

NICKEL SULFIDES IN PYROXENITE FROM LANGHOVDE, LÜTZOW-HOLM BAY, EAST ANTARCTICA

Satoshi MATSUBARA¹ and Yoichi MOTOYOSHI^{2*}

¹*Department of Geology, National Science Museum,
23-1, Hyakunin-cho 3-chome, Shinjuku-ku, Tokyo 160*

²*Department of Applied Geology, University of New South Wales,
P.O. Box 1, Kensington, N.S.W., 2033, Australia*

Abstract: Nickel sulfides occur as minute grains in a pyroxenite xenolith enclosed in a garnet-biotite gneiss from Langhovde, Lützow-Holm Bay, East Antarctica. They include pentlandite, millerite, violarite and Ni-bearing pyrite in the decreasing order of appearance. The Ni/Fe ratio in pentlandite is high and that in violarite is so variable that reaches $\text{Fe}(\text{Fe}, \text{Ni})_2\text{S}_4$ with $\text{Fe} > \text{Ni}$. Cobalt is exclusively found in violarite. The mode of occurrence and mineral assemblage of the pyroxenite indicate it to have been derived from an ultramafic igneous rock probably corresponding to an ultramafic component of a tectonic melange.

1. Introduction

The origin of ultramafic rocks, so-called metabasites, enclosed in upper amphibolite- to granulite-facies gneiss along the coast of Lützow-Holm Bay has been discussed based on bulk chemistry and mineral assemblage by many workers (*e.g.* HIROI *et al.*, 1986; SUZUKI, 1986). We have found nickel sulfides in a pyroxenite xenolith collected from Langhovde during the geological survey of the 24th Japanese Antarctic Research Expedition in 1983. The present paper reports their first occurrence in the Lützow-Holm Bay region and discusses the origin of this pyroxenite.

2. Occurrence

In Langhovde garnet-biotite gneiss and pyroxene gneiss cover a wide area (ISHIKAWA *et al.*, 1976). They include numerous blocks of mafic to ultramafic rocks. The collecting site of the studied pyroxenite is located about 2 km SE of Mt. Tyôtô in the northern area of Langhovde (Fig. 1). It occurs as a large lens approximately 4×9 m across in the garnet-biotite gneiss and consists of coarse grains of hypersthene and diopside with minor phlogopite and actinolite. Hypersthene is pale yellowish brown and diopside is pale green in color, and their euhedral to subhedral crystals reach 5 cm in size. Phlogopite is pale yellowish brown in color and rarely occurs interstitially in pyroxene grains, and minor actinolite is found along the rim of diopside grains.

Under the microscope many minute opaque grains less than 0.5 mm across are observed in pyroxene crystals and along the boundary of them (Figs. 2 and 3). Opaque minerals include chromite, chalcopyrite, pentlandite, millerite, violarite and nickel-

* Present address: National Institute of Polar Research, 9-10, Kaga 1-chome, Itabashi-ku, Tokyo 173.

