Mantle source components of the Early Cretaceous to Paleogene mafic tholeiitic and alkaline magmatism in Rio and related mantle metassomatism processes

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The Early Cretaceous (*c*. 132 Ma) to Paleogene (*c*. 55 Ma) mafic magmatism in Rio is mostly represented by tholeiitic dolerites and ultramafic and alkaline lamprophyres, respectively [1]. The tholeiites are often regular, long, tens of metres-thick, vertical, ENE-trending intrusions with remarkably uniform textures and structures. In contrast, the ultramafic and alkaline lamprophyre dykes are generally less than one metre thick and display variable textures, structures and morphologies. Litogeochemical and Sr-Nd-O isotopic data show that the least evolved tholeiitic dolerites seem not to represent contaminated melts and are likely to be related to a predominantly asthenospheric, plume source similar in composition to Tristan da Cunha lavas. Small contributions (~10%) from the overlying subcontinental lithospheric mantle may have imprinted lithospheric signatures in the least evolved dolerites such as negative Nb anomalies. The Paleogene alkaline dykes comprise a strongly undersaturated suite including ultramafic and alkaline lamprophyres and sodic agpaitic phonolites. Sr-Nd isotope data point to a contribution of asthenospheric mantle sources for the generation of the alkaline dykes likely to be related to the Trindade plume. Heat conduction and advection from the plume triggered the melting of the readly fusible, volatile-rich, mafic potassic parts of the overlying subcontinental lithospheric mantle beneath Rio, leading to the generation of the most primitive ultramafic ultrapotassic lamprophyres. Major and trace element characteristics of the ultrapotassic ultramafic lamprohyres (*e.g.* CaO/Al_2O_3 <1; $(La/Nb)_N$~0.9) and their Sm-Nd model DM ages (496-660 Ma) indicate that the Late Proterozoic enrichment process of the subcontinental lithospheric mantle seems to have been unrelated to subduction processes but largely controlled by the migration of high H_2O/CO_2 silicate melts from the underlying asthenosphere.

[1] Valente (1997) *PhD* thesis, QUB, UK. 400pp.

Lunar zircon: Primitive $\delta^{18}O$ of dry evolved and mafic magmas

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Oxygen isotope ratios of zircons from the Moon have been measured *in situ* by SIMS [1], including grains from: quartz monzodiorite (n=4; 4, 294 Ma [2]), impact melt (n=1), breccia and shocked norite (n=2), and Apollo 12 (n=6) and 14 (n=3) regolith. Zircons from regolith may represent lithologies not found at Apollo landing sites. Some zircons have K-feldspar ± silica as inclusions or infilling cracks, suggesting they represent extreme differentiates of mafic magmas, similar to zircons in lunar granophyre [2]. The average $\delta^{18}O$ for lunar zircons ranges from 5.19 to 5.82 ‰ (ave. = 5.59 ±0.33‰, 2SD). Trace element concentrations of these zircons, also measured by SIMS, are: Ti 37-170 ppm; P 425-1120 ppm; Y 780-2850 ppm; total REE 485-1780; Hf 10, 500-12, 750 ppm; Th 4-38 ppm; and U 12-108 ppm [1].

The $\delta^{18}O$ (whole rock) values of mare basalts range from 5.33 to 5.81: 5.69 ±0.17 (2SD, n=23) for low-Ti and 5.54 ± 0.26‰ (n=15) for high-Ti basalts [3, 4]. The low variability allows comparison with zircons from other samples. The average basalt has the same $\delta^{18}O$ as igneous zircons: $\Delta^{18}O$ (WR-Zrc) ~ 0. This WR-Zrc fractionation contrasts with samples from Earth, where $\Delta^{18}O$ (WR-Zrc) ~ 0.0612 (wt.% SiO_2) –2.50‰ [5]. For instance, unaltered MORB $\delta^{18}O$ (WR) values average ~ 5.6-5.7, while $\delta^{18}O$ (Zrc) values average 5.2 ±0.5 (n=197) for gabbro and plagiogranite from ocean crust: $\Delta^{18}O$ (WR-Zrc) ~0.5 [6]. Thus $\Delta^{18}O$ (WR-Zrc) values on the Moon deviate significantly from relations on Earth.

In general, values of $\delta^{18}O$ (Zrc) vary negligibly during closed system magmatic differentiation because $\Delta^{18}O$ (WR-Zrc) correlates to $\delta^{18}O$ (WR); both increase for siliceous rocks with high $\delta^{18}O$ minerals (Qt, Flds). However, in detail, variable T will change this relation and the best explanation of the lunar results is that magmatic T's were significantly higher due to low water content. High crystallization T for lunar zircons is supported by values of [Ti] in lunar zircons (37-170 ppm) that are significantly higher than in terrestrial igneous zircons (0.2-30 ppm) [7]. We thus infer a low water content of these highly evolved lunar melts and that mafic parent magmas on the Moon were significantly drier.

[1] Spicuzza *et al.* (2011) *LPSC*, abst 2455. [2] Meyer *et al.* (1996) *Met. Plan. Sci.* **31**, 370–387. [3] Spicuzza *et al.* (2007) *EPSL* **253**, 254–265. [4] Liu *et al.* (2010) *GCA* **74**, 6249–6262. [5] Lackey *et al.* (2008) *J Pet* **49**, 1397–1426. [6] Grimes *et al.* (2011) *CMP* **161**, 13–33. [7] Fu *et al.* (2008) *CMP* **156**, 197–215.