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Electron Microprobe (EMP) Dating on Monazite from Forefinger Point Granulites, East Antarctica: Implication for Pan-African Overprint

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Abstract. Electron microprobe (EMP) dating on monazite in granulite-facies rocks from Forefinger Point,East Antarctica, yielded dominant ages of ~500 Ma on matrix monazites.They are associated with secondary cordierite, biotite and sapphirine, formed during nearly isothermal decompression after the high *P-T* assemblages involving garnet, orthopyroxene and sillimanite. Older ages around 750– 1 000 Ma are detected in monazite cores and in monazite inclusions in garnet porphyroblast. Combining the available age data and the reaction textures, it becomes evident that the Forefinger Point granulites have been overprinted by a granulite-facies decompressional event of Pan-African age. Moreover, EMP monazite dating imply that the Forefinger Point granulites have experienced at least two stages of metamorphic evolution.

Introduction

Forefinger Point is a small outcrop in Casey Bay, East Antarctica (Fig. 2.6-1), located in the Rayner Complex close to the suspected boundary between the Rayner and Napier complexes (Sheraton et al. 1987). The basement rocks at Forefinger Point are essentially composed of granulitefacies pelitic-psammitic and felsic gneisses. They preserve a variety of marked reaction textures which are suggestive of nearly isothermal decompression (Harley et al. 1990; Motoyoshi et al. 1994, 1995). The Rayner Complex including the Forefinger Point granulites were considered to belong to the Proterozoic mobile belt reworked after the neighboring Archean Napier Complex (e.g., Sheraton et al. 1980, 1987; Harley and Hensen 1990; Harley et al. 1990) at 1 000 ±50 Ma (Grew 1978; Black et al. 1983, 1987). However, recent SHRIMP dating by Shiraishi et al. (1997) yielded abundant concordant U-Pb ages of ~520–540 Ma on zircons in two granulites from Forefinger Point, which imply a metamorphic overprint of late Cambrian (Pan-African) age. Moreover, Asami et al. (1997) reported ~530 Ma CHIME (Chemical Th-U-total Pb Isochron Method by Suzuki et al. 1991) ages for monazites in pelitic and charnockitic gneisses from Mt. Vechernyaya which also belongs to the Rayner Complex. In addition, older discordant U-Pb zircon ages of ~760–1 320 Ma, 907 Ma and 977 Ma have been reported from the inland region of the Rayner Complex (Shiraishi et al. 1997). That is to say, the timing of a major orogenic event of the Rayner Complex has not been clearly defined yet.
This paper tries to re-investigate the geochronology of the Forefinger Point granulites by means of electron microprobe (EMP) dating. The main purpose is to confirm the Pan-African overprint in this part of East Antarctica, and to characterize it in relation to the P-T evolution.

Samples

Samples used in this study (Sp. 93022206, 93022209, 93022222, 93022223, 93022225 and 93022231; they will be abbreviated as 2209 for 93022209, for example) are all metapelitic granulites with Opx + Sil + Grt, Opx + Grt, and Grt + Sil assemblages formed under the peak metamorphic conditions (Mineral abbreviations are after Kretz 1983). Secondary Crd-bearing assemblages formed at the expense of these peak mineral assemblages, as suggested by the following metamorphic reactions depending on the bulk chemical compositions;
Opx+ Sil+ Qtz=Crd
Opx+Sil=Crd+ Spr
Grt= Opx+Crd±Spr
Grt+ Qtz= Opx+ Crd

These reactions invariably suggest nearly isothermal decompression (Harley et al. 1990; Motoyoshi et al. 1994, 1995). On the basis of the model FeO-MgO-Al2O3-SiO2 (FMAS) grid (Hensen and Harley 1990), this decompressional P-T path has reasonably passed between two invariant points, namely [Spl] at 11 ±1 kbar and 1 040 °C ±15 °C and [Qtz] 8–9 kbar and 950 °C (Harley et al. 1990).However, there is no evidence that the P-T path came down from the Spr + Qtz stability field which characterizes the ultra-high temperature conditions of the neighboring Napier Complex. Harley et al. (1990) proposed that this decompression occurred during Archaean followed by the second stage decompression during Proterozoic.
Monazite in these samples occurs as rounded grains in the matrix in association with secondary cordierite, biotite and sometimes sapphirine. Monazite also occurs as inclusions in garnet. Internal structures of monazite grains were investigated using back scattered electron imaging (BSE) and elemental mapping. The monazites invariably demonstrate very heterogeneous structures due to heterogeneous concentrations of chemical components such as Th.

