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Sm-Nd AND Rb-Sr ISOCHRON AGES FOR META-TRONDHJEMITES FROM CAPE HINODE, EAST ANTARCTICA

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Abstract: A Rb-Sr and Sm-Nd isotope study of meta-trondhjemites and a pelitic gneiss from Cape Hinode, Lützow-Holm Complex (LHC), East Antarctica has been performed. A Sm-Nd whole rock isochron for nine meta-trondhjemites defines an age of 1031±69 Ma with an initial $^{143}Nd/^{144}Nd$ ratio of 0.5115520±0.000053 (MSWD=0.10, $\varepsilon_{Nd}=+4.7\pm1.0$). In the Rb-Sr isochron diagram, the same nine samples yield an age of 1273±104 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.70275±0.00017 (MSWD=7.4) although the data are slightly scattered. The Sm-Nd isochron age is indistinguishable from the previously reported U-Pb SHRIMP zircon age (1017±13 Ma). Nd model ages (T_{DM}) of the meta-trondhjemites and a pelitic gneiss are ~1.2–1.5 Ga and 2 Ga, respectively. Taking into account the initial ratios and the previous zircon study, we conclude that the ~1000 Ma age indicates the time of igneous crystallization of the trondhjemite. The pelitic gneiss, which probably originated from middle Proterozoic supracrustal material, is the host rock of the trondhjemite intrusion. However, the ~500 Ma high grade metamorphic age, which is ubiquitous in the LHC, is not documented in these rocks. Slight scattering in the Rb-Sr and Sm-Nd isochron diagrams might be the effect of the ~500 Ma metamorphism, but resetting of the isotopes was not complete, probably because of the scale of the 4 km×5 km sample collection area.

1. Introduction

The Lützow-Holm Complex is a medium-pressure type metamorphic belt which extends for 300 km along the Prince Olav Coast and Lützow-Holm Bay region. The metamorphic grade increases from upper amphibolite-facies in the east to granulite-facies in the southwest (*e.g.* HIROI *et al*., 1991). Cape Hinode (Fig. 1) is situated in the eastern part of the Prince Olav Coast where it forms part of the upper amphibolite facies zone. Meta-trondhjemite is the dominant rock type in the area; it overlays an area of 4 km×5 km, occupying about 80% of the whole outcrop area. Other rock types are mainly pelitic gneisses and amphibolites with minor calc-silicate rocks. Although the field relationship between the meta-trondhjemite and the surrounding gneisses is not always evident, it is considered that the meta-trondhjemite intruded into the gneiss sequence before the main metamorphism (see geological map of Cape Hinode, YANAI and ISHIKAWA, 1978).

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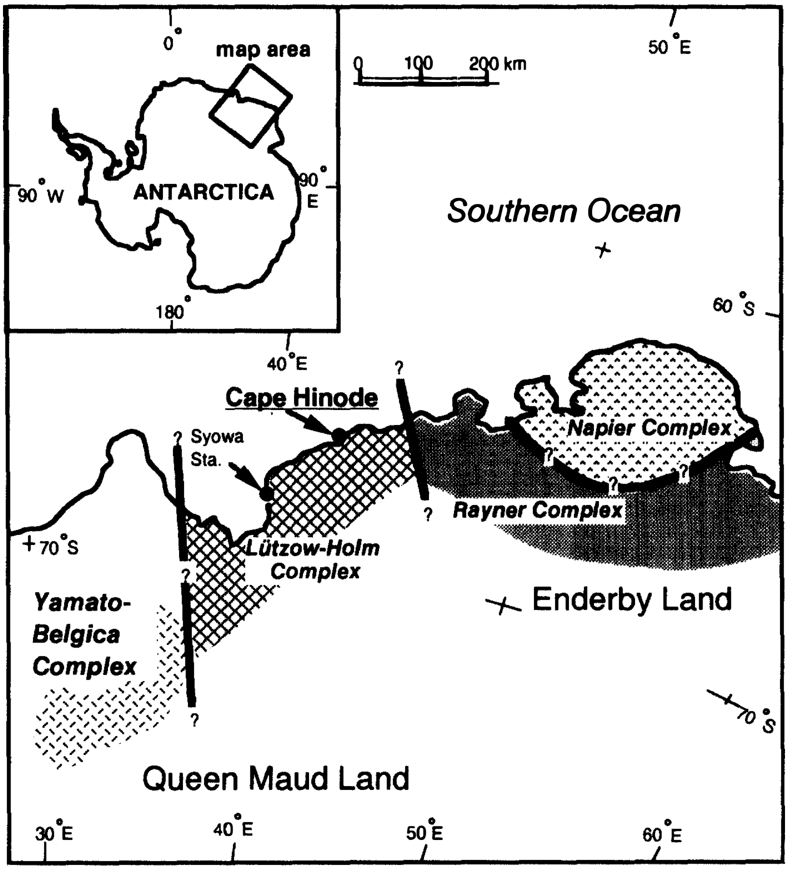