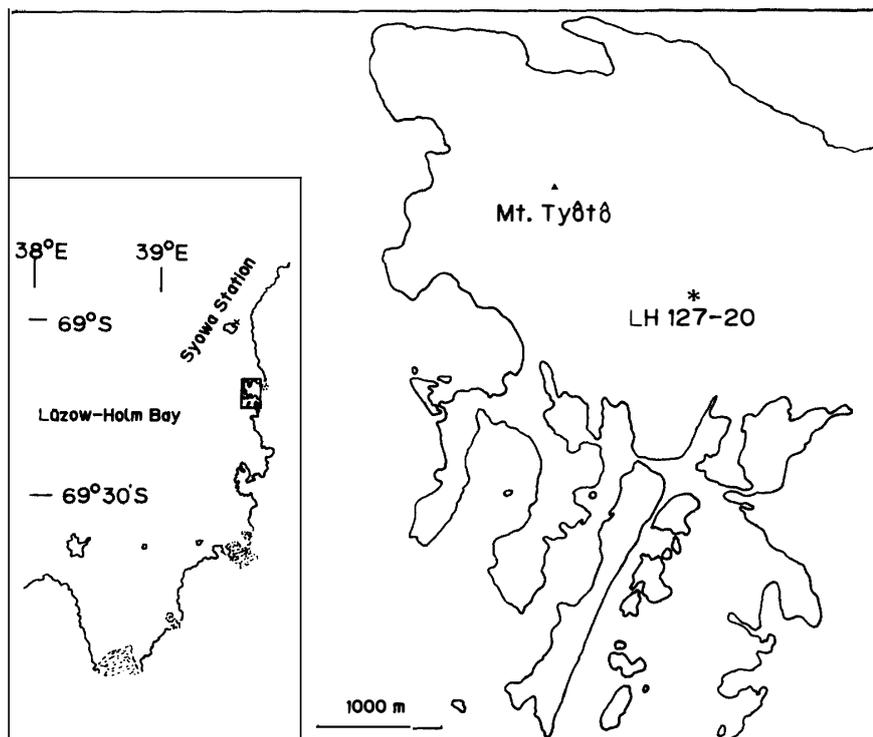


Fig. 1. Index map of the locality.

bearing pyrite. Pyrrhotite is absent. The mineral assemblages of opaque minerals are:

- 1) chromite-pentlandite-(millerite)
- 2) pyrite-pentlandite-(millerite)
- 3) pentlandite-millerite
- 4) pentlandite-violarite-millerite-(chalcopyrite)

Among them pentlandite is most abundant and is often partially replaced by millerite (Fig. 4). Violarite occurs rarely as euhedral-looking crystals irregularly intersected by millerite veinlets (Fig. 5). It is also intergrown with millerite and occurs as an alteration product of pentlandite. Chromite and nickel-bearing pyrite are found in association with pentlandite (Figs. 6 and 7).

3. Chemical Composition

The chemical analyses of the principal minerals were made using a Link Systems energy-dispersive X-ray spectrometer. The results of selected analyses are given in Tables 1 and 2. Diopside and hypersthene are rich in MgO and free from Al_2O_3 . Chromium in diopside is increasing with the increase of total iron, but Cr_2O_3 is always less than 1 wt%. The nickel content of pyrite reaches 2.6 wt% and is variable within one grain. The Ni/Fe ratio in pentlandite ranges from 1.41 to 2.05, indicating the Ni-richer nature after the solid-solution limits defined by KNOP and IBRAHIM (1961). Millerite includes iron up to 2 wt%. Violarite is cobaltian and its Ni/Fe ratio reaches 0.46. If the boundary between violarite ($FeNi_2S_4$) and greigite ($FeFe_2S_4$) is drawn at $Fe(Fe, Ni)_2S_4$ with $Fe : Ni = 1 : 1$ in the parentheses, the composition is involved in the greigite area (Fig. 8).

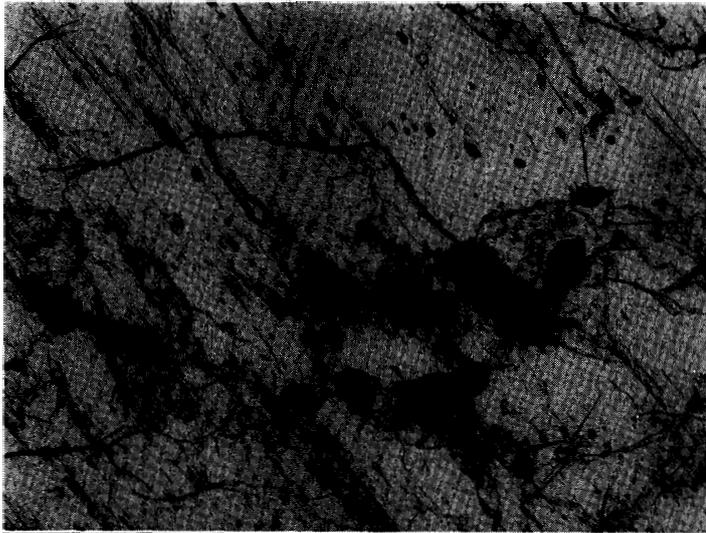


Fig. 2. Photomicrograph of the thin section of the pyroxenite. Opaque grains are observed in orthopyroxene. One polar. Field view: approx. 1.4×1.9 mm.

