Ba, Sr and $^{87}Sr/^{86}Sr$ in Indian estuaries: Impact of submarine groundwater discharge

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Dissolved Sr, Ba and $^{87}Sr/^{86}Sr$ were studied in three Indian estuaries linked to the Arabian Sea i.e. the Narmada, Tapi and the Mandovi. The concentration of dissolved Sr and Ba in the rivers show significant variations; ranges from 0.7-2.5 μmol/kg, 27-207 nmol/kg respectively whereas $^{87}Sr/^{86}Sr$ vary between 0.70875 and 0.71062 reflecting the lithologies they drain. The Sr/salinity profile in all these estuaries shows conservative mixing between river water and seawater end members whereas Ba shows nonconservative mixing with its gain in mid salinity region (10-15‰). The $^{87}Sr/^{86}Sr$ shows non-conservative behaviour; its distribution exhibits significant departures from the expected conservative mixing lines in all these estuaries. This difference in the behaviour between dissolved Sr and its $^{87}Sr/^{86}Sr$ is intriguing and suggests that there is supply of Sr from additional sources to these estuaries. Similarly, Ba gain could not be explained by Ba release from particles in the estuaries and river-seawater mixing and requires its additional source. The additional source seems to be submarine groundwater discharge (SGD). The non-conservative behaviour of $^{87}Sr/^{86}Sr$ provides a handle to estimate the quantum of SGD to these estuaries. Inverse model calculations have been used to characterize the Sr concentration, $^{87}Sr/^{86}Sr$ and salinity of the SGD and estimate its water fluxes to the Narmada estuary. The model derived SGD flow rates to the Narmada estuary are ~7 and 275 cm/day during nonmonsoon and monsoon respectively indicating large seasonal variability of SGD. This estimate is consistent with those reported from the south-west coast of India using dissolved ^{222}Rn [1] and other coastal regions of the world [2].

[1] Jacob *et al.* (2009) *Curr. Sci.* **97**, 1313–1320. [2] Burnett *et al.* (2003) *Spec Issue, Biogeochemistry* **66**, 202.

Constraints on the formation of a lunar core from metal-silicate partitioning of siderophile elements

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Most models for the interior of the Moon include a small iron–rich core with a maximum diameter of several 100 km [1], but the composition and formation conditions of the lunar core are poorly constrained. One major consequence of core-mantle differentiation in planetary bodies is that the majority of the siderophile elements are strongly partitioned into the iron-rich core. Since the degree of extraction of these elements into the metallic phases is governed according to their metal/silicate partition coefficients (D) and the pressure-temperature-composition conditions during core formation, abundances of these elements in the silicate Moon can in principle be used to constrain lunar core formation and chemistry.

Estimates of siderophile element abundances in the lunar mantle have previously been used to argue for the presence of a small metallic core (0.1-5.5 wt%) [2-4], but recent improved approaches to terrestrial core formation models (including better thermodynamic models and the ability to model changing conditions through time) have not yet been applied to the Moon.

Here we re-examine whether a consistent set of conditions can be obtained to match observed siderophile element depletions in the silicate Moon. We combine new metal-silicate partitioning data for Ni, Co, Cr, Mn, Ga, P, Pb, W and V with literature data and characterize the dependence of the partition coefficients on temperature, pressure, oxygen fugacity and silicate melt structure and composition to derive equations of the following form: $\log D = \alpha + \beta\,(\Delta IW) + \delta\,(1/T) + \varepsilon\,(P/T) + \chi\,(nbo/t)$.

Initial results suggest that when using the proposed bulk Moon composition of [5] and siderophile element abundances from [6], data are consistent with the Moon possessing a small metallic core, with metal-silicate equilibration pressures close to the current core-mantle boundary, consistent with whole-Moon melting at the time of core formation.

[1] Weber *et al.* (2011) *Science* **331**, 309–312. [2] Righter & Drake (1996) *Icarus* **124**, 513–529. [3] O'Neill (1991) *GCA* **55**, 1135–1157. [4] Walter *et al.* (2000) In *Origin of the Earth & Moon*, U of A Press, Tucson, pp.265–289.