Early Precambrian mantle derived rocks in the southern Prince Charles Mountains, East Antarctica: age and isotopic constraints

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Abstract Mafic and ultramafic rocks occurring as lenses, boudins, and tectonic slabs within metamorphic units in the southern Mawson Escarpment display mantle characteristics of either a highly enriched, or highly depleted nature. Fractionation of these mantle rocks from their sources may be as old as Eoarchaean (ca 3850 Ma) while their tectonic emplacement probably occurred prior to 2550 Ma (U-Pb SHRIMP data). These results provide for the first time evidence for Archaean suturing within East Antarctica. Similar upper mantle sources are likely present in the northern Mawson Escarpment. A younger age limit of these rocks is 2200 Ma, as indicated by presumably metamorphic zircon ages while their magmatic age may be constrained by single zircon dates at 2450-2250 Ma. The area of the northern Mawson Escarpment is most likely of ensimatic origin and includes mafic rocks which were derived from distinct mantle source(s) during Palaeoproterozoic time.

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Introduction

East Antarctica is well known for its high-grade metamorphic rocks – felsic (granitic to trondhjemitic) orthogneisses or paragneisses. These rocks are up to 3800–3900 Ma old as evidenced by zircon U–Pb studies (Harley & Black, 1997) and corresponding Sm–Nd model ages (Grikurov & Mikhalsky, 2002 and references therein). The latter indicate that parts of the East Antarctic crust were derived from the mantle as early as in the Eoarchaean. However, there are only rare occurrences of mantle-derived rocks retaining their primary mantle characteristics, which were not reworked during subsequent events. The southern Prince Charles Mountains (sPCM) is one of a few areas in East Antarctica where Archaean metamorphic rocks occur. Furthermore, locally abundant mafic to ultramafic rocks of presumably mantle origin occur in this area. The sPCM are underlain by Mesoarchaean to Neoproterozoic Ruker Province (Phillips et al., 2006), a part of which (central and northern Mawson Escarpment) may be distinguished as Palaeoproterozoic Lambert Terrane (Kamenev et al., 1993, Mikhalsky et al., 2006, Boger et al., 2006). The central and northern parts of the Prince Charles Mountains are underlain by Meso- to Neoproterozoic Beaver (or Rayner, by some authors) Province, with the Fisher Terrane forming a southern part of it (Fig. 1). In this report we present new geological and isotopic (U–Pb SHRIMP and Sm–Nd) data for mafic to ultramafic rocks from the Mawson Escarpment in the sPCM and put some geochemical and age constraints on their mantle sources.

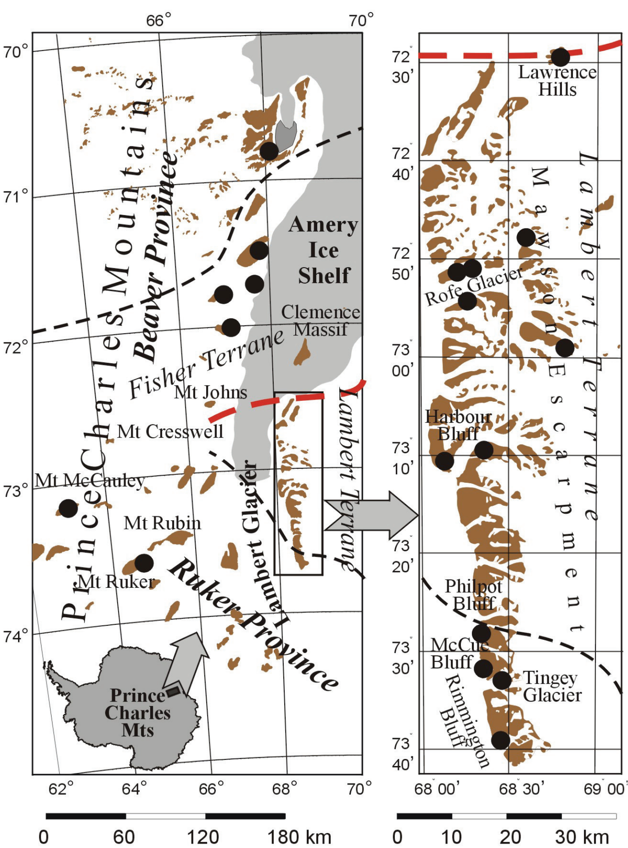

Figure 1. Locality map, showing occurrences of ultramafic rocks in the Prince Charles Mountains (thick dot). Thick red dashed line – province boundary, black dashed line – terrane boundary.