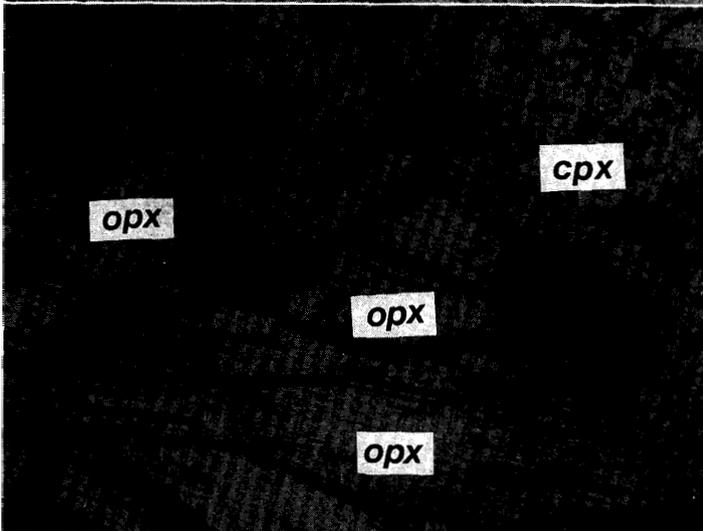


Fig. 3. Photomicrograph of the thin section of the pyroxenite. Opaque grains are observed along the boundary of orthopyroxene and clinopyroxene. One polar. Field view: approx. 0.6×0.8 mm.

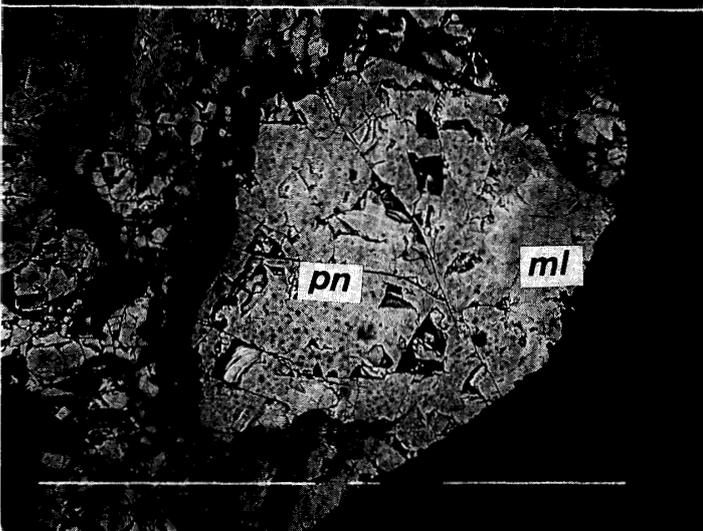


Fig. 4. Photomicrograph of the backscattered electron of pentlandite (pn) and millerite (ml). The bar indicates $100 \mu\text{m}$.

Fig. 5. Photomicrograph of the backscattered electron of violarite (dark gray) irregularly intersected by millerite (white) in pentlandite (gray). The bar indicates 100 μm .

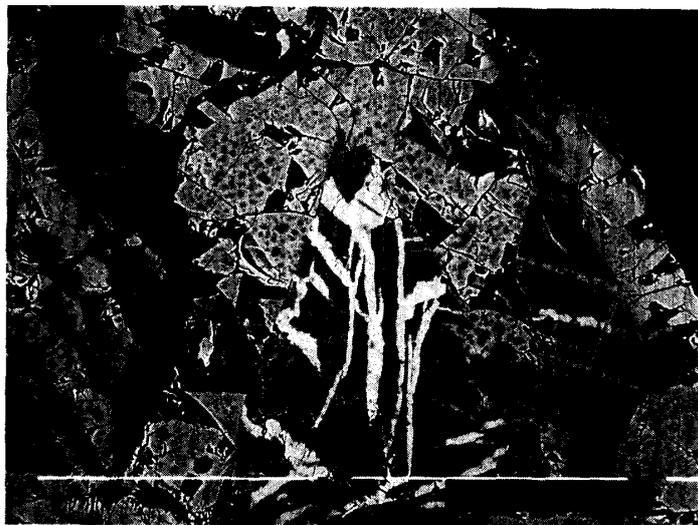


Fig. 6. Photomicrograph of the backscattered electron of chromite (dark gray) associated with pentlandite (white). The bar indicates 100 μm .

