Spatial and temporal variations in mid-ocean ridge basalt geochemistry along the 9°–10°N East Pacific Rise

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Temporal constraints on mid-ocean ridge basalt (MORB) magmatism both on and off-axis are critically needed to better understand problems associated with MORB petrogenesis and the processes of crustal accretion at the MOR. Using measurements of U-series disequilibria, radiogenic isotopes and major- and trace-element compositions in a suite of MORBs, from 9°–10°N East Pacific Rise (EPR), we are addressing two questions related to the temporal component of MORB magmatism:

1) How does magma storage time (i.e. the time after which the melt is no longer in equilibrium with its source) affect the degree of crystal fractionation of MORBs and what is the time-scale of this storage?

2) Is MOR magmatism focused at the ridge or is there a significant component of off-axis volcanism?

MORB magma storage times and their implications for U-series measurements

To constrain magma storage times beneath the MOR and to better understand the application of U-series measurements to the study of MORB petrogenesis, we have measured U-series disequilibria and radiogenic isotopes in a suite of axial MORB samples, from the 9°–10°N area of the EPR, whose geology, location and young ages are well-established (Perfit *et al.*, 1994; 1995; Fornari and Perfit, unpublished data). These samples were collected on the AdVenture I-IV cruises using the deep sea submersible Alvin. For many of the samples, their eruption in 1991-1992 has been established by both observation and by Po-Pb dating (Rubin *et al.* 1994); for the others, there is extensive observational and geological evidence to suggest that their ages are young (<300 yrs).

Application of U-series isotopes to the study of MORB petrogenesis has been limited in most data sets by: 1) large uncertainties in our knowledge of the actual location and eruption of the samples, and 2) a lack of constraints on the transport and storage times of the magmas prior to their eruption. Knowing the location and eruption ages for these axial samples eliminates a large uncertainty in the interpretation of the U-series measurements in this area and enables us to put constraints on the transport and crustal storage times of magmas along a fast-spreading ridge segment.

Among the suite of axial trough lavas from the 9°–10°N EPR, there is a wide range of compositions from more primitive to more evolved (Mg # ranges from 58–66). In these young axial trough samples, our preliminary results indicate that ^{226}Ra excesses vary significantly and systematically as a function of Mg#: samples from 9°50′ N are more primitive and have higher ^{226}Ra excesses, whereas samples from 9°31′N are more chemically evolved and have lower ^{226}Ra excesses. Using a closed-system fractional crystallization model and assuming a primitive Mg# of 71, magma transport and storage times for these lavas range from ~300–2,000 years. Open system models, on the other hand, yield smaller magma storage times. This relatively short 'residence time' for these lavas is corroborated by measured ^{231}Pa excesses which are large, but independent of the samples Mg#. From these residence times, independent estimates of other magma chamber characteristics such as crystallization rate and magma chamber melt volumes can also be obtained.

These results indicate that U-Th and U-Pa disequilibria measured in young axial trough MORBs can be interpreted as original and unaltered by decay. However, knowledge of eruption ages and magma transport and storage time is critical for the interpretation of Th-Ra disequilibria and MOR melting processes.

Episodicity and volumetric contribution of off-axis volcanism

Accurate determination of the episodicity and volumetric contribution of axial and off-axis volcanism has implications for a number of MOR processes and characteristics, including: melt focusing and transport, ridge crest topography, magma chamber dynamics, etc. At present, the temporal characteristics of MOR magmatism, both on and off-axis, are largely unknown.

To evaluate the timing, proportion, nature and relative extent of off-axis volcanism occurring along the EPR, we are measuring U-series disequilibria and radiogenic isotopes in a two-dimensional gridded suite of off-axis MORB samples from the 9°48′–9°52′N EPR (Perfit *et al.*, 1994; 1995; Fornari and Perfit, unpublished data). These samples were collected, by the deep submersible Alvin, along transects outside the axial summit trough (AST) that extend out to 4 km on either side of the ridge axis. Using the axial samples as a baseline, we then use the U-series measurements in the off-axis samples to establish their U-Th and U-Pa "model ages". Comparison of the distribution of these 'model ages' with age estimates based upon palaeomagnetic spreading rates is then used to establish the temporal and spatial pattern of magmatism occurring off-axis at the ridge crest.

The off-axis lavas on the crestal plateau show a much wider range of magmatic fractionation (Mg# ranges from 53–66) and chemical characteristics (e.g. transitional MORB are common) than the axial samples. Field observations indicate that some off-axis lavas (up to 4 kms from the ridge axis) appear to be much younger than surrounding lava flows (Perfit *et al.*, 1995; Fornari and Perfit, unpublished data). In general, these flows tend to be volumetrically small and more chemically evolved and/or enriched. Young ages for these samples are indicated by their measured (^{231}Pa/^{235}U) disequilibria activity ratios (2.60–2.66) which are greater than or equal to those measured in the young axial samples (2.45–2.66) from this area. Calculated U–Pa 'model' ages for these more evolved, off-axis MORBs (0 $\pm$ 8,000 yrs) indicate that they are much younger than would be inferred by 'model ages' based on the average crustal spreading rate (60,000–80,000 yrs). In addition, these off- axis samples have large ^{226}Ra excesses (>200%). If (^{226}Ra/^{230}Th) is a result of the melting process, then the observation that (^{226}Ra/^{230}Th) is greater than one limits the ages of these samples to be less than 8,000 yrs. The large magnitude of these ^{226}Ra excesses suggests even younger ages for these samples. These ^{226}Ra excesses are an important confirmation of the young U–Pa 'model' ages for these samples.

These initial results are in general agreement with U-series evidence for off-axis volcanism at other locations (9°30′N EPR, Juan de Fuca and Gorda Ridges)(Goldstein *et al.*, 1994). The observation that the basaltic compositions and U–Pa 'model' ages vary significantly, over short distances, places important constraints on the petrogenetic and accretionary processes occurring in this area of the EPR.

References

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