

GEOCHEMICAL INVESTIGATIONS OF MINERALS IN THE ANTARCTIC

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Abstract: Many evaporites, such as halite, sylvite, epsomite, mirabilite, bloedite, gypsum, carphosiderite, aragonite, hexahydrite and atakamite were found around Syowa Station. These minerals are thought to have been formed by sea spray and/or concentration under the frigid condition, and in some cases by rock weathering. Garnet and euxenite were analyzed from the view points of geochemistry and mineralogy.

On the other hand, a new mineral, antarcticite, was found by geochemical investigation in the Dry Valleys. In the Dry Valley Drilling Project, many evaporites and secondary minerals were analyzed by X-ray and chemical method, and from these results the geological processes in the Dry Valley were clarified to some extent.

1. Introduction

Geochemical investigation was carried out on the minerals obtained around Syowa Station to know the geological processes of the area. Minerals such as garnet and euxenite were analyzed from the viewpoints of geochemistry and mineralogy. Many evaporites were investigated to examine their relation to air-borne salt which should be an origin of salt in lake water or pond water.

In the Dry Valleys, on the other hand, many evaporites and secondary minerals in the drilled cores or on the ground surface were investigated to clarify the geological

processes in the area. In this paper the authors try to summarize the geochemical investigations on the minerals carried out throughout the Japanese Antarctic Research Expedition.

2. Geochemical Studies of Minerals Around Syowa Station

Geochemical investigation on the minerals around Syowa Station was carried out on the minerals contained in pegmatite and on the evaporites on the ground surface. Euxenite collected at Skallen by TATSUMI was analyzed by X-ray and chemical method. The chemical composition of the mineral was as follows: UO_2 11.84%, ThO_2 3.20%, TiO_2 24.74%, $\text{Nb}_2\text{O}_5 + \text{Ta}_2\text{O}_5$ 30.76%, $\Sigma\text{Ce}_2\text{O}_3$ 0.38% and $\Sigma\text{Y}_2\text{O}_3$ 25.26%. From the results, this euxenite was identified as polycrace by HAYASHI and NAGASHIMA (1961). Age determination of mineral had been made by SAITO *et al.* (1961). The age 4.7×10^8 years coincided with that of the rock collected at Ongul Islands and Langhovde (YANAI and UEDA, 1974).

Garnet collected by TORII at East Ongul Island was analyzed by MINAMI *et al.* (1961) with X-ray and chemical method. The garnet was identified as pyralspite and the mineral composition was as follows: almandite 47.64%, pyrope 35.49%, grossularite 10.10%, andradite 4.59% and spessarite 2.18%.

In the 1961–1962 season, evaporites were collected to examine their relation to air-borne salt, and were analyzed by X-ray diffraction. These evaporites were identified as halite, calcite, gypsum and thenardite (WATANUKI, unpublished data). And in this season large mica was collected in the pegmatite at Nesöya. After an intermission of the Japanese Antarctic Research Expedition, several evaporites were collected around Syowa Station and analyzed by KANESHIMA *et al.* (1968). These evaporites were halite, sylvite, bloedite, epsomite, thenardite, mirabilite and gypsum. Two other minerals collected also in the same season from a weathered rock were identified as carphosiderite and copiapite. The weathering effect on the rock around Syowa Station was reported by MEGURO (1962). In the succeeding season, a general survey of evaporites was carried out by HIRABAYASHI during his wintering. Halite, calcite, aragonite, mirabilite, thenardite, gypsum, epsomite, carphosiderite, hexahydrate and atakamite were found by X-ray analysis carried out at Syowa Station (HIRABAYASHI and OSSAKA, 1976). These minerals are thought to have been formed by sea spray and/or concentration under the frigid condition, and in some cases by weathering of rock or mineral.