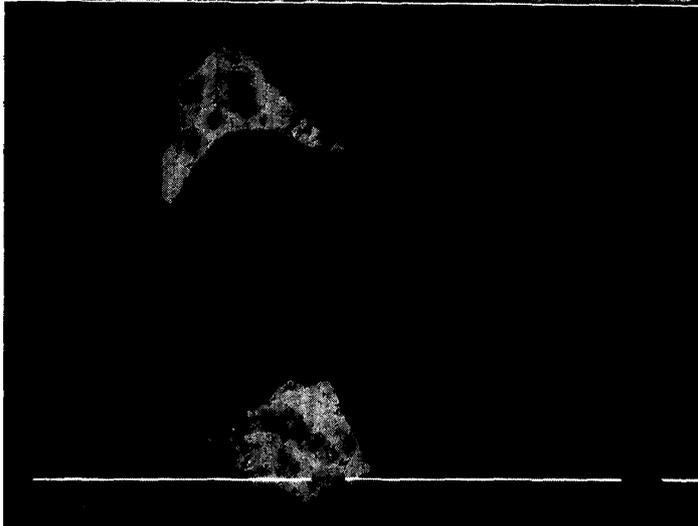


Fig. 7. Photomicrograph of the backscattered electron of nickel-bearing pyrite (gray) associated with pentlandite (white). The bar indicates 100 μm .

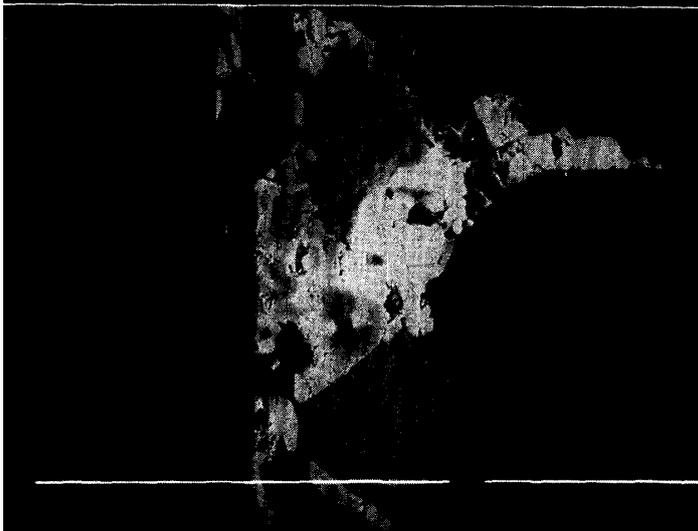


Table 1. Representative chemical analyses of pyroxenes and chromite.

| | Diopside | | Hypersthene | | Chromite | |
|--------------------------------|----------|--------|-------------|-------|----------|-------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| SiO ₂ | 54.77 | 54.87 | 57.04 | 56.79 | --- | --- |
| Al ₂ O ₃ | --- | --- | --- | --- | 6.47 | 5.75 |
| Cr ₂ O ₃ | 0.89 | 0.34 | --- | --- | 57.19 | 59.46 |
| FeO* | 2.90 | 1.75 | 10.20 | 9.82 | 32.75 | 29.21 |
| MgO | 16.76 | 17.84 | 32.34 | 32.83 | 3.54 | 5.47 |
| CaO | 24.80 | 25.28 | 0.37 | 0.43 | --- | --- |
| Total | 99.72 | 100.08 | 99.95 | 99.87 | 99.95 | 99.89 |

* Total Fe.

