Importance of a thin, low viscosity layer on top of the slab for rock deformation and fluid migration in subduction zones

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In subduction zones the existence of a thin, low viscosity layer (LVL) on top of the slab has been proposed to explain a low surface heat flow in the fore-arc region. In this presentation I will show some possible implications of LVL for other geophysical observations (Morishige, 2015; Morishige & van Keken, 2017).

It is well known that LVL effectively decouples the movement between the slab and the mantle just above it, producing a cold fore-arc mantle. However, the discussion has been limited to the across-arc cross section. We find that when the viscosity inside LVL is sufficiently low, along-arc component of the flow arises in and around LVL and it leads to a large along-arc temperature variation. This type of 3D flow arises due to the temperature dependence of viscosity. We also find that the wavelength of along-arc temperature variation increases with the thickness of LVL. When the thickness of LVL is 6 km, the obtained wavelength (~80 km) is similar to that of volcano clustering observed in Tohoku, Japan.

Although it is still an open question what controls the formation of LVL, several previous studies have suggested that weak hydrous minerals such as serpentine may play essential roles for it. When strongly sheared by subducting slab serpentinite layer has permeability anisotropy, that is, fluid can migrate faster in the direction subparallel to the slab surface. We find that when the effect of permeability anisotropy is combined with 3D slab geometry, 3D fluid focusing occurs where the slab bends away from the trench and it leads to the increase in porosity (volume fraction of fluid) there. It may help explain the along-arc variation in average slip rate of short-term slow slip events observed in SW Japan and Cascadia. The flow inside LVL produces dynamic pressure gradient inside it, which will further enhance the fluid flow subparallel to the slab surface.

Reference

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