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Sediment-peridotite interactions in a thermal gradient: mineralogic and geochemical effects and the "sedimentary signature" of arc magmas

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Strong thermal and chemical gradients are characteristic of the slab-mantle interface in subduction zones where relatively cold sediments become juxtaposed with hotter peridotite of the mantle wedge. The formation of arc magmas is directly related to mass transfer processes under these conditions. We have undertaken a series of experiments to simulate interactions and mass transfer at the slab-mantle interface. In addition to having juxtaposed sediment and peridotite layers, the experiments were performed under different thermal gradients. The sediment had a composition similar to GLOSS (1) and also served as the source of H_2O, CO_2 and a large selection of trace elements. The peridotite was a depleted garnet harzburgite formed from a mixture of natural hand-picked olivine, opx and garnet. Graphite was added to this mixture to establish a redox gradient between the two layers. Experiments were performed at 7.5-10 GPa to simulate the processes during deep subduction. The thermal gradient was achieved by displacing the sample capsule (Re-lined Pt) from the center of the pressure cell. The gradient was monitored with separate thermocouples at each end of the capsule and by subsequent opx-garnet thermometry across the sample. Maximum temperatures varied from 1400°-900°C and gradients ranged from 200°-800°C. Thus, in some experiments melting occurred in the sediment layer and in others this layer remained subsolidus, only devolatilizing.

Major and trace elements were transported both in the direction of melt percolation to the hot zone, as well as down temperature. This leads to the development of zones with discrete phase assemblages. Olivine in the peridotite layer becomes converted to orthopyroxene, which is due to Si addition, but also migration of Mg and Fe towards the sediment. In the coldest part of a sample, the sediment is converted into an eclogitic cpx + garnet assemblage. A thin zone depleted in almost all trace elements is formed in peridotite directly above the sediment/peridotite boundary and defines the region of maximum metasomatic alteration.

With a low T_{min}, fluid-mobile Ba, Rb, Sr and Li are more strongly transported into the melt zone compared to HFSE and REE. At $T_{min} > 700$°C, all incompatible elements are extracted from the solid into the melt. However, the mineral assemblage controls which elements are held back in the solid residue (i.e. MREE, HREE, Y, Sc, and to a lesser extent Ti, Zr and Hf in garnet). Peridotite–sediment interaction can produce humite-group minerals, particularly in the presence of F. Negative Nb–Ta anomalies are caused by rutile and/or humite phases.

Transport of melt or fluid from the sediment to the overlying mantle wedge produces metasomatized magma sources from which basaltic melts with sedimentary geochemical signatures can be derived. Adding even 1% of melt or fluid to depleted mantle peridotite is sufficient to produce basaltic melts with incompatible element contents similar to those observed in natural subduction-related magmas. Such signatures are retained at 6.5 and even 10 GPa when $T_{min} < 700$°C.

Plank, T., Langmuir C., 1998. Chem. Geol. 145, 325–394.