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Uranium budget at subduction zones: implications for the lead paradoxes

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At present subduction rates a volume of oceanic crust equivalent to $\approx$ 10% of the entire mantle has been recycled throughout Earth´s history. Consequently the composition of the recycled material must be considered as an important constraint of mantle composition, especially for incompatible elements. During alteration significant amounts of U are added to the oceanic crust ($\approx$1.5 - 4 x 10^9g.a^{-1}; Elliott et al., 1999), which has been considered a plausible explanation both for the locus of oceanic basalts to the right of the Geochron and the Th/U decrease implicit from the inconsistency between lead isotopic ratios and measured Th/U for MORB.

However the chemical composition of oceanic crust is significantly altered by dehydration/melting processes occurred during subduction, which has consequences for models invoking the role of recycled materials for mantle evolution. In convergent margins slab melting was prevalent in the Archean, whereas slab dehydration dominated Proterozoic and Phanerozoic subduction zones, ultimately triggering the melting processes responsible for arc magmatism. If we consider:

(1) arc magma production; (2) the mean density of arc magmas; (3) a minimum of 70% of the U budget of the arc magmas is of slab origin (e.g. Regelous et al., 1997); and (4) the mean U content of arc magmas;

the mass of U transferred from the slab to arc magmas is $\approx$1.3 - 3.3 x 10^9g.a^{-1}, close to the amount previously added to oceanic crust by alteration. Given that a significant fraction of water released from dehydration reactions flows along subduction shear planes rather than infiltrating the overlying wedge (e.g. Barnicoat & Cartwright, 1995), we conclude that deep mantle recycling of U previously added to the oceanic

crust is not a viable explanation for the mantle U/Pb increase and Th/U decrease. The case against a significant role of deep mantle uranium recycling also stems from the following arguments:

(1) some of the highest Nb/U ratios ever reported in recent unaltered oceanic lavas were determined on HIMU type basalts, considered as representatives of ancient recycled altered oceanic crust; (2) Nb/U ratios do not correlate with εNd in oceanic lavas (Hofmann, 1997); (3) HIMU basalts have $^{3}He/^{4}He$ only slightly more radiogenic than MORB (R/Ra = 5 -7 vs. 8); (4) strong positive correlation between μ and Nd/Pb ratios in subducted eclogite rocks; (5) mass balance calculations showing that the average Th/U ratio of the deep mantle recycling flux is similar to the Th/U of the depleted mantle (Porter & White, 2003).

In conclusion the crust to mantle transfer of U, via subduction, is insignificant and consequently does not offer a plausible explanation for the Th/U and U/Pb mantle evolution and hence for the lead paradoxes. The alternative model of Mata & Kerrich (2003) involving a transition from Archean slab melting to Proterozoic-Phanerozoic slab dehydration-wedge melting (secular switch of Ds for Th,U,Pb) accounts for both paradoxes.

References:

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