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Fluid flow and melting in subduction zones

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Liquid-solid flow within the Earth's mantle can be regarded as a flow of two (or more) viscous fluids, in which tranportations of mass, momentum and energy are strongly coupled. Recent knowledge from high-pressure experiments and developments of powerful computers, together with a series of simplifications, allow us to construct realistic models.

Here I present (1) numerical models for the transportation of H2O and melting in subduction zones, in which generation and migration of aqueous fluid, its interaction with the convecting solid, and melting are considered, based on the phase relationships, (2) predictions of the corresponding seismic structures based on the calculated distribution of the fluids (aqueous fluids and melts), (3) 3-D seismic tomographic images beneath the islands, (4) analyses on distribution of the volcanoes and the volcanic chains, and (5) comparisons between the model predictions and the observations.

The model calculation suggests that in northeast Japan, nearly all the H2O expelled from the subducted Pacific plate is hosted by serpentine and chlorite just above the plate, and is brought down to about 150 km. Breakdown of serpentine and chlorite at these depths results in the formation of a fluid column through which H2O is transported upwards, and results in the initiation of melting in the mantle wedge beneath the backarc. The seismic tomographic studies suggest the existence of such a melting region beneath the backarc. In central Japan, the subducted Philippine Sea plate overlaps the subducted Pacific plate. This geometry causes slow thermal recovery of the subducted Pacific plate, resulting in dehydration reactions at levels (200-300 km) deeper than in northeast Japan, and deflection of the volcanic chain towards the backarc side. In contrast, in southwest Japan, where a relatively hot part of the Philippine sea plate (Shikoku basin) subducts, the dehydration reactions are predicted to occur at relatively shallow levels (less than 100 km). The seismic tomographic image supports well the predicted distribution of the fluids beneath the volcanic front to the forearc region. These comparisons between the model predictions and the observations suggest that the thermal structure (determined by age and subduction velocity) of the subducting plate strongly controls the distribution of the aqueous fluids and melts in subduction zones through the position of the dehydration reactions.