3. Geochemical Studies of Minerals in the Dry Valleys

Prior to the Dry Valley Drilling Project (DVDP), Japanese geochemists investigated the saline lakes and evaporites in the Dry Valleys, and found a new mineral "antarcticite," which is calcium hexahydrate (TORII and OSSAKA, 1965). And to

know the origin of salt in saline lakes, a general survey of evaporites in the area was carried out (TORII *et al.*, 1966). Since DVDP, geochemical researches on the minerals were carried out not only on the evaporites on the ground surface but also on the secondary minerals obtained from the DVDP cores. On the ground surface, halite, sylvite, thenardite, mirabilite, gypsum, calcite, aragonite, torona, thermonatrite, monohydrocalcite, soda niter, bloedite burkeite, and drapskite were found (MORIKAWA *et al.*, 1975; NISHIYAMA, 1977). In general, carbonate minerals predominate in the Taylor Valley, while sulfate minerals, except thenardite, predominate in the Wright Valley. Halite and thenardite are widespread in both areas. Torona and thermonatrite are found exclusively in the eastern Taylor Valley, and soda niter, bloedite, and drapskite in the Wright Valley. From the comparison of the distribution of these salts and the chemical composition of lake water in the area, it seems that the main sources of salts distributed in Taylor Valley and the Wright Valley are of marine and/or wind-transported origin, and a small amount of salts in the cores was derived from a hydrothermal solution (NISHIYAMA, 1979).

Mineralogical investigations carried out by MORIKAWA revealed that gypsum was the most abundant mineral near the shoreline of Lake Vanda, and halite was the most abundant mineral in the elevated area, and that abundant secondary minerals on the Dais indicated low grade hydrothermal metamorphism of the dolerite. The origin of magnesium and potassium ions in lake water was explained on the basis of the distribution of evaporites (MORIKAWA *et al.*, 1975).

In the cores, calcite, aragonite, fluorite, laumontite, chabazite chlorite and gypsum were identified (WATANUKI and MORIKAWA, 1975; MORIKAWA *et al.*, 1977). From the distribution of laumontite, prehnite, and illite in the vicinity of the intrusive plutonic rock, hydrothermal alteration was suggested in the DVDP cores. From the distribution of minor elements in the minerals, the chemical composition of the mineral-forming solution was calculated (WATANUKI and MORIKAWA, 1975). For example, the mole ratio of Sr to Ca in calcite is 7.06×10^{-4} , and the mole ratio of Sr to Ca in gypsum is 4.60×10^{-4} . From these data the ratio of Sr to Ca in the mineral-forming solution was calculated. The results are shown in Table 1.

Table 1. Mole ratio of Sr to Ca.

	Mole ratio in mineral	Mole ratio in solution
Calcite	7.06×10^{-4}	5.43×10^{-3}
Gypsum	4.60×10^{-4}	2.30×10^{-3}

Abundance of Sr and Ca in the crust and the sea water is shown in Table 2 in ppm, with the mole ratio of Sr to Ca in the last column. From the result, it is reasonable to think that Sr and Ca in the mineral-forming solution have resulted from rock weathering. From the content of Sr in antarcticite, the percentage of calcium

Table 2. Abundance of Sr and Ca.

	Ca	Sr	Mole ratio Sr/Ca
Crust	36300	450	5.6×10^{-3}
Sea water	400	8	9.1×10^{-3}

deposition from the original solution can be calculated. If the original solution had a ratio of Sr to Ca 5.60×10^{-3} , 84.5% of calcium was deposited to make the water of Don Juan Pond in which calcite is formed and in the case of forming gypsum 87.0% of calcium was deposited.

The lake water was 6550 m³ in 1974, and the Ca content was 91.48 kg/kg. The calcium content of the initial solution is estimated at $4.88\text{--}5.82 \times 10^9$ g. If the original solution had the same concentration as that of sea water, the volume of the original solution is calculated as $1.18\text{--}1.44 \times 10^7$ m³. TORII using the ancient shoreline calculated the original volume of Don Juan Pond water as 1.2×10^7 m³. These data suggest that at least contribution by weathering should be taken into consideration.

Geochemical investigation of chemical components, isotopic composition and minor element distribution of minerals in the Antarctic may shed light on the geologic processes of this region (NAKAI and MIZUTANI, 1977).