1: Ca_{0.96}Mg_{0.91}Fe_{0.09}Cr_{0.03}Si_{2.00}O₆, 2: Ca_{0.98}Mg_{0.97}Fe_{0.05}Cr_{0.01}Si_{1.99}O₆, 3: Ca_{0.01}Mg_{1.69}Fe_{0.30}Si_{2.00}O₆,
 4: Ca_{0.02}Mg_{1.71}Fe_{0.29}Si_{1.99}O₆, 5: Fe_{0.98}Mg_{0.19}Cr_{1.62}Al_{0.27}O₄, 6: Fe_{0.86}Mg_{0.29}Cr_{1.66}Al_{0.24}O₄.

Table 2. Representative chemical analyses of Ni-bearing sulfides.

| | Pyrite | | | Pentlandite | | | Millerite | | Violarite | | |
|-------|--------|--------|--------|-------------|--------|-------|-----------|-------|-----------|-------|-------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| S | 53.60 | 53.10 | 53.74 | 32.85 | 33.03 | 32.99 | 35.23 | 35.43 | 42.02 | 42.07 | 43.12 |
| Fe | 43.77 | 44.98 | 44.90 | 25.60 | 21.27 | 26.75 | 1.30 | 1.86 | 31.62 | 18.13 | 19.77 |
| Ni | 2.59 | 1.97 | 1.44 | 41.48 | 45.94 | 39.74 | 63.48 | 62.35 | 25.50 | 35.19 | 33.59 |
| Co | --- | --- | --- | --- | --- | --- | --- | --- | 0.53 | 4.52 | 3.44 |
| Total | 99.96 | 100.05 | 100.08 | 99.93 | 100.24 | 99.48 | 100.01 | 99.64 | 99.67 | 99.91 | 99.92 |

1: Fe_{0.94}Ni_{0.05}S₂, 2: Fe_{0.97}Ni_{0.04}S₂, 3: Fe_{0.96}Ni_{0.03}S₂, 4: Ni_{5.52}Fe_{3.58}S₈, 5: Ni_{6.08}Fe_{2.96}S₈,
 6: Ni_{5.26}Fe_{3.72}S₈, 7: Ni_{0.98}Fe_{0.02}S, 8: Ni_{0.96}Fe_{0.03}S, 9: Ni_{1.33}Fe_{1.73}Co_{0.03}S₄, 10: Ni_{1.83}Fe_{1.00}Co_{0.23}S₄,
 11: Ni_{1.70}Fe_{1.05}Co_{0.17}S₄.

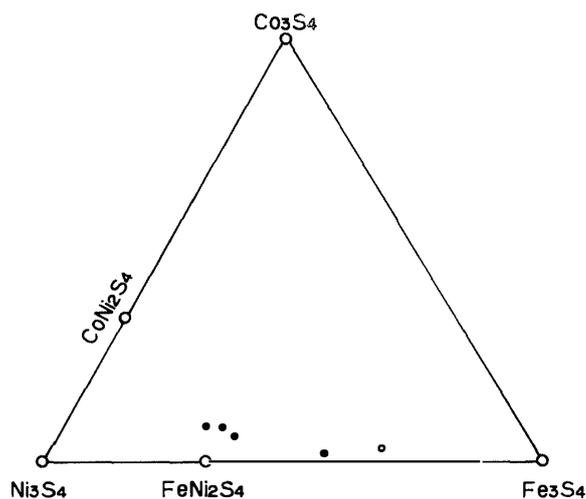


Fig. 8. Composition diagram of violarite (solid circle) and greigite (small open circle).

4. Discussion

The mode of occurrence of the pyroxenite xenolith and Mg-Fe distribution between coexisting orthopyroxene and clinopyroxene show it to be a member of Type A after

the ultramafic granulite grouping by SUZUKI (1986) (Fig. 9).

The phase relationship of the present sulfide minerals is indicated in Fe-(Ni, Co)-S diagram (Fig. 10). The assemblage pyrite-violarite does not appear. It seems that pyrite and/or violarite were firstly, and subsequently millerite and pentlandite were formed, respectively, after the interpretation of observed textural relations. However, violarite usually appears in lower temperature than pentlandite. This throws doubt on the above sequence. The most probable interplatation of the texture is that violarite is a pseudomorph after cobaltian pentlandite which might have appeared in the earlier stage.