Fig. 1. Location map of the Cape Hinode and four metamorphic complexes in the Enderby Land–Queen Maud Land, East Antarctica.

SHIRAISHI *et al.* (1992, 1994) reported zircon U-Pb age with ion microprobe (SHRIMP) and revealed the monotonous age of ~1000 Ma for the meta-trondhjemite. In this paper, we report the whole-rock Rb-Sr and Sm-Nd isochron ages of the meta-trondhjemite. Petrogenesis of the original trondhjemite will be discussed elsewhere on the basis of the geochemical data including REE and other minor elements.

2. Samples

Cape Hinode was geologically mapped by YANAI and ISHIKAWA (1978) for the first time. They described the meta-trondhjemite as "anorthositic gneiss". However, the "anorthositic gneiss" is petrographically defined here as meta-trondhjemite because it contains a large amount of quartz. Ten meta-trondjemites which were collected from widely spaced localities across the whole area were analyzed for the present isotopic study. Sample 73120106 was previously analyzed with SHRIMP for U-Pb age of zircons (SHIRAISHI *et al.*, 1992, 1994). In addition, a pelitic gneiss (Sample 74010304) was collected from the area surrounding the meta-trondhjemite body.

Major chemical elements and a short description of the samples together with other rock types were given by KANISAWA *et al.* (1979). The mineral assemblages of the samples analyzed are listed in Table 1. The meta-trondhjemites are medium- to coarse-grained rocks with mosaic texture, and consist mainly of plagioclase, quartz, biotite with or without hornblende. Some hornblende-free rocks contain garnet. K-feldspar is not common and occurs as antiperthite lamellae in plagioclase. Accessories are apatite, zircon and opaque minerals. Secondary muscovite, biotite, hornblende and carbonate minerals are common but subtle.

3. Dating

3.1. *Analytical procedure*

Extraction procedures for Rb, Sr, Sm and Nd have been discussed in KAGAMI *et al.* (1987). Isotopic analyses were performed on a MAT261-type mass spectrometer equipped with five Faraday cups. $^{87}Sr/^{86}Sr$ ratios were normalized to $^{86}Sr/^{88}Sr=0.1194$ and $^{143}Nd/^{144}Nd$ ratios to $^{146}Nd/^{144}Nd=0.7219$. The measured $^{87}Sr/^{86}Sr$ ratio for NBS987 during this study is 0.710240 ± 12 (2σ, $N=5$). Rb and Sr concentrations were measured by the isotope dilution method using ^{87}Rb-^{86}Sr mixed spike. $^{143}Nd/^{144}Nd$ ratios in Table 1 are reported relative to $^{143}Nd/^{144}Nd=0.512640$ for BCR-1 (USGS standard). Sm and Nd concentrations were also measured by the isotope dilution method using ^{149}Sm-^{145}Nd mixed spike. We estimate an error of 0.5% for the Rb/Sr ratios and 0.1% for the Sm/Nd ratios of each sample based on reproducibility of the data. We used the following CHUR (Chondritic Uniform Reservoir) parameters for calculation of the initial ε_{Nd} value: $^{147}Sm/^{144}Nd(present)=0.1966$, $^{143}Nd/^{144}Nd(present)=0.512638$. Model ages using depleted mantle (T_{DM}) were calculated using the following parameters: $^{147}Sm/^{144}Nd(present)=0.2136$, $^{143}Nd/^{144}Nd(present)=0.51315$ ($\varepsilon_{Nd}=+10$). Rb-Sr and Sm-Nd isochron ages were calculated using a personal computer program prepared by KAWANO (1994) in which the equation of YORK (1966) and the following decay constants were used: $\lambda^{87}Rb=1.42\times10^{-11}$ y^{-1} and $\lambda^{147}Sm=6.54\times10^{-12}$ y^{-1}.