References

- HAYASHI, S. and NAGASHIMA, K. (1961): A mineralogical note on the euxenite-polycrase series mineral from Syowa Base, Antarctica. *Nankyoku Shiryô (Antarct. Rec.)*, **11**, 27–30.
- HIRABAYASHI, J. and OSSAKA, J. (1976): The X-ray diffraction pattern and their mineral components of evaporites at Prince Olav Coast. *JARE Data Rep.*, **32** (Geochem. 1), 58 p.
- KANESHIMA, K., TORII, T. and MIYAHIRA, K. (1968): Syowa Kiti shûhen ni san suru ebaporaito narabini ôshoku enrui no kôbutsu sosei (Mineralogical composition of white evaporites and yellow salts found around Syowa Station Antarctica). *Nankyoku Shiryô (Antarct. Rec.)*, **33**, 39–52.
- MEGURO, H. (1962): Nankyoku chiiki kaigan-sen no rogan chitai no ike oyobi fûka-butsumi ni tsuite (Report on the pools and some products of weathering around pond on the coast of Antarctica). *Nankyoku Shiryô (Antarct. Rec.)*, **14**, 44–47.
- MINAMI, E., OSSAKA, J. and NAKAMURA, T. (1961): Higashi Onguru-to-san zakuroishi ni tsuite (Garnet from East Ongul Island in the Antarctic Region). *Nankyoku Shiryô (Antarct. Rec.)*, **11** 31–35.
- MORIKAWA, H., MINATO, I., OSSAKA, J. and HAYASHI, T. (1975): The distribution of secondary minerals and evaporites at Lake Vanda, Victoria Land, Antarctica. *Mem. Natl. Inst. Polar Res., Spec. Issue*, **4**, 45–59.
- MORIKAWA, H., MINATO, I., OSSAKA, J. and WATANUKI, K. (1977): DVDP 3 (Ross Island) oyobi 6 (Lake Vida) no bôringu kôbutsu (Secondary minerals from the drilling cores of DVDP 3 (Ross Island) and 6 (Lake Vida)). *Nankyoku Shiryô (Antarct. Rec.)*, **58**, 186–194.

- NAKAI, N. and MIZUTANI, Y. (1977): Antei dôitai sosei kara mita Dorai Barê no rekishi-teki hensen (Geological history of the Dry Valleys Antarctica, based on the stable isotope studies). *Nankyoku Shiryô (Antarct. Rec.)*, **58**, 244–253.
- NISHIYAMA, T. (1977): Nankyoku Dorai Barê chiiki no enrui sekishutsu-butsumi ni tsuite (Studies on evaporites from Dry Valley, Victoria Land, Antarctica). *Nankyoku Shiryô (Antarct. Rec.)*, **58**, 171–185.
- NISHIYAMA, T. (1979): Distribution and origin of evaporite minerals from Dry Valleys, Victoria Land. *Mem. Natl Inst. Polar Res., Spec. Issue*, **13**, 136–147.
- SAITO, N., TATSUMI, T. and SATO, K. (1961): Absolute age of euxenite from Antarctica. *Nankyoku Shiryô (Antarct. Rec.)*, **12**, 31–36.
- TORII, T. and OSSAKA, J. (1965): Antarcticite, a new mineral, calcium hexahydrate, discovered in Antarctica. *Science*, **149**, 975–977.
- TORII, T., MURATA, S., YOSHIDA, Y., OSSAKA, J. and YAMAGATA, N. (1966): Nankyoku Bikutoria Rando no Dorai Barê chôsa hôkoku. 1. (Report of the Japanese summer parties in Dry Valley Victoria Land, 1963–1965. 1. On the evaporites found in Miers Valley, Victoria Land, Antarctica). *Nankyoku Shiryô (Antarct. Rec.)*, **27**, 1–12.
- WATANUKI, K. and MORIKAWA, H. (1975): Geochemical studies on the minerals obtained by the Dry Valley Drilling Project. *Mem. Natl Inst. Polar Res., Spec. Issue*, **4**, 60–66.
- YANAI, K. and UEDA, Y. (1974): Syowa Kiti fukin-san ganseki no zettai nendai to sono kôsatsu (Absolute ages and geological investigations on the rocks in the area of around Syowa Station, East Antarctica). *Nankyoku Shiryô (Antarct. Rec.)*, **48**, 70–81.

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