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Deformation of arc crust and a model for generation of shallow inland earthquakes in the northeastern Japan subduction zone

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Seismic tomography studies have revealed highly heterogeneous structure for the mantle wedge beneath northeast Japan. This structure is inclined seismic low-velocity and high-attenuation zone at depths shallower than ~150 km in the mantle wedge sub-parallel to the slab, which probably correspond to the upwelling-flow portion of subduction-induced convection. Seismic studies suggest that temperatures are higher than the wet solidus of peridotite and that melt inclusions with volume fractions of 0.1-1 % exist within this upwelling flow. Aqueous fluids supplied from the underlying slab meet this hot upwelling flow at depths of 100-150 km and perhaps cause partial melting. Observations of heat flow and seismic anisotropy also support the existence of the upwelling flow. Seismic tomography study of the mantle wedge of NE Japan has further revealed an along-arc variation of the inclined low-velocity zone: very low velocity regions periodically occur about every 80 km along the strike of the arc. Clustering of Quaternary volcanoes and topographic highs at the surface are located immediately above these very low-velocity areas in the mantle wedge, and low-frequency microearthquakes, perhaps caused by rapid movements of fluids in the lower crust, occur right above them also.

The low-velocity, high-attenuation zone reaches the Moho immediately beneath the volcanic front (or the Ou Backbone Range) running the middle of the arc nearly parallel to the trench axis, which suggests that the volcanic front is formed by this hot upwelling flow. Aqueous fluids supplied by the suducted slab are probably transported upward through this upwelling flow to reach shallow levels beneath the Backbone Range where they are expelled from solidified magma and migrate further upward. The existence of aqueous fluids may weaken the surrounding crustal rocks, resulting in local contractive deformation and uplift along the Backbone Range under the compressional stress field of the volcanic arc. A strain-rate distribution map generated from GPS data reveals a notable concentration of east-west contraction along the Backbone Range, consistent with this interpretation. Shallow inland earthquakes are also concentrated in the upper crust of this locally large contraction deformation zone. Based on these observations, a simple model is proposed to explain the deformation pattern of the crust and the characteristic shallow seismic activity beneath the northeastern Japan arc.