EMP Dating Method

Quantitative chemical analyses on monazite were performed by means of an electron microprobe analyzer using JEOL JXA-8800 equipped with five wavelength-dispersive spectrometers at the National Institute of Polar Research, Tokyo. The operating conditions were 15 kV accelerating voltage, 0.2 mA beam current and 2 μm beam diameter. In addition to UO2, ThO2 and PbO, other REE, SiO2, CaO, P2O5 were also measured, and the intensity data were adjusted using the $\phi\rho(Z)$ correction method (Packwood and Brown 1981). Only analyses higher than 0.02 wt.% PbO were selected for further processing.CHIME (chemical Th-U-total Pb isochron method) date reduction and calculation of apprent ages were performed by using the age calculation program of Kato et al. (1999).

Results

Pan-African Ages

Monazites which occur in the matrix in Sp. 2206, 2209, 2222, 2223, 2225 and 2231 yielded apparent ages close to 500 Ma (470~550 Ma). Representative results are listed in Table 2.6-1. Among them, examples of apparent ages on some of the grains in Sp. 2209 and 2231, along with the CHIME results (528.2 ±13.6 Ma for Sp. 2209 and 517.3 ±22.1 Ma for Sp. 2231) are presented in Fig. 2.6-2. Because these monazites all occur in the matrix in association with cordierite, sapphirine, biotite, etc., the monazite is inferred to have crystallized simultaneously with these minerals. The CHIME ages of 517–528 Ma are within error identical to SHRIMP U-Pb zircon ages of 530–537 Ma obtained by Shiraishi et al. (1997) from Forefinger Point.

Evidence for Older History

Older ages which predate the Pan-African event were also obtained from the monazites. In Sp. 2222,one of the monazite grains in the matrix (mnz 6) preserved a distinctive euhedral core,which yielded apparent ages of 750–960 Ma (Fig. 2.6-3). Because the rim was dated at around 500 Ma, this core is probably an inherited part crystallized prior to the Pan-African event.
Another example can be seen in Sp. 2225 in which monazite in the matrix yielded Pan-African ages (Fig. 2.6-4a and 2.6-4b), whereas a monazite inclusion in a garnet porphyroblast yielded older ages between 760–1 078 Ma (Fig. 2.6-4c and 2.6-4d).

Discussion

In view of similar ages obtained by SHRIMP dating (Shiraishi et al. 1997) and CHIME dating (present study), it is no doubt that the Forefinger Point granulites have certainly been subjected to the Pan-African overprint at around 520–540 Ma. Although the granulite-facies event which predates the Pan-African overprint has not been well constrained yet, the difference in mode of occurrence and different ages of the monazites clearly suggest that there have been at least two stages of monazite formation, one of Pan-African age and an earlier one of likely 750–1 000 Ma ages, respectively.
Shiraishi et al. (1997) argued on the basis of SHRIMP ages that the western coastal region of the Rayner Complex including Forefinger Point represents an eastward continuation of the Lützow-Holm Complex which has been also subjected to the regional Pan-African event (Shiraishi et al. 1994, 1997). On the basis of the monazite ages and reactions textures, the Pan-African event in the Forefinger Point granulites may be characterized by substantial decompression even un-der high-temperature conditions at granulite grade.

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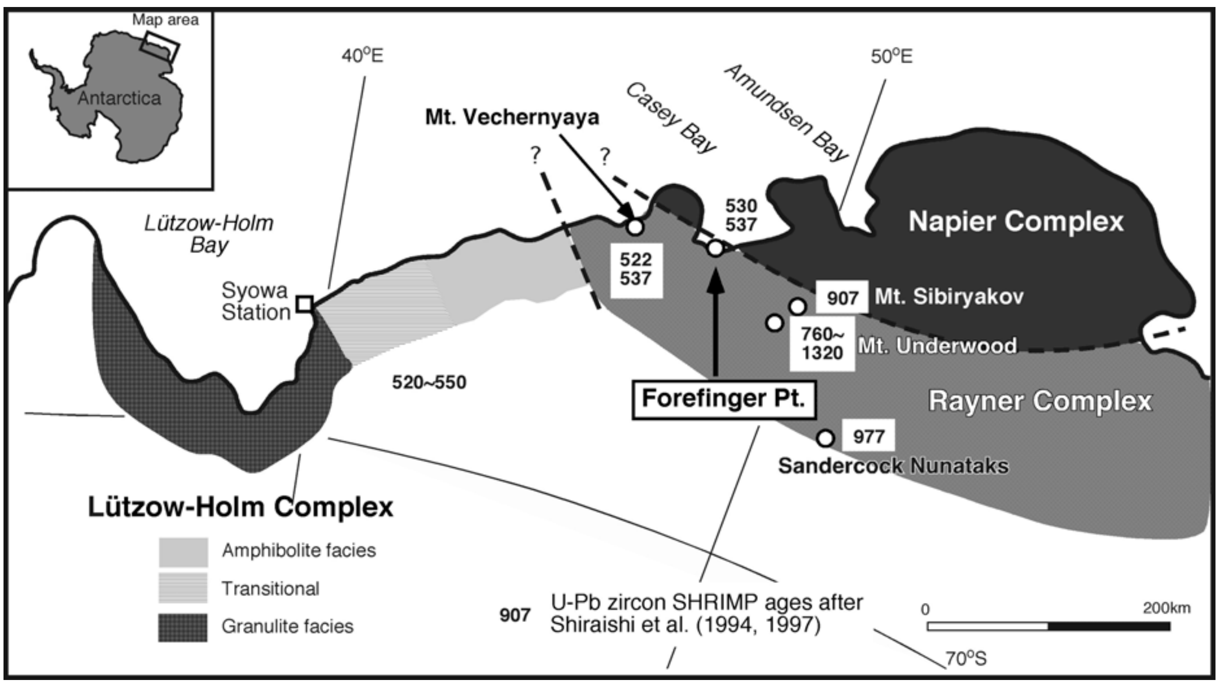

