

A two-lithology model for melting and melt migration in an upwelling and chemically heterogeneous mantle

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Several lines of evidence suggest that the melt generation and segregation regions of the mantle are heterogeneous consisting of chemically and lithologically distinct domains of variable size and dimension. Partial melting of such heterogeneous mantle source regions give rise to a diverse range of basaltic magmas erupted on the sea floor. Although the diversity and importance of mantle source heterogeneity have long been recognized, simple models for trace element fractionation during concurrent melting and melt migration in a lithologically heterogeneous mantle have not been fully developed. In this study we develop a two-lithology model for trace element fractionation during concurrent melting and melt migration in a vertically upwelling, chemically and lithologically heterogeneous mantle column. As a first model, we consider a special case in which strings of enriched lithology are regularly distributed in a depleted background or ambient mantle. The enriched and depleted lithologies, referred to as channel and matrix, respectively, are treated as two overlapping continua each with a prescribed melting rate and starting composition. Part of the melt generated in the matrix is segregated into the channel along the upwelling column. Part of the channel melt is extracted into a melt-filled open network within the channel continuum at a prescribed depth. Analytical solutions for the abundances of a trace element in the matrix melt, channel melt, and open channel melt have been obtained. Essential features of the two-lithology model have been investigated through simple analysis and case studies. Using the two-lithology model as a module, we have also developed a "bundle of columns" model for melting and melt migration in a heterogeneous mantle over a broad upwelling region.

Applications of the two-lithology model to REE abundances in olivine-hosted melt inclusions in one hand sample from Mid-Atlantic Ridge and ⁸⁷Sr/⁸⁶Sr, ¹⁴³Nd/¹⁴⁴Nd, La/Sm ratios and REE abundances in basalts in near-ridge seamounts and axial valleys from East Pacific Rise demonstrate the importance of melting and melt migration-induced mixing in a two-component mantle and magma mixing at the top of the melting column in producing compositional diversities and variations observed in basalts erupted on the surface. Such mixing poses considerable challenges to deciphering the original mantle source composition and lithology based on compositions of basalts erupted on the surface.

Mineralogy and oxygen-isotope geochemistry of clays from the Te Mihi area, Wairakei Geothermal Field, New Zealand

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Abstract

Drill cuttings recovered from the Te Mihi area of the Wairakei Geothermal Field, New Zealand, have been analyzed to determine the mineralogical, morphological, and isotopic systematics of hydrothermal clays present in these samples. These data provide a tool for assessment of the paleo-hydrological conditions and temperature variations that have operated in the subsurface. Mixed-layer illite-dioctahedral smectite (I-S) and R0 chlorite-trioctahedral smectite phases are the principal clay minerals present. Mixed-layer I-S clays in well WK244 display a well-defined prograding sequence exhibiting R1 to R3 ordering and illite proportions grading from 50 to >90% over a 160 m depth interval. The interlayer proportion of illite in I-S correlates positively to measured downhole temperatures with a correlation coefficient (r) of 0.98. SEM photomicrographs demonstrate a change in clay morphology from micron-scale laths and hairy fibers to pseudo-hexagonal plates alongside this illitization sequence. Methylene blue estimates of swelling clay percentages show a strong inverse relation to %I of mixed-layer I-S with a correlation coefficient of -0.91, which further validates this method as a tool for delineating illitization sequences in active geothermal environments. The oxygen isotope compositions of I-S exhibit a continuous downhole depletion of ¹⁸O, which tracks the corresponding gradation of subsurface temperatures prevailing at the time of clay formation. The oxygen isotopic compositions are used to calculate fluid compositions, under isotopic equilibrium assumptions, and assess thermal changes in the subsurface. Estimates of water/rock mass ratios calculated using the I-S oxygen isotope compositions display an inter-stratigraphic variability that correlates with known unit permeabilities. The isotopic methods applied in this study have proven useful for delineating reservoir evolution and detailed permeability characteristics in an active geothermal system.