Southern Mawson Escarpment

Mantle derived mafic and ultramafic rocks occur as small lenses, boudins or larger blocks and tectonic slabs within metamorphic units. Typically, these rocks occur as chains and groups of boudins enclosed in steeply dipping, generally east–west trending high-strain shear zones or as scattered boudins within felsic granite-gneiss. These rocks consist of amphibole (actinolite, tremolite, or anthophyllite), magnetite, relict orthopyroxene and olivine, and secondary talc, serpentine, epidote, phlogopite, carbonate, chlorite, and titanite. Less altered rocks are olivine orthopyroxenite, amphibole orthopyroxenite, dunite, and amphibole dunite. The rocks apparently experienced two metamorphic events.

The most prominent high-strain shear zone runs along the northern fringe of Tingey Glacier. Here ultramafic and less abundant mafic lenses and blocks occur within a 50–100 m thick tectonic melange zone. A syntectonic felsic vein from this melange zone was studied for zircon chronology by SHRIMP at the Isotopic Center (VSEGEI, St. Petersburg). Zircon grains are of elongated prismatic (apparently magmatic) shape and are inhomogeneous in terms of the inner structure (core and thick mantle). Seven mantle analyses on seven grains were obtained (Th/U = 0.12–0.18), all are highly discordant, but six of these form a reference line with an upper intercept at 3333±60 Ma, and a lower intercept at 2539±61 Ma (Fig. 2). The upper intercept is close to the emplacement age of trondhjemitic gneiss (3377±9 Ma, Mikhalsky et al., 2006) to the north of Tingey Glacier, but older than the emplacement age of granitic gneiss (3180–3170 Ma, Mikhalsky et al., 2006, Boger et al., 2006) south Tingey Glacier. The lower intercept is close to the age of a post-tectonic pegmatite vein (ca 2650 Ma, Boger et al., 2006), but may be influenced by thermal overprint, distinguished by Boger et al. (2006). We interpret the ca 3330 Ma age as inherited, and the ca 2550 Ma date as the younger age limit of tectonic melange.

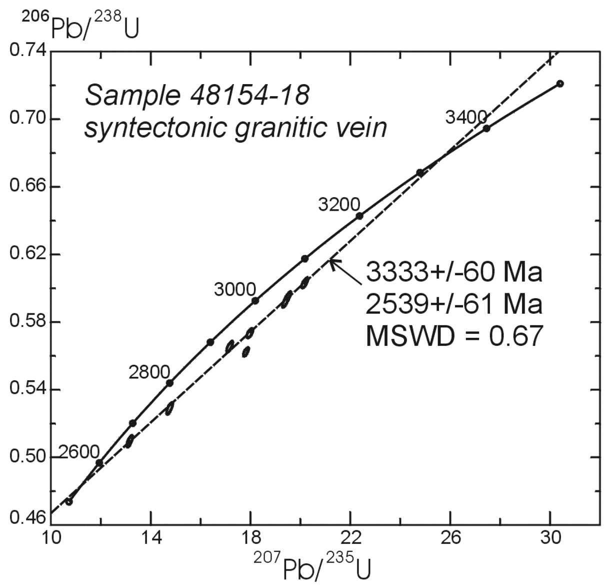

Figure 2. U–Pb concordia plot for a granitic vein from the Tingey Glacier area.

