

Submarine Stombolian Eruptions Along the Mid-ocean Ridge System: The Gorda Ridge

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The primary volatile contents of mid-ocean ridge basalt have been controversial for many years. Such basalts are almost universally dense pillow lavas or sheet flows, commonly oversaturated in CO₂ in relation to their eruption depth (Dixon et al., 1988). Rare, primitive, moderately-vesicular "popping rocks" from the Mid-Atlantic Ridge have been proposed to contain the initial volatile complement of MORB (Sarda and Graham, 1990). These authors proposed that eruptions at mid-ocean ridges include an early gas-rich stage and that subsequently erupted basalt is degassed melt. Such degassing presumably takes place while the magmas are stored in axial magma chambers (AMC), as proposed by Gerlach (1989).

We have recently found abundant and compositionally variable limu o Pele, or bubble-wall fragments, in widely distributed sediments collected during ROV Tiburon dives along the Gorda Ridge axis. These bubble-wall fragments were recovered in push-cores and have been separated from the enclosing muddy sediment for subsequent analysis. Because most of the Gorda Ridge axis is >3200 m deep, these bubbles of glass cannot be formed by expansion of seawater to steam, leaving magmatic gas, dominated by CO₂ due to its low solubility, as the only way to make such bubbles at 320 bars pressure. The curvature of the bubble fragments suggests that the bubbles are cm(s) across and are therefore formed at eruptive vents by a separated gas phase. The widespread distribution and variable composition of the fragments indicate that formation of limu o Pele during Strombolian activity is a common, but unrecognized, component of eruptions along mid-ocean ridges. The thin bubble-wall fragments are distributed at least several km from the eruptive vents as they settled from the buoyant event plumes in which they were apparently entrained during the eruptions.

We also collected three vesicular pillow fragments, but without glass rinds. These primitive N-MORB samples (K₂O = 0.09-0.15%) from about 2970 m depth contain 12.8-15.6% round vesicles, somewhat less than the 15.9-17.8% in the E-MORB popping rocks with 0.63% K₂O from the Mid-Atlantic Ridge. These data suggest a CO₂ content of these N-MORB melts of about 0.5-0.7%, somewhat less than the 0.8-1.0 estimated for the popping rocks (Gerlach, 1991). We propose that this CO₂-rich separated gas phase exsolves from magma stored in shallow crustal reservoirs and accumulates at the top of the reservoirs. Some

portion may leak out continuously and be incorporated into overlying hydrothermal fluids, but a significant portion is released in a brief burst during eruptions. The rise of magma from crustal reservoirs to the seafloor is driven by the buoyancy of this separated and expanding gas phase. Eruptions along the ridges should be characterized by Strombolian activity throughout the eruption. Eruptions may end when the gas phase accumulated at the top of the reservoir is exhausted.

The evidence that a separated gas phase drives Strombolian eruptions on the seafloor also implies that the gas accumulates at the top of the AMC. The strong seismic reflections that define the presence of the AMC may therefore be imaging a gas-rich zone at the top of the AMC rather than the distribution of melt beneath the ridges.

Strombolian eruptions along the spreading ridges release this magmatic CO₂-rich vapor component into the overlying water column. In order to evaluate the carbon flux from mid-ocean ridge magmatism one must therefore time integrate the carbon in the erupted basalts, in the chronic hydrothermal vented fluids, and in event plumes generated during seafloor eruptions.