3.2. *Results*

Analytical data and model ages (T_{DM}) are shown in Table 1. The meta-trondhjemeite data are slightly scattered on both the Rb-Sr and Sm-Nd isochron diagrams (Figs. 2 and 3).

On the Rb-Sr diagram, one of ten meta-trondhjemites (73123106S) plots below the isochron defined by the other nine samples. Though the reason is not certain, the other nine samples define an isochron yielding 1273 ± 104 Ma with an initial $^{87}Sr/^{86}Sr$ isotopic ratios of 0.70275 ± 0.00017 (MSWD=7.4). The Sm-Nd isochron for ten meta-trondhjemites yields 1008 ± 81 Ma. However, if we extract one sample (73123106S), as in the Rb-Sr isochron, the Sm-Nd isochron for nine meta-trondhjemites defines an age of 1031 ± 69 Ma with an initial ratio of 0.5115520 ± 0.000053 (MSWD=0.10, $\varepsilon_{Nd}=+4.7\pm1.0$). On the two diagrams, the pelitic gneiss plots far from the isochrons (not shown on the Rb-Sr diagram). The Nd model ages (T_{DM}) for the meta-trondhjemite yield ~1200-1500 Ma and ~2000 Ma for the pelitic gneiss.

4. Discussion

Previously reported SHRIMP U-Pb zircon ages indicate a very homogeneous popula-

Table 1. Nd-Sr isotopic data of metamorphic rocks from Cape Hinode.

Original No.	Mineral assemb.	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	$\varepsilon_{Nd}(O)$	$\varepsilon_{Nd}(T)$ T = 1030 Ma	T_{DM}
Meta-trondhjemite								
73123103	Bt-Hbl-Pl-Qtz	1.67	7.86	0.1281	0.512383(10)	−5.21	3.84	1.366
74010107	Bt-Hbl-Pl-Qtz	2.39	11.4	0.1267	0.512390(13)	−5.07	4.16	1.332
73123116	Bt-Hbl-Pl-Qtz	1.18	5.70	0.1255	0.512384(11)	−5.19	4.22	1.323
74010606	Bt-Hbl-Pl*-Qtz	3.60	14.5	0.1498	0.512510(08)	−2.73	3.47	1.525
74010701	Bt-Hbl-Pl-Qtz	0.90	5.84	0.0928	0.512141(13)	−9.93	3.78	1.272
73123106S	Bt-Pl-Qtz	0.72	4.80	0.0906	0.512173(11)	−9.30	4.70	1.210
73123106K	Bt-Pl-Qtz	1.00	5.72	0.1059	0.512220(10)	−8.39	3.59	1.315
74010105	Bt-Pl*-Qtz	0.23	2.06	0.0679	0.511985(17)	−12.97	4.02	1.218
74010115	Bt-Pl-Qtz	0.52	3.3	0.0956	0.512159(14)	−9.58	3.76	1.279
74010113	Grt-Bt-Pl*-Qtz	2.51	11.6	0.1306	0.512427(13)	−4.35	4.37	1.326
Pelitic gneiss								
74010304	Sil-Bt-Grt-Pl-Qtz	5.65	27.9	0.1221	0.511943(15)	−13.79	−3.96	2.003