In considering the genesis on sulfides, a source of nickel is the most important problem. If nickel-iron sulfides were originally included, the present sulfide aggregates are considered as recrystallized products during metamorphism. If the original rock included olivine which is the most reasonable source of nickel in a silicate phase, nickel might have been derived from decomposition of olivine by a reaction, olivine + SiO₂ → orthopyroxene. This reaction is highly expectable seeing from the existence of nearby silica-oversaturated sediments unless the supply of silica is impeded. In the first and

Fig. 9. Mg-Fe distribution between coexisting orthopyroxene and clinopyroxene. Star: present study. Circle: Type A (solid) and Type B (open) after SUZUKI(1986).

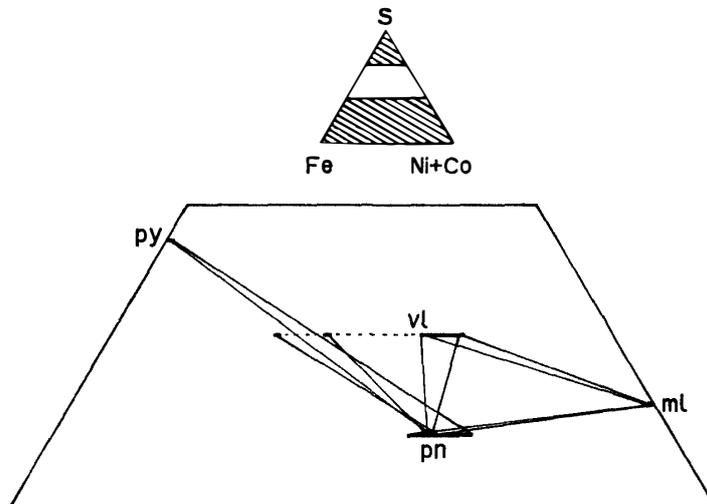
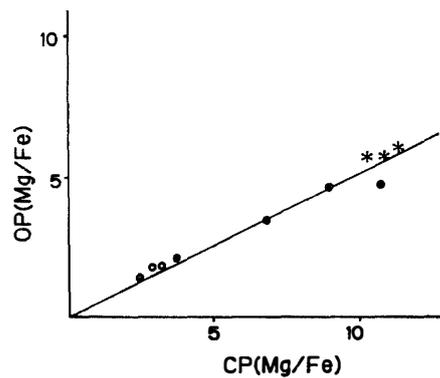


Fig. 10. The phase relationship of pentlandite (pn), millerite (ml), violarite (vl) and nickel-bearing pyrite (py).

second cases, websterite and wehrlite or lherzolite are the most probable original rocks, respectively. It is distinct that the studied pyroxenite has been derived from ultramafic igneous rock, which is probable as an ultramafic component of a tectonic melange.

Acknowledgments

We express our sincere gratitude to Dr. A. KATO, Department of Geology, National Science Museum, Tokyo, for his useful suggestions and critical reading of the manuscript.

References

- HIROI, Y., SHIRAIISHI, K., MOTOYOSHI, Y., KANISAWA, S., YANAI, K. and KIZAKI, K. (1986): Mode of occurrence, bulk chemical compositions, and mineral textures of ultramafic rocks in the Lützow-Holm Complex, East Antarctica. *Mem. Natl Inst. Polar Res., Spec. Issue*, **43**, 62–84.
- ISHIKAWA, T., TATSUMI, T., KIZAKI, K., YANAI, K., YOSHIDA, M., ANDO, H., KIKUCHI, T., YOSHIDA, Y. and MATSUMOTO, Y. (1976): Geological map of Langhovde, Antarctica. *Antarct. Geol. Map Ser.*, Sheet 5 (with explanatory text 10 p.). Tokyo, Natl Inst. Polar Res.
- KNOP, O. and IBRAHIM, M. A. (1961): Chalkogenides of the transition elements. II. Existence of the π phase in the M_9S_8 section of system Fe-Co-Ni-S. *Can. J. Chem.*, **39**, 297–317.
- SUZUKI, M. (1986): Short note on ultramafic granulites in the Ongul Islands area, East Antarctica. *Mem. Natl Inst. Polar Res., Spec. Issue*, **43**, 85–100.

(Received January 28, 1988; Revised manuscript received May 9, 1988)