Sm–Nd data were obtained at the BGR (Hannover). Ultramafic and mafic rocks have highly variable Sm/Nd ratios ($f_{Sm/Nd}$ = -0.30–-0.10, up to 0.30, where $f_{Sm-Nd} = (^{147}Sm/^{144}Nd_{sam}/^{147}Sm/^{144}Nd_{CHUR}) - 1$) with single stage T_{DM} model ages between 2.0–4.2 Ga, but strikingly consistent $\varepsilon_{Nd}(0)$ values of mostly between -19 – -23 (Fig. 3 a). A two point (Cpx–WR) reference line

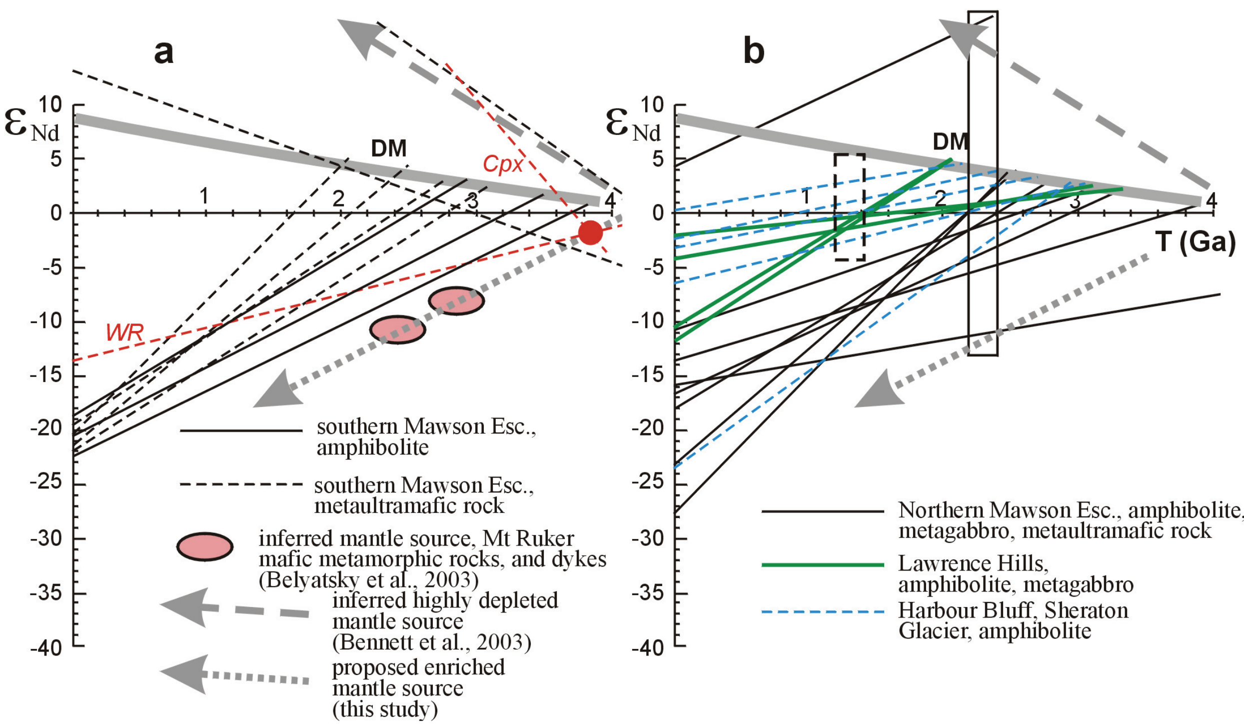

Figure 3. Sm-Nd evolution diagram for ultramafic and mafic rocks from the southern (a) and northern (b) Mawson Escarpment. See text for explanations.

