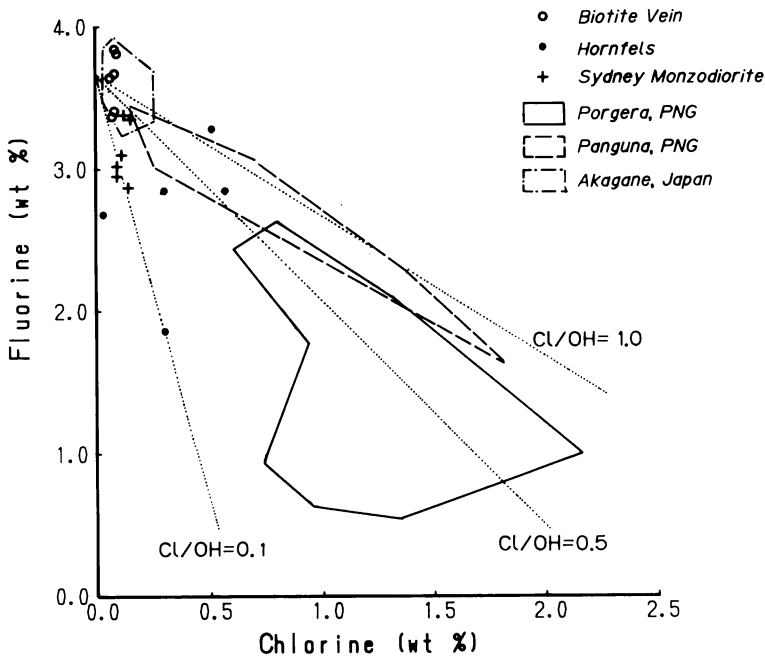


Fig. 3. Cl and F contents of apatite in the Ok Tedi porphyry copper deposit, PNG.

Apatite: The halogen contents of apatite are shown in Fig. 3. Fluorine content of apatite in hornfels are from 2 to 3 wt % and chlorine is upto 0.5 wt %. Comparing to hornfels, the apatite from the Sydney monzodiorite and biotite vein have the composition close to fluorapatite. For comparison, the apatites from other mining areas are also plotted in the figure. NEDACHI (1988) pointed out that the Cl/OH ratio of apatite is higher in the rocks related to mineralization than those not related to mineralization, and higher in the earlier stage of mineralization than those in the later stage. Cl/OH ratios of apatite in the biotite vein are high as same as those of ore deposits elsewhere. The Cl/OH ratio of apatite from hornfels widely scatter. The sample is from the close to the contact with Fubilan monzonite porphyry. It seems that hydrothermal solutions emanated from the Fubilan monzonite porphyry changed the composition of apatite in hornfels.

Fluid Inclusions

There are many fluid inclusions in quartz from all samples examined here, as shown in Fig. 4. Almost all fluid inclusions are multiphase inclusions. Microscopic observation and some qualitative electron probe analyses suggest that the solid phases are halite, silvite, fluorite, anhydrite, dawsonite, pyrrhotite and others. The volumetric ratio of vapor, liquid and solid phases varies widely. NEDACHI et al. (1990) detected Na, S, Cl, K, Ca, Mn, Fe, Zn and Cu in fluid inclusions in quartz from the biotite vein, using electron probe microanalyzer.

In accord with the chemistry of hydrous rock-forming minerals, the microscopic observations and electron probe analyses of fluid inclusions suggest that the chlorine content of hydrothermal solution is very high.

