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Understanding the dynamics of thermo-chemical mantle wedge based on a simple model

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Complex dynamical phenomena may be expected in the mantle wedge, since it will be controlled by a combination of thermal and chemical effects. Recent our studies show the possibility of the existence of small-scale convection in the mantle wedge, which may be driven by thermal/chemical buoyancies. Such a small-scale convection may explain the along-arc variation of arc volcanism. In order to understand the complex phenomena associated with thermal and chemical effects, we have constructed a simplified model of thermo-chemical convection in the mantle wedge. In this model, we assume the kinematic flow of a chemical agent, such as water, from the top of the subducting slab. This chemical agent affects both the density and the viscosity of the region where it resides and decreases the density and viscosity.

We found that major effects of this low density and viscosity anomaly is to suppress the three-dimensional characteristic of mantle flow. Chemically polluted, thus buoyant region tends to stagnate and this results in the low temperature zone in the corner of mantle wedge. This result suggests the chemical origin of non-moving mantle part in the corner of the mantle wedge (nose), which is sometimes necessary to explain the low heat flow in the fore-arc. We also constructed a hybrid model: The chemical agency close to the trench affects both density and viscosity and it in the back arc region does only the viscosity. The model shows the co-existence of the low temperature nose and the small-scale thermally driven convection in the back arc. This may explain some of the geologic character of the northern Honshu arc.

Keywords: subduction zone, small-scale convection, water, arc volcanism