Sorting out contributions from slab and mantle wedge in arc magmas

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The trace element abundances and isotopic compositions in primitive lavas from the Mt. Shasta region, N. California are used along with estimates of pre-eruptive H_2O contents and constraints from experimental petrology to infer the contributions from the mantle wedge and subducted slab. Approximately 90 wt. % of the major elements of the primitive Shasta region lavas are derived from the mantle wedge. In contrast, > 99 wt. % of the large ion lithophile (LIL) and the light rare earth elements (LREE) are contributed by an H_2O-rich component derived from the subducted oceanic lithosphere. Critical to the modelling are estimates of the pre-eruptive water contents. In the Shasta region lavas contain from <1 to >10 wt. % H_2O. Evidence from experimental petrology indicates that the high H_2O content lavas were extracted as melts from a harzburgitic residue at shallow mantle depths (30 km). Magmatic water content and modelled trace element abundances in the mantle source are used to carry out a mass balance for the relative contributions from the slab-derived fluid-rich component. Estimated fluid-rich component compositions are characterized by strong light rare earth element (LREE) enrichments ($[La/Gd]_N$ = 3 to 7) and variable heavy rare earth element (HREE) depletions ($[Dy/Yb]_N$ = 1 to 3). Sr and Ba abundances vary by approximately a factor of 2.5 among the fluid compositions. The calculated isotopic composition of the fluid-rich component is bimodal. One component has $^{87}Sr/^{86}Sr = 0.7028$ and $\varepsilon Nd = +8$, and is most similar to a MORB source. The second component has more radiogenic $^{87}Sr/^{86}Sr = 0.7038$ and $\varepsilon Nd = +1$ and is most similar to a sediment. The major elements in the fluid-rich component are: H_2O (~55-68 wt. %), Na_2O (~25-33 wt. %) and K_2O (~5-13 wt. %). The fluid-rich component could be either a supercritical fluid or a low-degree melt of slab eclogite that has reacted with the overlying mantle wedge. Although the slab beneath Mt. Shasta is inferred to be hot (~600 – 650 °C), the calculated fluid-rich components do not resemble a pure slab melt. These fluid-rich components probably represent a mantle-wedge-modified mixture of fluids and/or melts from a heterogeneous source (serpentinized mantle, altered basalt, and sediment).

Influence of H_2O on the development of spinifex textures in komatiites

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We performed cooling rate experiments to evaluate the role of variable crucible size and magmatic H_2O on the development of olivine spinifex textures. Experiments were cooled from the dry and wet liquidus at rates between 100 and 3 °C/hr. Increasing crucible volume decreases the number of nucleation sites and leads to the growth of spinifex olivine at anhydrous conditions. The presence of H_2O increases growth rate and decreases nucleation rate dramatically, and also promotes the development of spinifex textures. When experiments are compared to field exposures of spinifex in the 3.5 Ga Komati formation, evidence supports conductive cooling at the upper chill margin. One set of experiments used a variety of sizes and types of crucibles: olivine single crystals, MgO, Al_2O_3, AuPd and Pt capsules and loops, varying from 0.01 to 60 ml in volume. Decreasing crucible volume promotes heterogeneous nucleation of liquidus olivine by increasing the surface area available for heterogeneous nucleation sites. In small volume capsules (0.01 – 0.7 ml) at anhydrous conditions hundreds of small (0.1 to 1 mm) equant and hopper olivine crystals grew at slow cooling rates (3 °C/hr). In the 60 cc crucible, where surface area is at the minimum, we produce 18 to 33 mm x 0.3 mm branching spinifex-like olivine crystals at slow (3 °C/hr) cooling under anhydrous conditions. We also carried out cooling rate experiments at 200 MPa, H_2O-saturated. In the hydrous cooling experiments spinifex-like olivine crystals develop, even in the small capsule volume. In a 0.04 ml AuPd alloy capsule, seven 5 x 0.2 mm olivines filled the melt volume. Previous explanations of olivine spinifex textures in komatiites have called upon large amounts of superheat and rapid cooling to produce spinifex textures. At Barberton the komatiite chill margins contain equant olivine microphenocrysts, indicative of emplacement at supercooled conditions. The coarsest and largest spinifex crystals (300 to 500 mm long) grow in the slowest cooled centers of cooling units (2 m from the upper chill). The field observations eliminate rapid cooling from superliquidus temperatures as a mechanism for spinifex formation. Large crystals will grow at slow cooling rates if nucleation rate is lowered and growth rate is enhanced. The presence of H_2O accomplishes this by depolymerising melt structure and decreasing melt viscosity. Moreover, the large amount of H_2O dissolved in the komatiite melt lowers the liquidus and enhances undercooling in the cooling units when the magma is emplaced at a lower pressure at its site of final solidification.