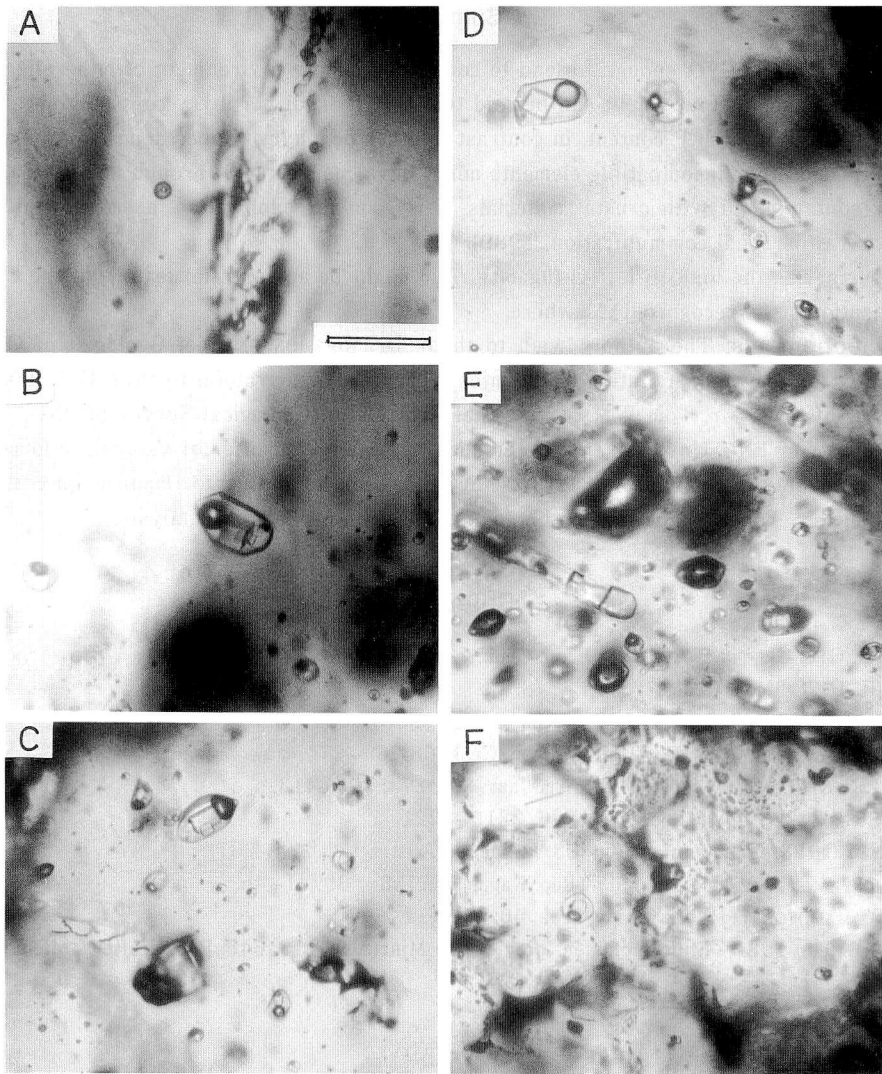


Fig. 4. Fluid inclusions in quartz in the Ok Tedi porphyry copper deposit, PNG. The bar length in photo A is 50 microns.

A: Liquid-gas inclusion in quartz of the Sydney monzodiorite (319-2).

B, C: Multiphase inclusions in quartz of the Fubilan monzonite porphyry (334-4).

D, E: Multiphase inclusions and gaseous inclusions in quartz of the biotite vein (3-4).

F: Multiphase inclusions in quartz of "Quartz Core" (6-2)

Summary

The data are not yet enough to lend to conclusion on the environment of mineralization of Ok Tedi ore deposit. However, it can be said that the Ok Tedi porphyry copper mineralization is characterized by high F content, in contrast to other porphyry copper deposits in island arc systems. F and other incompatible elements might have concentrated through acidic magmatism strongly contaminated with crustal materials. F is good for exploration, as mentioned by Dr. P.M. AFENYA (personal communication, 1989).

Nevertheless the high HCl/H₂O fugacity ratio might be an essential feature of the Ok Tedi mineralization, as is recognized elsewhere.

Acknowledgements: The authors wish to thank Dr. Rod JONES, Chief Geologist of Ok Tedi mining Ltd. for the kind invitation to the mine. They are also grateful to Prof. H. L. DAVIES of University of PNG, Mr. Tom WELSH, Principal Geologist of Geological Survey of PNG, and Dr. P. M. AFENYA of PNG University of Technology, for their kind offer of valuable informations. They are indebted to Dr. Laurence P. JAMES of BHP–Utah Japan Inc., for manuscript correction. They thank Mr. Tohru SHIN-YAMA for his help on electron probe microanalysis.

References

- ARNOLD, G. O. & GRIFFIN, T. J. 1978. *Econ. Geol.*, 73: 785–795.
FORD, J. H. 1978. *Econ. Geol.*, 73: 721–748.
MASON, D. R. & McDONALD, J. A. 1978. *Econ. Geol.*, 73: 857–877.
MOORE, W. J. & CZAMANSKE, G. K. 1973. *Econ. Geol.*, 68: 269–274.
MUNOZ, J. L. & LUDINGTON, S. D. 1974. *Am. Jour. Sci.*, 274: 396–413.
— & SWENSON, A. 1981. *Econ. Geol.*, 76: 2212–2221.
NEDACHI, M. 1988. Bicentennial Gold '88, Expanded Abstract, 2: 234–237.
—, SHIN-YAMA, T. & UENO, H. 1990. *Rep. Kagoshima Univ.*, 39: 41–46.
— & YAMAMOTO, M. 1990. *Mining Geol.*, 40: in press.
ROEDDER, E. (ed.) 1984. "Fluid Inclusion." *Reviews in Mineralogy*, 12: 646. BookCrafters, Michigan.