A forward simulation model (OBS version 1) of the adiabatic melting of mantle peridotite and recycled material

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The role of recycled material in mantle peridotite has become increasingly important in understanding the geochemical variations exhibited by ocean island basalts (OIB). Variations in radiogenic isotopes, incompatible trace elements, and transition metals in OIBs have suggested the involvement of fertile clinopyroxinite or garnetite mineralogy in the source peridotite (PERID). These fertile materials are believed to be derived from either altered or unaltered recycled oceanic crust (ROC). However, quantitative examination of the element behavior is difficult as, because there are at least two different phases (ROC and PERID), the melting regime is complex; simple adiabatic melting is not applicable. Melting experiments have revealed how major and trace element partition between ROC and PERID, and the basalt melts they generate. A thermodynamic model (Phipps-Morgan J., 2001, G-Cubed, 2, doi.2000GC00049) has been proposed, and the behavior of trace element and isotopes in OIBs has been discussed assuming simple mixing between ROC and PERID melts (Ito G. and Mahoney J.J., 2005a & b, EPSL, 230, 29-46, 47-63). Melt transport in the two phase system is not simple due to (a) complex changes in residual mineralogy in both ROC and PERID along the P-T path and (b) reactive/ non-reactive behavior between the ROC melt and host PERID. In order to investigate the element behavior in the ROC-PERID system, we have developed a simulation program, Ocean Basalt Simulator version 1 (OBS 1). OBS1 includes Phipps-Morgan (2001)'s thermodynamic equations and parameterizations of residual mineral phases in ROC (MORB) and PERID (PM) between 6 and 1 GPa using the pMELTS algorithm. The calculated degree of partial melting (F) of ROC and PERID at a given P-T in the two-phase adiabatic melting regime is used to calculate the residual mineralogy (Xa) in both ROC and PERID at steps in P. Melting of ROC occurs earlier due to a lower liquidus temperature. The generated ROC partial melt metasomatizes the host PERID or pond in ROC. PERID melting is suppressed compared to the single-phase system because latent-heat is consumed by ROC melting. The first OIB melt from the two-phase system is generated by melting of PERID. Generated melts from the two-phase system are accumulated and provide the source basalt for OIB. These processes are simulated by discrete incremental batch melting calculation sequences for ROC and PERID. The role of mantle porosity is also examined by altering the extracted melt fractions from the two melting systems, with the residual melt fraction ranging from 1 (batch melting) to 0 (fractional melting). Melt accumulation form (1) melting of the metasomatized PERID and (2) simple mixing between PERID and ROC melts are two extreme cases for the primary OIB. The behavior of incompatible trace elements and Sr-Nd-Hf-Pb isotopes were investigated using the OBS1 program. The program reproduces (a) the convex-up incompatible multi-element plot patterns, (b) correlation between Fo, Mn, and Ni in olivines, and (c) the complex behavior (sigmoidal to curvilinear shapes etc.) generated by isotope mixing, all exhibited by OIBs. The result suggests that the simple mixing between PERID melt and ROC melt used in the OBS1 program is likely for that of the OIB source. Although OBS1 has been developed for OIBs, it is also applicable to adiabatic melting in an area of ridge-plume interaction, and in the island arc source mantle, which may include fertile materials such as slab melts or buoyant solid slab materials.