Focused Mantle Melting

H.J.B. DICK[1*] AND H. ZHOU[2]

[1]Woods Hole Oceanographic Inst., Woods Hole, MA 02543
(*correspondence: hdick@whoi.edu)
[2]Tongji University, Shanghai China (zhouhy@tongji.edu.cn)

Na8 and Fe8 represent the composition of mid-ocean ridge basalt corrected for fractional crystallization back to bulk MgO of 8 wt.% (Klein and Langmuir, JGR, 1987). Decreasing Na8 is widely accepted as reflecting increasing extents of mantle melting, while increasing Fe8 greater depths of melting due to higher mantle potential temperature. Variations in these variables over several oceanic rises are consistent with hotter deeper melting with proximity to the associated mantle hotspots. However, this interpretation of Na8-Fe8 does not fit all ocean rises. Some have thin crust over the rise (Zhou and Dick, Nature, 2013) while others have high Na8 and low Fe8 at the peak of the rise, opposite to the prediction based on KL87. Their approach assumed a constant mantle source composition, which thus presents a problem given the variability of mantle mineralogy along ocean ridges. While the rationale for decreasing sodium with extent of melting is well understood and accepted (e.g.: Dick *et al*.., 1984), this is not the case for Fe8. The explanation of KL87 was that melts from different depths would pool and excape the mantle, and thus record an average melting depth. This explanation however appears inconsistent with substantial mineralogic evidence in abyssal peridotites for shallow melt re-equilibration. Thus a thermodynamically consistent explanation for Fe8 has until now not been found.

It is widely accepted that at ocean ridge melt focusing to the ridge axis occurs in the underlying mantle. We have thus undertaken modeling of focused melting beneath ocean ridges using PMELTS (Ghiorso *et al*.., G3, 2002) to see if variations in depth of melting or mantle source composition can provide a thermodynamically consistent explanation for Fe8. This is done by successively removing solid increments while conserving melt during incremental batch equilibrium melting as an analog for the ocean ridge melting regime, This differs from modeling fractional melting, by the same technique, in that we progressively remove solid from the bulk composition rather than melt. This represents an evolving bulk composition in such a way that it explains why Fe8 increases with increasing depth and temperature of melting, but also shows that the effect of varying mantle source composition is at least as important as the effect of temperature. Thus, by varying both temperature and mantle composition we can explain increasing Fe8 with decreasing Na8 over ocean rises with both thick and thin crust.

Osmium isotope records of continental weathering and volcanism spanning the Paleocene-Eocene Thermal Maximum

ALEXANDER J. DICKSON,[1,2] ANTHONY S. COHEN,[2] ANGELA L. COE,[2] MARC DAVIES,[2] EKATERINA SHCHERBININA[3] AND YURI GAVRILOV[3]

[1]Department of Earth Sciences, University of Oxford, South Parks Road, Oxford, OX1 3AN, United Kingdom.
[2]Department of Environment, Earth and Ecosystems, Centre for Earth, Planetary and Space Science, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom.
[3]Geological Insitute, Russian Academy of Sciences, Pyzhevsky 7, Moscow 119017, Russian Federation.

The Paleocene-Eocene Thermal Maximum (PETM) was one of several brief global warming events that took place superimposed on a long-term warming trend during the early Eocene. The cause of the rapid warming has been atributed to the introduction of large amounts of carbon dioxide to the atmosphere and oceans, but the trigger for initial carbon release, and the mechanisms that sequestered it back into non-exchangeable reservoirs have been debated.

New osmium (Os) isotope records spanning the PETM are presented from four sites located in the Arctic and Tethys Oceans. All sites exhibit an increase in $^{187}Os/^{188}Os$ ratios during the PETM compared to pre- and post-event background values. The magnitude of this increase is consistent between sites and previously published records, and indicates a ~40% increase in the flux of radiogenic Os from weathered continental rocks to the oceans during the main phase of global warming.

The new Os-isotope data also contain two lines of evidence that support the role of volcanism as a trigger for the PETM. Firstly, the Arctic-Ocean record exhibits a shift to more radiogenic $^{187}Os/^{188}Os$ ratios >50,000 yrs prior to the onset of the PETM (as defined by the negative carbon isotope excursion), associated with volcanic uplift of the North Atlantic Seaway and hydrographic restriction in the Arctic Basin. Secondly, the Tethys sites exhibit a rapid excursion to very low $^{187}Os/^{188}Os$ ratios coincident with the onset of the PETM, indicating a larger flux of unradiogenic (volcanic-derived) Os to the oceans at this time. The new data suggest that volcanic activity became pronounced close to, but preceding, the start of the PETM, and therefore could have set in motion climate-system feedbacks (such as ocean circulation changes) that eventually triggered the release of large amounts of carbon at the Paleocene/Eocene boundary.

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