Recycling of marine carbonate as a possible solution to the Pb paradox

PATERNO R. CASTILLO

Scripps Institution of Oceanography, UCSD, La Jolla, CA 92093-0212 USA, pcastillo@ucsd.edu

One of the most remarkable and unexpected features of the bulk of oceanic lavas is their Pb isotopic ratios are too radiogenic to be coming from the undifferentiated mantle or a bulk Earth source [1]. The increase in Pb isotopic ratios is due to the decay of the radioactive element U (plus Th) over time and, thus, such "paradoxical", radiogenic Pb isotopic ratios imply long time-integrated high U/Pb ratio (or HIMU) of the mantle source(s) of oceanic lavas. The most extreme expression of the Pb paradox, also known as the HIMU effect, is displayed by the classic HIMU islands of St. Helena, Mangaia and Tubuaii. Recently, it was proposed that previously subducted marine carbonate is the key component of classic HIMU and younger HIMU (or FOZO) mantle end-members [2]. This hypothesis differs from existing models as it does not call for geologic processes that preferentially increase U or decrease Pb (and Rb) in the sources of oceanic lavas. Instead, it relies on the intrinsic geochemical properties (e.g., high U/Pb and low Rb) of marine carbonate, which is a ubiquitous component of the oceanic crust. Specifically, the uniquely low $^{87}Sr/^{86}Sr$ ratio and incompatible trace element content of Archaean carbonate make it an excellent candidate for the source of the HIMU end-member; this is consistent with the anomalous, mass independently fractionated sulphur isotope signatures in olivine-hosted sulfides from Mangaia Island [3]. On the other hand, the relatively lower U/Pb and higher $^{87}Sr/^{86}Sr$ values of Proterozoic (and possibly younger) carbonate make it an appropriate source of the young HIMU or FOZO end-member. If the hypothesis is true, then recycled carbonate should also be able to explain the Pb paradox in mid-ocean ridge basalts (MORB), the most abundant oceanic lavas. Interestingly, recent studies have indicated that small-degree partial melting of the upper mantle actually starts deep and is caused by CO_2-rich volatiles [4]. Such volatiles most probably come from previously subducted carbonate, which contains radiogenic Pb. Thus, mixing of Pb from recyled carbonate and from depleted upper mantle can generate the slightly to moderately radiogenic Pb isotopic compositional array of MORB. Available data also show empirically that the addition of Pb from recycled marine carbonate to the upper mantle can produce the ~constant Ce/Pb ratio of MORB.

[1] Allegre (1969) *EPSL* **5**, 261-269 [2] Castillo (2013) *Min. Mag.* **77.5**, 838 [3] Cabral *et al* (2013), *Nature* **496**, 490-493 [4] Dasgupta *et al* (2013), Nature **493**, 211-215