

## The Fate of Subducted Oceanic Crust and the Sources of Intraplate Volcanism

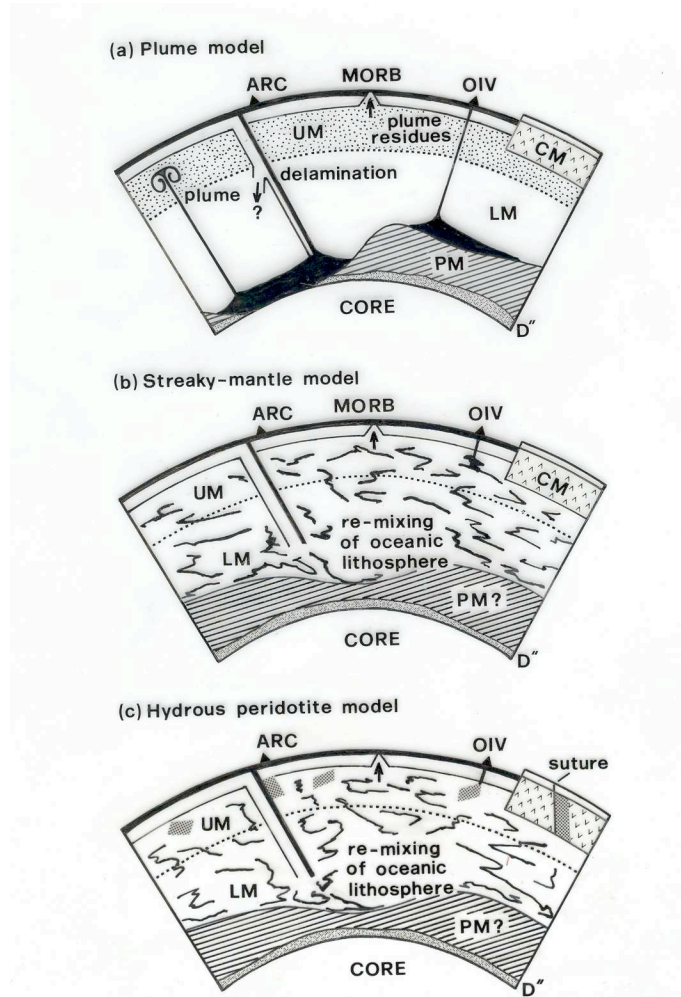
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Relative to other planetary bodies (Moon, Mars) the Earth's mantle shows a suppressed rate of isotopic evolution (Smith and Ludden 1989). The key difference between Earth and the other bodies is the operation of subduction. Such crustal recycling, as in marble-cake or streaky mantle models (Allègre and Turcotte 1986, Fitton and James 1986) would provide a satisfactory buffer to moderate mantle isotopic evolution. However, for two decades such processes have been largely ignored because of a requirement to accommodate the mantle plume model. The isolation of subducted crust in the latter (Fig. 1a) sets up a series of circular arguments, such as a perceived necessity to buffer the depleted mantle with plume residues (e.g. Morgan and Morgan 1999), which appear to make the plume model indispensable. However, with objective evaluation it becomes apparent that the logic used to mandate the plume model can not be justified and the model itself is unnecessary. One of the principal arguments used to substantiate the plume model and to reject alternatives, is based on the trace element ratios Nb/U and Ce/Pb. Similar ratios between MORB and OIB compared to crustal compositions have been taken as evidence that crust can not be recycled into the convecting mantle (e.g. Hofmann 1997) except for the possible exception of in the Indian Ocean mantle. Such logic is flawed because it fails to consider the possibility of formation of the depleted mantle MORB-source by remixing of recycled material with a more depleted component than the depleted mantle MORB-source. This hypothetical "very depleted" component can be equated with mantle from which crust has been extracted. Simple mass balance calculations indicate that Nb/U ratios comparable to those observed in the depleted mantle are only found when the entire volume of mantle contributes to crustal generation. However, extraction of continental crust from 30-50% of the mantle leads to the generation of very depleted residues with Nb/U ratios of 70 to 150. The Nb/U- Ce/Pb ratios in MORB can then be explained by a ternary mixing array between subducted sediment, recycled basaltic crust, and very depleted mantle.

The fate of subducted oceanic crust in any layered mantle regime is therefore remixing into the convecting mantle, not isolation into plume sources. The questions that then arise on adopting a streaky/marble-cake mantle structure, are to the nature and distribution of source components for intraplate volcanism and the causes of melting. Relative to MORB, the sources of such rocks are enriched in K. This compositional difference would appear to support generation of intraplate melts from sediment-rich streaks (Fig. 1b). However, if variations in recycled sediment type provide a suitable explanation for the large range of  $^{176}\text{Hf}/^{177}\text{Hf}$  relative to  $^{143}\text{Nd}/^{144}\text{Nd}$  seen in MORB, a large range of Hf isotopic variation should also be seen in intraplate basalts. The general lack of such a signature suggests K-enrichment is related to a process which does not fractionate Lu from Hf, such as the formation of volatile-bearing phases such as amphibole and phlogopite in the mantle wedge

at convergent margins (Fig. 1c). Concentrations of such minerals along collisional sutures may be particularly important in the generation of intraplate volcanism in opening ocean basins, where intraplate tracks invariably correlate with lineaments in the continental architecture (Smith 1993). In long-lived ocean basins, high pressure amphiboles may provide a source of potassic metasomatism, either on thermal equilibration with the mantle or if destabilised by fluids from deeply subducted carbonates. Volatiles-bearing components would also play a key role as fluxes to facilitate melting of streaky/marble-cake mantle such that intraplate volcanism can be generated without deep-seated thermal anomalies.



**Figure 1.** Fate of subducted oceanic crust and origin of ocean island volcanism (OIV) according to (a) plume (b,c) streaky/marble-cake mantle models. Abbreviations: UM upper mantle; LM lower mantle; CM continental mantle; PM primitive mantle.

## References

Allègre, C.J. and Turcotte, D.L., 1986. Implications of a two component marble cake mantle.

- Nature 323, 123-127.
- Fitton, J.G. and James, D., 1986. Basic volcanism associated with intraplate linear features. Phil. Trans. Roy. Soc. Lond. A317, 253-266.
- Hofmann, A.W., 1997. Mantle geochemistry: The message from oceanic volcanism. Nature 385, 219-229
- Morgan, W.J. and Morgan, J.P., 1999. Two-stage melting and the geochemical evolution of the mantle: A recipe for mantle plum pudding. Earth Planet. Sci. Lett. 170, 215-239.
- Smith, A.D., 1993. The continental mantle as a source for hotspot volcanism. Terra Nova 5, 452-460.
- Smith, A.D. and Ludden, J.N., 1989. Nd isotopic evolution of the Precambrian mantle. Earth Planet. Sci. Lett., 93, 14-22.