Original No.	Mineral assemb.	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
Meta-trondhjemite					
73123103	Bt-Hbl-Pl-Qtz	2.19	891	0.0071	0.703103(13)
74010107	Bt-Hbl-Pl-Qtz	25.2	653	0.1116	0.704456(13)
73123116	Bt-Hbl-Pl-Qtz	3.01	687	0.0127	0.703108(14)
74010606	Bt-Hbl-Pl*-Qtz	18.0	681	0.0763	0.704087(12)
74010701	Bt-Hbl-Pl-Qtz	19.3	723	0.0772	0.704003(13)
73123106S	Bt-Pl-Qtz	30.4	657	0.1339	0.704325(12)
73123106K	Bt-Pl-Qtz	12.6	554	0.0657	0.703933(13)
74010105	Bt-Pl*-Qtz	2.17	767	0.0082	0.703000(13)
74010115	Bt-Pl-Qtz	14.7	646	0.0656	0.703835(12)
74010113	Grt-Bt-Pl*-Qtz	15.2	141	0.3118	0.708640(13)
Pelitic gneiss					
74010304	Sil-Bt-Grt-Pl-Qtz	82.3	60.9	3.9312	0.764267(13)

Mineral abbreviations after KRETZ (1983). Pl*: plagioclase with antiperthite.
Numbers in parentheses refer to the 2 sigma errer in the last digits.

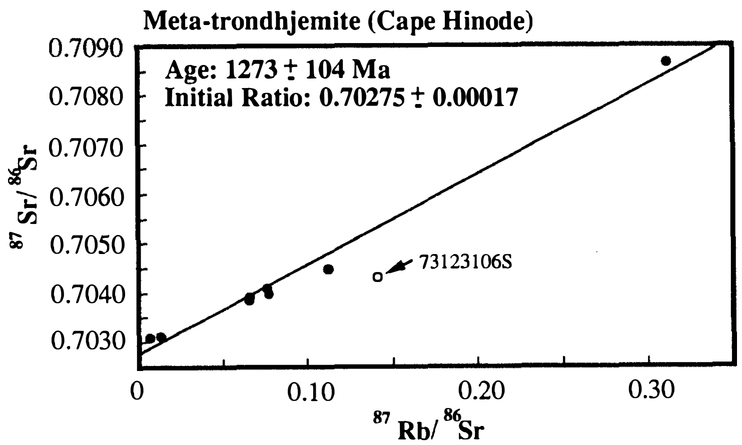

Fig. 2. Rb-Sr whole rock isochron diagram. Closed circle are the data used for the age calculation.

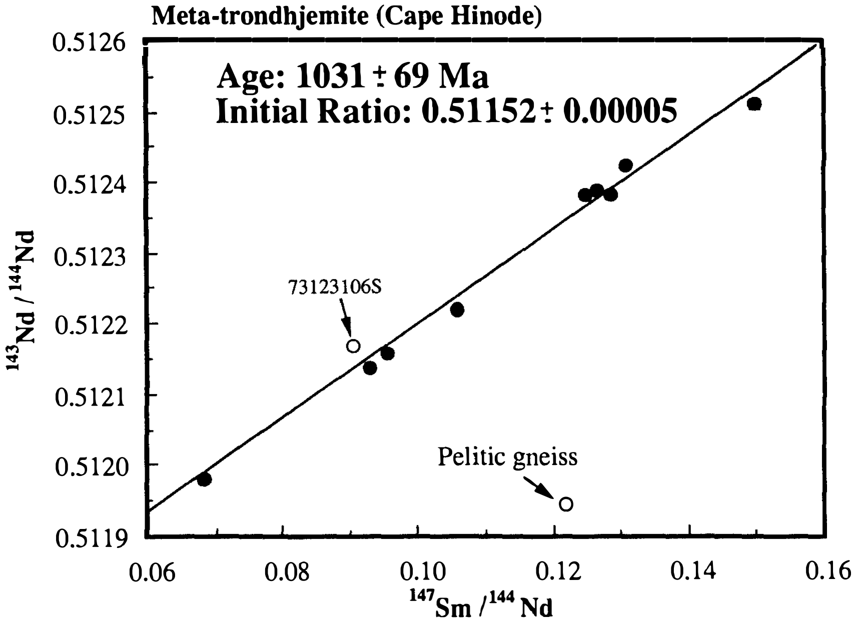

Fig. 3. Sm-Nd whole rock isochron diagram. Closed circle are the data used for the age calculation.

tion of zircon ages of ~1017±13 Ma throughout the core and rim portions (SHIRAISHI *et al.*, 1992, 1994). Thus, the results obtained in this study are very similar to the zircon ages. The zircon grains of the meta-trondhjemite show idiomorphic shape and distinct zonal growth structure concordant with the outline. The initial $^{87}Sr/^{86}Sr$ isotopic ratio of 0.70275 is similar to the ratio of CHUR, 0.7030 at this age. The initial ε_{Nd} of +4.7 is high compared with those of Neoproterozoic ultramafic to intermediate igneous rocks except for eclogites originated from ophiolite (KAGAMI and KOIDE, 1987). The Nd model ages (T_{DM}) are consistent with the above. These facts suggest that the ~1000 Ma ages represent the crystallization age of the trondhjemite magma.