Fig. 2.6-1. Location of Forefinger Point and geological outline of the surrounding areas. U-Pb zircon SHRIMP ages are after Shiraishi et al. (1994, 1997). The estimated boundary between the Rayner Complex and the Napier Complex is after Sheraton et al. (1987). Metamorphic zonation on the Lützow-Holm Complex is after Hiroi et al. (1991)

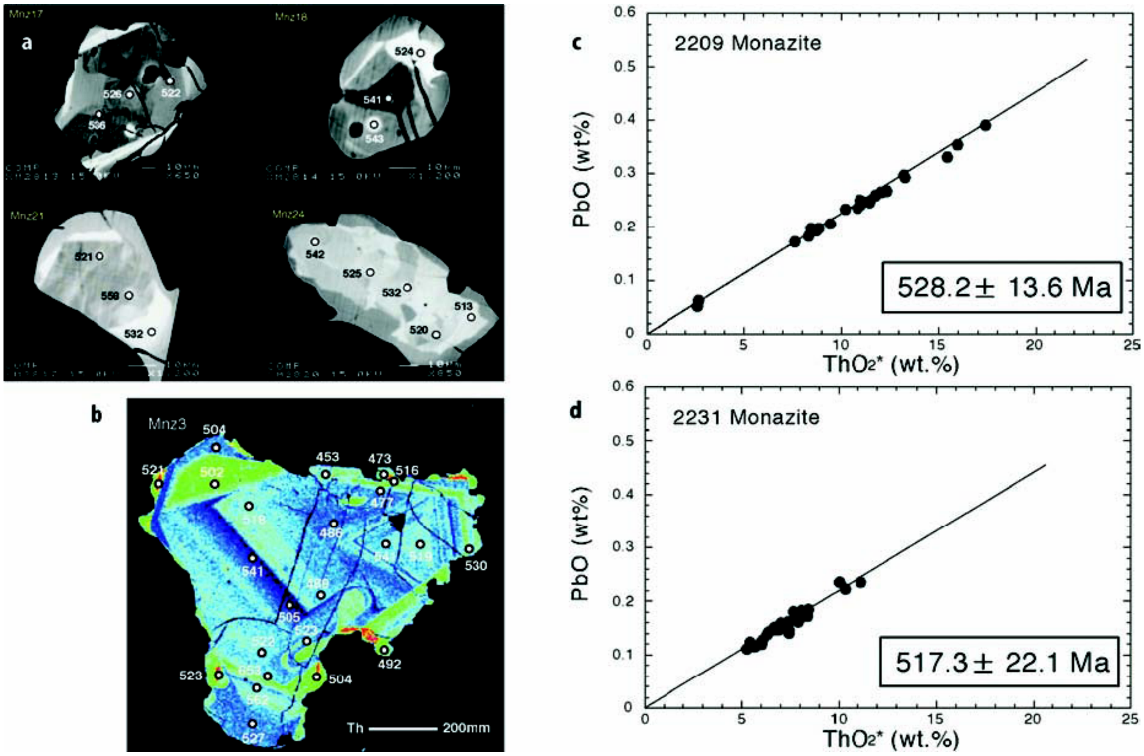

Fig. 2.6-2. a BSE images of representative monazites in Sp. 2209 and apparent ages in Ma. **b** Elemental mapping on Th for monazite (Mnz3) in Sp. 2231 with apparent ages in Ma. **c** CHIME ages on monazites in Sp. 2209. **d** CHIME ages on monazites in Sp. 2231. *ThO_2** denotes sum of the measured ThO_2 and ThO_2 equivalent of UO_2 for monazite