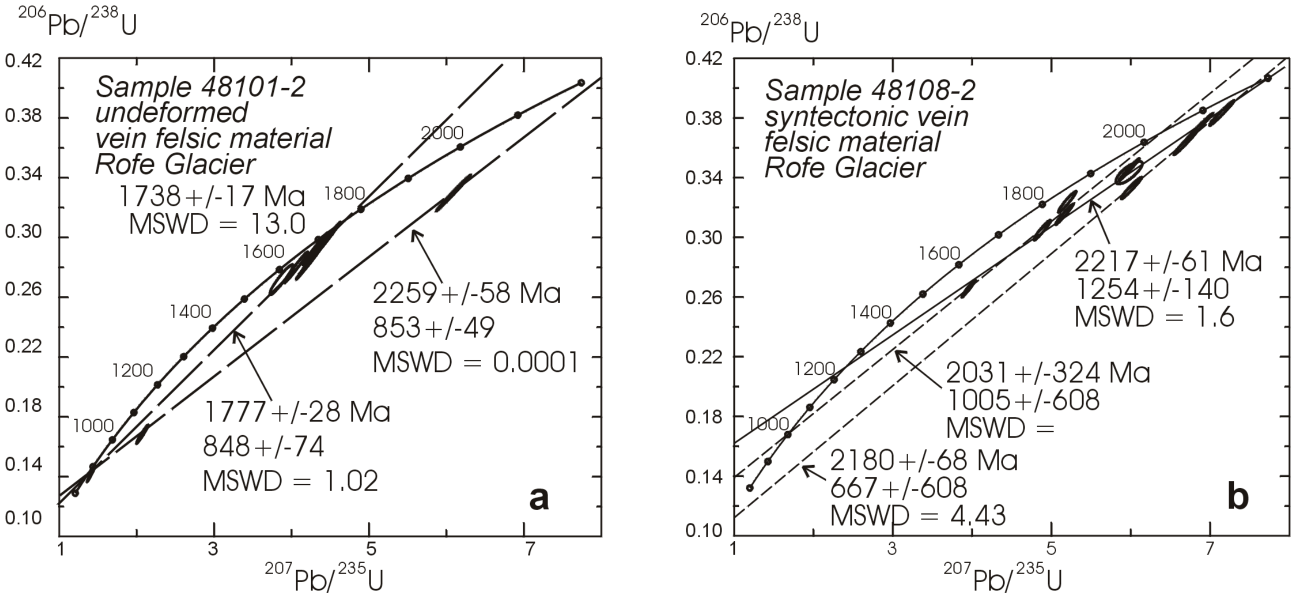

Figure 4. U–Pb concordia plots for granitic veins from the northern Mawson Escarpment.

defines an age of ca 3850 Ma with $\varepsilon_{Nd}(t)$ = -2 for a least altered rock. We refer these values to the approximate age when the rock was formed in the upper mantle and to the primary composition of the upper mantle source, respectively. The other rocks likely experienced Sm–Nd fractionation during the subsequent metamorphic events which caused the apparent T_{DM} scatter. Highly enriched mantle sources have been previously reported from Mt Ruker (Belyatsky et al., 2003; Fig. 3 a). These sources, and the newly defined composition in southern Mawson Escarpment define an evolution trend in Fig. 3 providing evidence that a highly enriched mantle source underlay the southern Ruker province during the Archaean. However, one sample has a very high $f_{Sm/Nd}$ and a T_{CHUR} model age of ca 4.2 Ga which closely matches the composition of the presumed early Archaean highly depleted mantle reported by Bennett et al. (1993). Accordingly, isotope data of mafic to ultramafic rocks from the sPCM point to a heterogeneous character of the mantle.

Northern Mawson Escarpment

In the Rofe Glacier area a predominantly mafic–ultramafic unit, cropping out as isolated blocks or lenses and spatially associated with marble and paragneiss, shows compositional layering suggestive of a plutonic origin. A wide variety range of ultramafic rocks was found: orthopyroxenite, websterite, peridotite, dunite, hornblendite; some varieties are of strongly ferruginous composition. Mafic rocks include hornblende–clinopyroxene–plagioclase, hornblende–plagioclase schist, metagabbro and garnet amphibolite. Ultramafic rocks seem to have undergone only minor metamorphic transformation. Pale-green amphibole or cummingtonite and phlogopite are all in textural equilibrium with olivine and pyroxenes. This suggests that these minerals crystallized early in the rock evolution, maybe at upper mantle conditions. The geochemical features point to an origin of the unit by igneous fractionation and/or accumulation processes.

