Rb/Cs IN ARCHEAN KOMATIITE GLASS INCLUSIONS: A COMMON Rb/Cs IN EARTH & MOON, AND IMPLICATIONS FOR CRUSTAL GROWTH; **T. R. Ireland**, Research School of Earth Sciences, The Australian National University, Canberra ACT 0200, Australia, and **W. F. McDonough**, Earth and Planetary Sciences, Harvard University, Cambridge MA 02138, U.S.A.

Formational models for the Earth-Moon system are constrained by the bulk compositions of the Earth and Moon. While there are remarkable similarities in the more refractory elements, the volatile elements are systematically depleted in the Moon relative to the Earth [e.g., 1]. Jones and Drake have proposed that the Rb/Cs ratio is substantially higher in the Silicate Earth than in the Moon [2]. If this is so, the Moon could not have formed from material derived from the Earth's mantle, since lunar formation processes would deplete Cs relative to Rb. However, the Rb/Cs ratio of the Silicate Earth is highly model dependent and there are considerable uncertainties in our understanding of the distribution of Rb and Cs in the present-day Earth.

The Cs abundance of the present-day mantle is a sensitive indicator of mantle evolution since Cs is strongly incompatible and is partitioned into the crust. It has been estimated [1] that 55% of the Silicate Earth's inventory of Cs is held in the continental crust. Rb and Ba are also strongly incompatible during mantle melting, but recycling of oceanic crust back into the mantle and fluid transfer processes in the arc environment lead to the fractionation of these elements from Cs. Hence there should be a secular evolution of the mantle towards higher Rb/Cs values with progressive growth of continental crust. It may therefore be possible to examine the integrated volume of continental crust with geologic time, simply by measuring the secular evolution of the Rb/Cs ratio in the mantle.

The problem, however, is that suitable geologic materials are not easy to come by. The alkali metals are highly mobile and contamination of samples is a major problem. We recently analyzed glass inclusions in fresh komatiitic olivines that gave an unprecedented glimpse into the Archean mantle. The analyses of McDonough and Ireland [3] showed that the glass inclusions reflect their formation in an intraplate setting as plume magmas. We have now extended our analyses of these glass inclusions to include Cs in order to measure the Rb/Cs ratio of the Archean mantle and hence examine the implications for continental growth through geologic time and better constrain the initial Rb/Cs of the Silicate Earth. Glass inclusions were analyzed from two Archean (2.7 Ga) komatiites: Belingwe, Zimbabwe and Alexo, Canada. Owing to the small size of the inclusions (largest ca. 50 μm) and the low expected Cs abundance (<100 ppb), the Cs abundance was determined by a separate procedure in order to obtain the required counting statistics.

Trace element abundances were measured on the ANU ion microprobe SHRIMP I operating at mass resolution 3000 M/ΔM and at an energy offset of 100 V to discriminate against complex molecular interferences. The presence of dimers of major elements ($FeMg^+$, $FeSi^+$, Ca_2^+) precludes the direct measurement of the Rb abundance. However, it is well noted that the Ba/Rb ratio is essentially constant during crust-mantle differentiation at ~11 and so we analyzed the Ba/Cs ratio as an analog of the Rb/Cs ratio. A suite of well constrained USGS glasses with differing Ba/Cs and Cs concentrations (8.6 to 0.1 ppm Cs) were analyzed to calibrate the measured $^{138}Ba^+/^{133}Cs^+$ ratio to actual Ba/Cs ratios (Fig. 1). The satisfactory measurement of BIR (7 ppb Cs) indicates a lack of interferences at low concentrations. The Ba/Cs ratios of the two komatiite glass inclusions analyzed give inferred Rb/Cs ratios of 30 ± 3 (1σ) for Belingwe, and 38 ± 4 (1σ) for Alexo komatiites and presumeably the same for their source regions.

Trace element patterns for glass inclusions in the Belingwe and Alexo komatiites are similar to those reported in [3] with the characteristic incompatible-element depletion, except that the anomalous depletions of Zr and Ti evident in our earlier work are not present in the inclusions of this study. The Zr and Ti fractionations are probably some function of sampling

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bias of the clinopyroxene rims of the glass inclusions [3]. While there is a generally smooth decrease in normalized abundances with increasing incompatibility, the Ba abundance in Alexo glass is a factor of three higher than the projected trend. The elevated Ba abundance was apparent in both Alexo inclusions analyzed; $^{138}Ba^{+}/^{30}Si^{+}$ was measured during the Ba-Cs as well as trace element analyses. The Alexo glass inclusions may be contaminated by crustal material resulting in elevated Ba and possibly affecting the Rb/Cs ratio. However, the Belingwe sample appears to be pristine and unaffected by contamination and therefore suggests that the 2.7 Ga mantle had a lower Rb/Cs than the modern value of around 80 [1].

The Rb/Cs ratio of the continental crust is contentious. McDonough et al. [1] have argued that the initial Rb/Cs of the Silicate Earth is around 28 based on K, Rb, and Cs abundances in the present crust, MORB source and OIB source. A consequence of this inventory was that only 60% of the total alkalis was accounted for and there must be an additional reservoir(s). On the other hand Jones and Drake [2, 4] argued that such a reservoir is not necessary if the crust has a Rb/Cs of 40-50, similar to their value for the Silicate Earth. One ramification is that while McDonough et al.'s value for the Silicate Earth is close to the lunar value of 22, the Jones et al. value is clearly distinct from that of the Moon.

The Archean glass inclusions require a mantle Rb/Cs ratio below Jones and Drake's putative initial value. Even the Alexo sample with possible crustal contamination lies below the initial value. Since continent formation forces the residual mantle to higher values, a mantle value of 30, as indicated by the Belingwe sample, is not possible. This alone precludes arguments for a Rb/Cs ratio of 40 for the bulk Silicate Earth. In order to reconcile the measured komatiite values with the Jones et al. model, sedimentary material (with low Rb/Cs) would be required in the source region of the komatiites. Such a scenario is inconsistent with the trace element pattern in the lavas; we find no evidence to suggest that the Earth's Rb/Cs differs substantially from that of the Moon (around 22; similar to eucrites and SNC meteorites). If we use the lunar value of 22 as representative of the initial Silicate Earth, then at 2.7 Ga the Rb/Cs ratio had progressed to a value of ≈30 on it's way to a value of ≈80 today. These values indicate that around 40% of the continental crust had formed by 2.7 Ga. This is consistent with the proportions of Archean continental crust now exposed. The Archean glasses therefore provide an internally consistent picture for Rb/Cs in the Earth-Moon system and the secular evolution of the Silicate Earth.

References: [1] McDonough *et al.* (1992) *GCA* **56**, 1001. [2] Jones and Drake (1993) *GCA* **57**, 3785. [3] McDonough and Ireland (1993) *Nature* **365**, 432. [4] Norman, Drake, and Jones (1994) *LPS XXV*, 1009.