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The role of eclogite in the rift-related metasomatism and Cenozoic magmatism of Northern Victoria Land, Antarctica

Massimiliano Melchiorre [a,*], Massimo Coltorti [a], Costanza Bonadiman [a], Barbara Faccini [a], Suzanne Y. O'Reilly [b], Norman J. Pearson [b]

[a] Department of Earth Science, Ferrara University, via Saragat 1, 44123 Ferrara, Italy
[b] GEMOC, Department of Earth and Planetary Sciences, Macquarie University, NSW 2109, Australia

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ABSTRACT

Sr, Nd, and Hf isotopic analyses of separated clinopyroxenes and in situ Re–Os isotopic analysis of sulphides in mantle-peridotite xenoliths from Baker Rocks (BR) and Greene Point (GP), less than 100 km apart in Northern Victoria Land (NVL), Antarctica, provide further constraints on the evolution of the sub-continental lithospheric mantle beneath NVL and suggest that eclogitic reservoirs may have played a role in the metasomatism and magmatism of the area.

Most of the BR sulphides have radiogenic $^{187}Os/^{188}Os$ (0.1318–0.379 with $^{187}Re/^{188}Os$ ratios between 0.46 and 3.3), while unradiogenic $^{187}Os/^{188}Os$ characterizes the GP suite (0.1068–0.1279 with $^{187}Re/^{188}Os$ ratios from 0.0002 to 0.045). In BR silicates $^{87}Sr/^{86}Sr$ varies between 0.70296 and 0.70488, $^{143}Nd/^{144}Nd$ lies within a narrow range (0.51271–0.51296), and $^{176}Hf/^{177}Hf$ ranges from 0.28300 to 0.28337. Clinopyroxenes from GP have similar $^{87}Sr/^{86}Sr$ (0.70277 to 0.70434), $^{143}Nd/^{144}Nd$ between 0.51261 and 0.51347, and $^{176}Hf/^{177}Hf$ between 0.28332 and 0.28519.

Notwithstanding the rather limited number of sulphides in the GP suite, Os model ages for BR and GP largely overlap. A histogram of T_{RD} (Time of Rhenium Depletion) model ages shows peaks at 3.0–3.3 Ga, 2.3 Ga, 1.3–1.4 Ga, 0.9–1.1 Ga, 580–620 Ma and 120 Ma (the youngest being recorded only at BR). These ages fit reasonably well with the events that affected Antarctica during its geological evolution.

The highly radiogenic Os found in the BR xenoliths can be explained through mixing with an eclogitic lithotype. Mafic magmas, now eclogite, may have been introduced into the sublithospheric NVL mantle during the Ross Orogeny (550–600 Ma) or older subduction events and reactivated during the opening of the West Antarctic Rift System. The mixing component will depend on the age of the subducted material. About 15% of recycled Archean material would be necessary in order to account for the most radiogenic Os-isotope values. Based on Hf systematics the most radiogenic Hf in the GP clinopyroxenes could also be explained by adding between 35 and 20% eclogite. However in this locality the possible presence of garnet in the peridotitic domains and successive re-equilibration in the spinel stability field, could also account for the highly radiogenic Hf in the clinopyroxene values.

1. Introduction

Extensive petrological investigations on both mantle xenoliths and lavas have been carried out on rocks from several localities of Northern Victoria Land (NVL, Antarctica). Most of the studies on mantle xenoliths have focussed on major- and trace-element compositions and on thermobarometric calculations. Petrological studies of lavas have been carried out with the aim of defining the nature of their mantle sources.

Berg et al. (1989) investigated the thermobarometric conditions of a suite of granulites hosted in the Cenozoic alkaline volcanic rocks from McMurdo Sound and proposed a geotherm, which was later confirmed by Beccaluva et al. (1991), indicating the thermobarometric conditions consistent with a dynamic rift. Some further constraints on the nature and evolution of the mantle beneath this region have been proposed by Coltorti et al. (2004), who explained the amphibole in mantle xenoliths from Baker Rocks as a reaction product between undersaturated alkaline-silicatic metasomatic fluids and pre-existing clinopyroxene. Perinelli et al. (2006), in a study of a suite of anhydrous mantle xenoliths entrained in the Cenozoic volcanics of Greene Point, concluded that some portions of the lithospheric mantle originated in the garnet stability field and subsequently equilibrated in the spinel facies. They also measured the isotopic composition of oxygen and suggested a possible influence of partial melting on oxygen isotope composition.

Cenozoic basalts from Northern Victoria Land have recently been described in detail and isotopically characterized by Nardini et al.

* Corresponding author.
E-mail address: mlcmsm1@unife.it (M. Melchiorre).

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(2009) with the aim of reconstructing the evolution of the West Antarctic Rift System. Major- and trace-element compositions are similar to Ocean Island Basalts (OIB), and the whole-rock isotopic composition suggested a HIMU (or high 'μ' = $^{238}U/^{204}Pb$), signature in the source. However, Nardini et al. (2009) argued that the He isotopic ratios excluded a mantle plume as the driving force responsible for the rifting processes. They proposed that the magmas originated in lithospheric mantle, which have been modified during a progressive replacement by asthenosphere-derived material. Small amounts of melt were generated during the Cretaceous, which were unable to reach the surface, but strongly metasomatized the lithospheric domains. These enriched domains successively melted as a consequence of the transtensional tectonics that formed the West Antarctic Rift System. Finally, magmas erupted to the surface following a NW–SE fault system to form plutons, dykes and lavas.

