Implications of a weak and buoyant asthenosphere for mantle flow and entrainment at a subduction zone

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At a subduction zone cold oceanic lithosphere is recycled back into the Earth's mantle. Furthermore, a downgoing plate may also entrain more buoyant (hotter/depleted) asthenospheric mantle material and transport it to greater mantle depth. This 'slab entrainment' may be an important mixing process between lithospheric, asthenospheric, and deeper mantle material that potentially effects both arc lava chemistry and the chemical evolution of the Earth's mantle.

However, the details of slab entrainment at subduction zones are poorly understood. Here we explore a scenario where oceanic lithosphere is underlain by a hot, weak, and buoyant plume-fed asthenosphere. In this scenario a subducting plate potentially entrains chemically and physically different asthenospheric material from beneath the subducting lithosperic plate and from the overlying mantle wedge. We quantify the amount of entrained material and explore how a plume-fed asthenosphere may effect the local subduction mantle flow field using a numerical model and analog laboratory experiments.

We use a Plexiglas reservoir filled with two unequal layers of syrup and a foil pulled along an inclined plate to simulating the subducting plate. The viscosity and density is varied by mixing water into the syrup; a reduction gear and a movable wall is used to change subduction rates and dip angles.

In addition, we use a numerical thermo-dynamic subduction zone model that solves for mantle flow and temperature; a tracer advection scheme is used to study potential asthenospheric material entrainment.

We systematically quantify for a wide parameter range how much asthenosphere is entrained. Furthermore, we study the shape of the boundary between the two layers and potential effects on mantle flow. Underneath the oceanic plate the asthenosphere-mantle-boundary tilts towards the subduction zone in both the laboratory experiment and the numerical simulations. Within the mantle wedge, instead of simple corner flow, a separate recirculating cell develops which may have strong implications for temporal variations in arc lava chemistry observed at some subduction zones.

Preliminary data on the crystal chemistry of synthetic fillowite-type phosphates

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Fillowite designates a Na-Mn-Fe phosphate mineral which occurs in granitic pegmatites. The complex crystal structure of this mineral was determined in the rhombohedral $R\bar{3}$ space group and led to the general structural formula $Na_2CaM^{2+}_7(PO_4)_6$ ($M^{2+} = Fe^{2+}$, Mn or Mg), with $Z = 18$ [1].

Chemical analyses of natural phosphates of the fillowite-johnsommervilleite series were recently performed [2], and experimental investigations permit to synthesize the fillowite-type compounds $Na_4Ca_4Mg_{21}(PO_4)_{18}$ and $NaCaCdMg_2(PO_4)_3$ [3][4]. Nevertheless, much experimental work is still needed in order to improve our knowledge of the fillowite crystal structure.

The aim of this study is to describe new synthetic compounds exhibiting the fillowite structure: $NaMn_3M^{2+}(PO_4)_3$ (M^{2+} = Mn, Ca, Mg, Fe^{2+}), $NaCaMnMg_2(PO_4)_3$, and $Na_2Cd_2Sc(PO_4)_3$. These compounds were synthesized by solid state reactions in air (650-950°C) or by hydrothermal techniques (400-800°C / 1-3.5 kbar).

The single-crystal structure refinements of $NaMn_4(PO_4)_3$ [5] and $Na_{1.3}Mn_{3.1}Fe^{2+}_{0.2}Fe^{3+}_{0.4}(PO_4)_3$ are in good agreement with that of natural fillowite [1], but a supplementary oxygen position has been observed, which was attributed to H_2O.

Finally, a correlation is established between the mean ionic radius of the cations localized on the octahedral sites of the structure, and the unit-cell parameters of synthetic and natural fillowites.

References

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