Extensive zircon U-Pb dating with SHRIMP for pelitic gneisses of the LHC indicates that the main high-grade regional metamorphism occurred in the range ~520–550 Ma (SHIRAISHI *et al.*, 1992, 1994). However, the ~500 Ma age has not been documented in the present study or in the previous zircon study of the Cape Hinode meta-trondhjemite.

There are two possibilities for the absence of ~500 Ma ages from the meta-tronhjemite:

1) The meta-trondhjemite body does not belong to the LHC, but is a tectonic block which is part of the Neoproterozoic complex.

2) The igneous crystallization age of the meta-trondhjemite was ~1000 Ma but the Rb-Sr, Sm-Nd and U-Pb isotopic systems and zircon grains of the rocks were not significantly affected by ~500 Ma metamorphism.

We prefer possibility 2). The Rayner Complex, situated ~50 km east of Cape Hinode, has been thought to be regionally metamorphosed at ~1000 Ma (GREW, 1978; BLACK *et al.*, 1987). And the Rayner Complex is the most promising candidate for the source of the meta-trondhjemite. However, a recent SHRIMP study on the Rayner Complex does not support the extensive ~1000 Ma metamorphism (SHIRAISHI unpublished data). Therefore if we take possibility 1), we need an unknown ~1000 Ma complex elsewhere as the origin of the meta-trondhjemite.

On the other hand, if we take possibility 2), we must explain why ~500 Ma metamorphism, which is the main phase of metamorphism in LHC, did not affect the Sm-Nd, Rb-Sr and U-Pb isotopic systems of the Cape Hinode rocks. In particular, the Rb-Sr system has been considered to be easily reset by later tectonothermal events (BLACK and WITHNALL, 1993). However, in the present study, analyzed samples were collected from a wide 4 km × 5 km area. We suggest that the Rb-Sr and Sm-Nd systems were simply not able to be reset completely across this scale during the ~500 Ma event. Slightly scattered plots on the Rb-Sr and Sm-Nd isochron diagrams might be due to the effect of the ~500 Ma metamorphism.

In contrast, FRASER and McDOUGALL (1995) report hornblende ^{40}Ar-^{39}Ar ages for an amphibolite from Cape Hinode which gives 526±5 Ma. This age is consistent with K-Ar ages from elsewhere in the LHC (SHIBATA *et al.*, 1985; FRASER and McDOUGALL, 1995) which record cooling from the ~520–550 Ma high-grade metamorphic event.

The nearly idiomorphic elongate zircons found in the meta-trondhjemite contrast with the typical rounded, clear, ~500 Ma age metamorphic zircons found in pelitic gneisses elsewhere in the LHC. Nearly idiomorphic elongate zircon grains without inherited cores, of the meta-trondhjemites, suggest that there was no new zircon growth during the ~500 Ma metamorphism.

The Nd model age (T_{DM}) for the surrounding pelitic gneiss suggests that the protolith originated from middle Proterozoic supracrustal material and constrains the age of sedimentation roughly between 2.0 Ga and 1.0 Ga in the present portion of the LHC, since there is no reason to reject the possibility that the pelitic gneiss is the host rock of the trondhjemite intrusion.

5. Conclusion

The ages obtained by Rb-Sr and Sm-Nd whole rock isochrons indicate the time of crystallization of the trondhjemite magma. Slight scattering in the isochron diagrams, especially for the Rb-Sr system, might be due to the effect of the ~500 Ma metamorphism. However, resetting of the isotopes was not complete, probably because of the scale of the 4 km × 5 km sample collection area. Thus we conclude that the Sm-Nd isochron age of 1031±69 Ma is the intrusive age of the trondhjemite.

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