Local diversity of MORB parent magmas: Evidence from melt inclusions in high-An feldspar from the Gorda Ridge

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Introduction

A primary reason to study MORBs is to constrain the chemical and physical properties and processes of the oceanic crust and mantle. In order for our interpretations to be accurate, we must use samples that have seen a minimum of modification since they were produced. One means by which primitive magmas can be preserved is as melt inclusions. However, even though trapped magmas are not subjected to the same differentiation processes as the magma body as a whole, they are not unaltered. This is because the melts were not quenched at the time of entrapment. Subsequent cooling in more evolved magmas, plus the development of quench crystals at the time of eruption both have a significant effect on the composition of the observed glass inclusions.

Our investigation centered on melt inclusions hosted in anorthitic plagioclase ($>An_{90}$) megacryst from a single sample dredged from the Gorda Ridge (D9-2-1 Davis and Clague, 1987). In our study we focused on two basic problems:

1) Could we develop an experimental technique for re-homogenizing melt inclusions?

2) What was the diversity of melt inclusion compositions at any single location, and what did that tell us about igneous processes in the crust and mantle?

Analytical and experimental method

To mitigate the effects of post-entrapment crystallization on the composition of the inclusions, the megacrysts were heated to 1250°C, the entrapment temperature. The entrapment temperature was determined by running a set of experiments at 10o intervals between 1220°C and 1280°C. Phenocrysts separated from the rock were suspended from fine platinum wires in a 1 atmosphere furnace for 4-6 hours and drop quenched into water. Analysis of the re-heated phenocrysts tracked back up the plagioclase-olivine control line to the point where the inclusions were saturated with plagioclase alone (see Sinton *et al.*, 1993; Nielsen *et al.*, submitted). This was assumed to be the entrapment temperature. Melt inclusions re-heated to temperatures below their entrapment temperature grew olivine crystals (Fo_{85-91}), consistent with the observed range of Mg# in the liquid. High-Al chromite in contact with some glass inclusions indicates that this primitive liquid is saturated with high-Al chromite, olivine and plagioclase. This has been confirmed by experiment (Hascall *et al.*, 1993).

Major element compositions were determined by electron microprobe at Oregon State University. Trace elements were determined by ion microprobe at the facility at the Woods Hole Oceanographic Institute.

Results and discussion

As in many previous investigations, we found that the inclusion compositions were heterogeneous prior to re-heating (Watson, 1976; Langmuir, 1980; Davis and Clague, 1987; Vicenci, 1990). However, after re-heating, the range of major element compositions within each phenocryst is relatively narrow. It is however, dependent on the speed of quenching. A quench time of 3 seconds resulted in 2–10% quench growth of the host mineral, compared to the results obtained using a quench time of 1/2 second. Based on a comparison of the melt inclusion compositions with tabulations of MORB parent magmas (Elthon, 1990), the liquids trapped in the melt inclusions represent a distinct, high Ca-Al MORB magma type. This is supported by modeling that indicates that the inclusion compositions can be related to the host glasses by 15–40% fractional crystallization of olivine, plagioclase and chromite (Sinton *et al.*, 1993; Nielsen *et al.*, submitted).

In contrast to the major element chemistry, the incompatible element compositions have an extremely wide range. For example, the range of La/Sm and Ti/Zr from inclusions analyzed from this single sample from the Gorda Ridge, exceeds the range reported for the entire ridge (Davis and Clague, 1987). The pattern of the distribution however, is coherent, and is consistent with the range of melts predicted to be produced by open system fractional melting of an initially homogeneous source. In addition, the pyroxene compositions predicted to be in equilibrium with the melt inclusions cover much of the depleted end of the range represented by pyroxenes from abyssal peridotites (Johnson *et al.*, 1990).

This difference between the major element and trace element systematics is consistent with reequilibration of magmas as they travel through the lower crustal cumulates. Given the phase equilibria of the inclusions, and the phenocryst assemblage, we infer that in this area the cumulates are made up of high-An plagioclase, forsteritic olivine and Al-rich chromite. Any magma traveling through this assemblage will be driven to that three phase co-tectic, generating a set of magmas characterized by a relatively homogeneous major element range at the top of the cumulates. However, this mineral assemblage is extremely low in Ti, K, P and most incompatible trace elements. Therefore, there is insufficient concentration to buffer the composition of those trace elements.

Preservation of the observed diversity in crystals formed in the crust requires that magmas formed in the mantle to have traveled on parallel paths, largely without mixing. The presence of diverse inclusion compositions within single phenocrysts also suggests that the individual magma batches were extremely small.

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