

Nd-Hf Isotope Constraints on the Petrogenesis of Al-Depleted and Al-Undepleted Komatiites, the Onverwacht Group, South Africa

Valérie Chavagnac (vchava@mit.edu)¹, Samuel A. Bowring (sbowring@mit.edu)¹, Steve W. Parman (parman@mit.edu)¹ & Richard W. Carlson (carlson@dtm.ciw.edu)²

¹ Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Bldg. 54-1020, Cambridge, MA 02139, U.S.A.

² Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington D.C., U.S.A.

Introduction

Komatiites are high-magnesium volcanic rocks that provide an opportunity to look at the primary chemical features of the oldest preserved mafic-ultramafic sequences of the Earth. They bear information on the conditions of melt generation in the Archean mantle. 3 types of komatiites were distinguished according to their aluminium content. Othani et al. [1] suggested that Al-depleted komatiites are generated by partial melting of an ascending mantle diapir at depths from 200 to 650km during which majorite is a residual phase separated from melt. Sun and Nesbitt [2] also proposed majorite fractionation during partial melting of an ascending diapir. Al-enriched komatiites were interpreted as being formed by partial melting of the majorite-enriched residuum of the ascending diapir. In contrast, Al-undepleted komatiites were considered as being representative of a primitive mantle melt generated at shallower depth [1]. Experimental petrology studies suggested the strong influence of water content on melting peridotite and on the stability field of garnet.

The 3.45Ga Barberton komatiites are mainly characterized by low $\text{Al}_2\text{O}_3/\text{TiO}_2$ and high $\text{CaO}/\text{Al}_2\text{O}_3$ ratios and HREE depletion which are typical features of the Al-depleted type [2]. Al-undepleted komatiites also occur within the Onverwacht Group providing an opportunity for comparison of the isotopic characteristics of these 2 compositional groups. We report new geochemical, Sm-Nd and Lu-Hf isotope analyses on komatiites of the Komati and Hooggenoeg formations in order (1) to examine the primary chemical features of the Archean mantle, (2) to constrain the Nd-Hf isotopic compositions of the Archean mantle, and (3) to determine the conditions of melt generation.

Geological setting

The Barberton greenstone belt Kaapvaal Craton (South Africa) is subdivided into three lithostratigraphic units: (1) the Onverwacht Group, (2) the Fig Tree Group, and (3) the Moodies Group. Our samples are peridotitic komatiite from several flows of the Komati and Hooggenoeg Formation in the Onverwacht Group. The metamorphic grade ranges from upper greenschist to amphibolite facies.

Results

Komatiites from the first flow of the Komati Formation are characterized by high $\text{Al}_2\text{O}_3/\text{TiO}_2$ ratios (>15) and $\text{CaO}/\text{Al}_2\text{O}_3$ ratios (~1.1-1.5), and chondritic HREE contents ($(\text{Gd}/\text{Yb})_N \sim 1$)

in contrast to the $\text{Al}_2\text{O}_3/\text{TiO}_2$ ratios ~10, and the $(\text{Gd}/\text{Yb})_N > 1.4$ reported by [3]. The other flows of the Komati formation show Al-depletion ($\text{Al}_2\text{O}_3/\text{TiO}_2 \sim 10$), highly variable $\text{CaO}/\text{Al}_2\text{O}_3$ ratios (0.2 to 2.8) and fractionated HREE patterns ($(\text{Gd}/\text{Yb})_N \sim 1.4$). In addition, Nb/La ratios decrease with increasing Nb contents but do not correlate with $(\text{La}/\text{Sm})_N$ ratios. Ti/Zr ratios cluster at about 100, similar to the Ti/Zr ratio of MORB.

$^{147}\text{Sm}/^{144}\text{Nd}$ ratios of all komatiite whole rocks from the Komati Formation range from 0.1704 to 0.2039 and $^{143}\text{Nd}/^{144}\text{Nd}$ ratios between 0.512113 to 0.512786. Initial $\epsilon_{\text{Nd}}(3.45)$ values vary from +1.3 to +3.2, with 4 exceptions at 0.28, -1.41 and -6.81 and one at +5.31. These exceptions do not show higher $(\text{La}/\text{Sm})_N$ or lower Ti/Zr ratios. The $\epsilon_{\text{Nd}}(3.45)$ range does not correlate with $(\text{La}/\text{Sm})_N$ ratios. $\epsilon_{\text{Nd}}(3.45)$ of all komatiite whole rocks from the Hooggenoeg Formation show a similar range interval between +1.4 to +3.3. $\epsilon_{\text{Hf}}(3.45)$ values komatiites from the Komati and Hooggenoeg Formations are all positive and vary between +2 to +12 as [6]. All data are obtained on Al-depleted komatiites. Duplicate analyses on Al-undepleted komatiites are in progress.

Discussion

First, similar trace element patterns on each flow indicate that alteration and metamorphism effects have been minor. Second, Nb concentrations and $\epsilon_{\text{Nd}}(3.45)$ do not correlate with $(\text{La}/\text{Sm})_N$ ratios suggesting that crustal contamination may not have influenced the compositions of samples. Finally, $\epsilon_{\text{Nd}}(3.45)$ do not correlate with $\text{CaO}/\text{Al}_2\text{O}_3$, $\text{Al}_2\text{O}_3/\text{TiO}_2$, and $(\text{Gd}/\text{Yb})_N$ ratios indicating that the geochemical features are not related to mantle source composition, crustal contamination or possible input from slab-derived fluid-melt. Instead, the compositional characteristics reflect variable conditions-degrees of partial melting. The high $\text{CaO}/\text{Al}_2\text{O}_3$ ratio of the Al-undepleted komatiites is suggestive of residual garnet, but the $(\text{Gd}/\text{Yb})_N = 1$ in these samples argues against garnet as an important residual phase. Pyroxenes from the Al-undepleted komatiites are much lower in Wollastonite content compared to those of the Al-depleted komatiites [4]. Preferential melting/retention of pyroxene in the komatiite source is unlikely to fractionate Gd/Yb, but could contribute high Ca/Al to the melt [5]. If so, this could suggest that the Al-undepleted sample was generated at relatively shallow depth where garnet was not a significant phase in the source.

Othani E, Kawabe I, Moriyama J & Nagata Y, *Contribution to Mineralogy and Petrology*, **103**, 263-269, (1989).

Sun SS & Nesbitt RW, *Contribution to Mineralogy and Petrology*, **65**, 301-325, (1978).

Lahaye Y, Arndt NT, Byerly G, Gruau G, Fourcade S & Chauvel C, *Chemical Geology*, **126**, 43-64, (1995).

Parman S, Dann JC, Grove TL & de Wit MJ, *Earth and Planetary Science Letters*, **150**, 303-323, (1997).

Lundstrom CC, Shaw HF, Ryerson FJ, Williams Q & Gill J, *Geochimica and Cosmochimica Acta*, **62**, 2849-2862, (1998).

Blichert-Toft J & Arndt NT, *Earth and Planetary Science Letters*, **171**, 439-451, (1999).