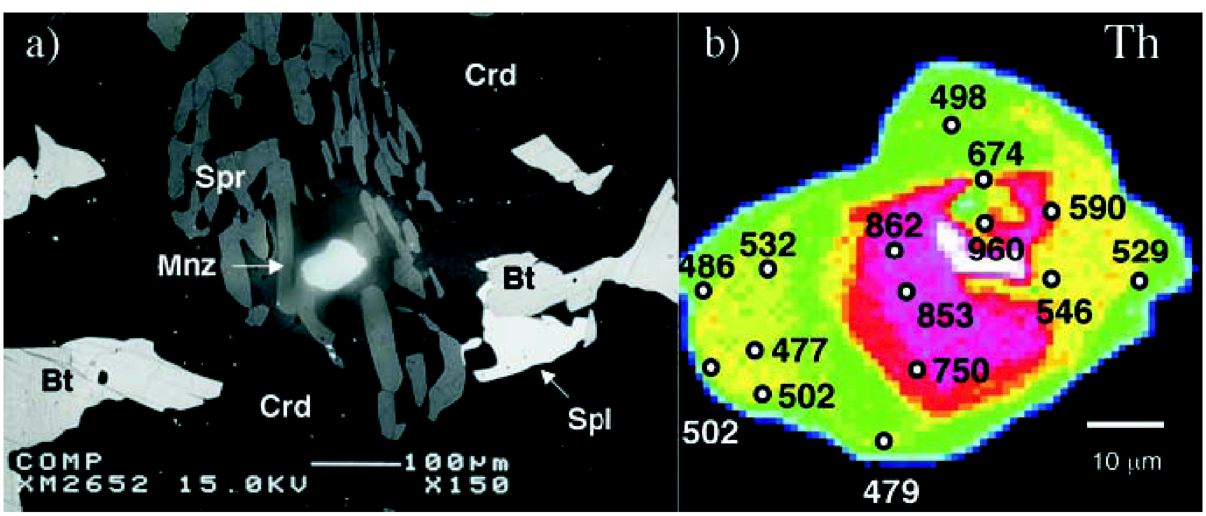

Fig. 2.6-3. a Mode of occurence of monazite in Sp. 2222 being associated with sapphirine, cordierite and biotite. Back-scattered electron image. **b** Elemental mapping on Th for monazite (Mnz6) in Sp. 2222 with apparent ages in Ma. ThO_2 contents in red core are around 13~14 wt.%, those in rim are around 9~10 wt.%, respectively. Note the euhedral core with older apparent ages

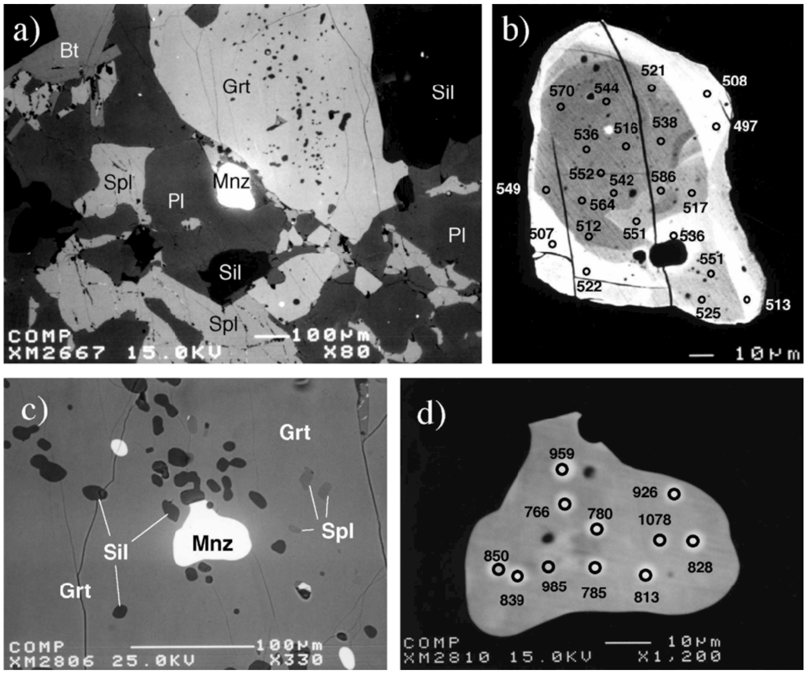

Fig. 2.6-4. Backscattered electron image of monazite in Sp. 2225. **a** Mode of occurrence of monazite in the matrix. **b** Apparent ages in monazite in the matrix. **c** Monazite inclusion (Mnz11) being associated with sillimanite and spinel in garnet. **d** Apparent ages in monazite inclusion

Table 2.6-1. EMP analyses of UO2, ThO2, and PbO on monazites from Forfinger Poinit granulites.
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