It is therefore expected that the West Antarctic Rift System lithospheric mantle is chemically and mineralogically highly heterogeneous. In order to constrain the extent and the nature of this heterogeneity, we have undertaken a detailed isotopic study (Sr, Nd, Hf, and Os) on two suites of mantle xenoliths from Northern Victoria Land, i.e. Greene Point (73° 46 186′S, 165° 57 003′E) and Baker Rocks (74°12 320′S, 164°50 090′E) (Fig. 1). Sampling was carried out during the 20° Italian Expedition organized by the PNRA (Programma Nazionale Ricerche in Antartide) during the 2004/05 Austral summer.

2. Geological setting

During Archean and Protorezoic the continental mass of Antarctica was subjected to several episodes of aggregation into supercontinents through collisions and separation due to the formation of new oceanic basins. Major events that produced or modified the crustal and Sub-Continental Lithospheric Mantle occurred in the Archean between 2.9 and 3.6 Ga (Condie, 1998; Griffin et al., 2004). Subsequently two main suturing events occurred, one at 2.7 and one at 1.9 Ga (Condie, 1998). The supercontinent Rodinia was formed during the Grenville Orogeny, resulting from the collision of ancient continental masses and remnants of this belt outcrop in Australia, Antarctica, North America (the present day eastern coast of Laurentia), the Andean margin of Amazonia and East Africa (Kaz'min, 1988; Khain, 2000). As a result of rifting between 850 and 800 Ma ago, Rodinia separated into three main groups of continental masses: the first comprised Antarctica, southwestern Africa (Congo and the Kalahari), India and Australia (Group 1); the second (Group 2) Laurentia, Amazonia, West Africa and Baltica, while the third was formed by North China, Tarim-Tien Shan continent and Siberia

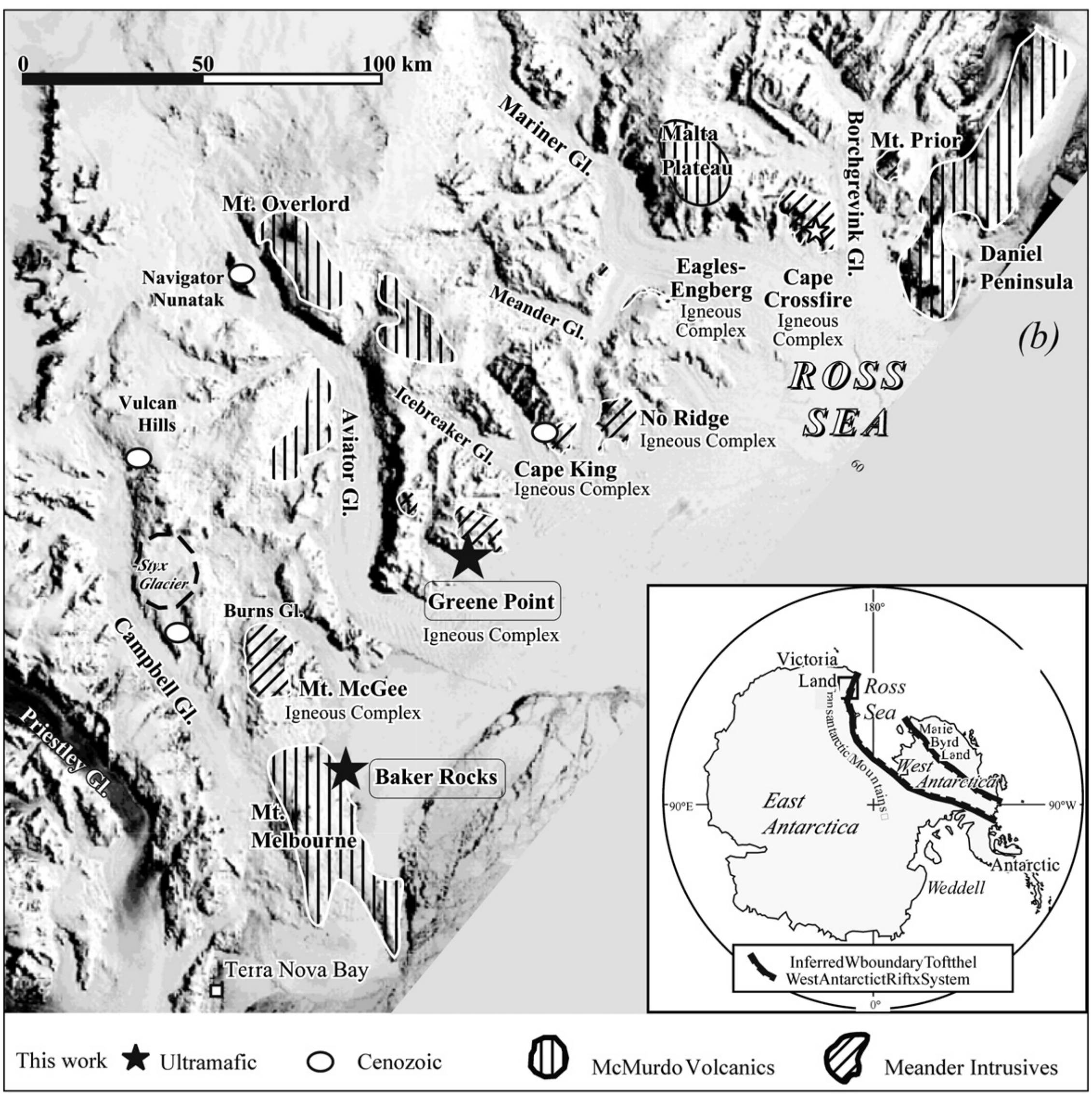

Fig. 1. Sketch map of Northern Victoria Land (from Perinelli et al., 2006). Black stars indicate the localities where the two mantle xenolith suites have been sampled (Baker Rocks and Greene Point). The square inset represents the inferred boundary of the West Antarctic Rift System, while the inset below shows the eruptive products.