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Modeling Hydrous Melt Production and Fractionation at Mid-ocean Ridges: Application to the Azores Region

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A number of authors have constructed forward models of mid-ocean ridge basalt (MORB) genesis that account for polybaric melting and mixing of primary melts to combine experimentally-calibrated melt compositions into aggregate MORB liquids. Models of the fractionation of these liquids at low pressure are then compared with fractionation-corrected observed compositions to draw inferences about source composition, potential temperature, and other parameters of the melting process. Geochemical data from various parts of the ridge system, as well as the MELT experiment results, however, demonstrate several specific shortcomings in the state of the art of detailed, accurate forward modeling of MORB melt production, migration, mixing, fractionation, and eruption. All the published models consider strictly anhydrous melting and fractionation and, furthermore, all have used one of two mixing functions to weight the primary liquid that amount to little more than cartoons -- the perfect passive flow double integral or the perfect active flow column. For these reasons, if no others, present models cannot meaningfully account for the slow seismic velocity and high electrical conductivity at more than 100 km depth or for the enormous width and asymmetric distribution of the region of apparent partial melt below the MELT region. Progress is urgently needed in descriptions of low-degree volatile-enriched melting at depths greater than 100 km and in physically reasonable mixing functions that obtain aggregate axial MORB liquid compositions from large (wide and deep) melting regimes.

Although no chemical model is available that can be considered reliable at the conditions where melting appears to begin, some attempts can be made. I will show results from the new updated pMELTS calibration and an attempt to combine the Hirth and Kohlstedt H_2O partitioning formulation with the pMELTS liquid activity model. Efforts to incorporate the physics of melt migration to produce a better mixing model are at an early stage, but they are a necessary component in understanding the connections between geochemistry of basalt and geophysical images of the melting regime.

The model will be used to examine plume-ridge interaction in the vicinity of the Azores. On-axis and near-axis Mid-Atlantic Ridge basalt samples recovered during the FAZAR cruise (Leg 127 of R/V Atlantis II) in along ~800 km of ridge including the Azores platform and the North Oceanographer Fracture Zone (NOFZ) anomaly reveal the major-element signature correlated with trace-element and isotope signatures of enrichment. Correction for fractionation requires considerable care in a heterogeneous, water-rich region. Neither standard LLD slopes nor simple regression can deal with the coexistence of differently fractionating sample suites in an individual segment. Armed with measured water contents and the MELTS algorithm, fairly reliable corrections to 8% MgO are possible. When so corrected, the enriched basalts associated both with the Azores platform and the NOFZ blob (an EMI anomaly) display high Ti, Al, K, and P and low Si, Fe, and Mn both as regional gradients and correlated with enrichment among samples within particular segments. There is a regional gradient toward low Na at the top of the Azores platform but individual enriched samples in each segment display high Na. The signal in Ca is obscure, but there appears to be a regional gradient towards high Ca at the Azores, and no Ca signal of the NOFZ anomaly. The low Fe is the most dramatic effect, and requires either a low Fe source or a major role for H_2O in the mantle petrogenesis and fractionation path of the enriched basalts. In general all the major-element signatures are consistent with the trends expected due to addition of H_2O to the melting regime and the fractionating liquid. The wet melting model provides a baseline for determining the composition of the Azores and NOFZ source components.