A late tectonic undeformed leucocratic quartz-feldspar leucosome within one of the ultramafic/mafic bodies contains rounded zircon grains with low Th/U = 0.03–0.05 except one prismatic grain (0.80). All analyses are to some degree discordant, and eight low-Th/U analyses give an upper intercept at ca. 1740 Ma (Fig. 4 a), which is believed to reflect the synmetamorphic leucosome emplacement age. A high-Th/U analysis suggests the presence of inherited material of ca 2250 Ma age, which may reflect the emplacement age of mafic protolith. A sample from a syntectonic vein contains rounded inhomogeneous zircon grains, which have domains of high (0.13–0.67) and low (0.04) Th/U ratios. Ten analyses were obtained, with low-Th/U analyses displaying more pronounced Pb loss. Eight analyses form a reference line (Fig. 4 b) with an upper intercept at 2217±61 Ma, and a lower intercept at ca 1250 Ma (MSWD = 1.6), which we interpret as crystallisation age, and thermal overprint age, respectively. U–Pb zircon ages of 2150–2000 Ma and a concordant zircon analysis at ca 2450 Ma were also obtained for a host amphibolite by A. Corvino (personal communication).

Mafic and ultramafic rocks in the northern Mawson Escarpment have highly variable Sm–Nd isotopic characteristics: $f_{Sm–Nd}$ = -0.08 – -0.50, T_{DM} = 0.6–3.8 Ma, ε_{Nd} (0) = -28 – +4 (Fig. 3 b). This scatter may be explained by mixing of two end-members (stretched vertical rectangle in Fig. 3 b), which may be the highly depleted, and highly enriched reservoirs already identified in the southern Mawson Escarpment.

Central Mawson Escarpment and other areas

In the central part of the Mawson Escarpment (Philpot Bluff – Harbour Bluff) amphibolite crops out as thin layers (meta-dykes?) or thicker members (metagabbro?) intercalated with felsic quartz–feldspar gneiss. These rocks have Sm–Nd isotopic compositions that are strikingly different from the aforementioned mafic rocks in the northern and southern Mawson Escarpment: ε_{Nd} (0) = -6 – 0, f_{Sm-Nd} = -0.08 – -0.12. These features are typical of rocks from the Fisher Terrane bordering the Ruker Province from the north (Mikhalsky et al., 2001 and references therein, dashed rectangle in Fig. 3 b). Similar amphibolites also crop out at Lawrence Hills, Mt Cresswell, Mt Johns, and Shaw Massif.

Conclusions

1. In the southern Mawson Escarpment ultramafic and mafic rocks display mantle characteristics of complementary highly enriched, and highly depleted nature. The age of these rocks may be as old as Eoarchaean (ca 3850 Ma), which corresponds to the earlier observed ages of crustal protoliths in Enderby Land. The time of tectonic emplacement of these rocks in the middle crustal level may not be established from our data, but is definitely older than 2550 Ma. This fact for the first time provides evidence for Archaean suturing within the present East Antarctica.
2. In the northern Mawson Escarpment ultramafic and mafic rocks represent a Palaeoproterozoic dismembered igneous complex of mantle origin. These rocks were derived by mixing of two contrasting mantle sources: highly enriched and highly depleted reservoirs. The younger age limit of these rocks is ca 2200 Ma, as indicated by presumably metamorphic zircon ages (orogeny at ca 2.2–2.0 Ga?), and the older age limit may be indicated by single zircon dates at ca 2450–2250 Ma.
3. The Archaean and Palaeoproterozoic ultramafic–mafic rocks from the southern and northern parts of Mawson Escarpment may originate from similar mantle sources, which proves that both areas belong to a single (Ruker) Province, as suggested by Phillips et al. (2006). However, these authors and Mikhalsky et al. (2006) also emphasized that the central and northern parts of the Mawson Escarpment are underlain, unlike the southern part of it, by Proterozoic orthogneisses and metasediments. Hence, these areas (Lambert Terrane by Kamenev et al., 1993, Mikhalsky et al., 2006) are most likely of ensimatic, rather than ensialic origin.

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