Mechanism of aqueous fluid migration through a thin, low-viscosity layer near the subducting plate interface

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It is well known that aqueous fluid released from the slab plays critical roles in the generation of earthquakes along the subducting plate interface. However, we still do not have sufficient understanding on how the fluid migrates and reaches this region. Several lines of evidence including low surface heatflow in the forearc suggest the existence of a thin, low viscosity layer (LVL) on top of the slab. If such a layer exists, the deformation due to the subducting slab is localized in this layer, leading to cold and stiff fore-arc mantle. In this presentation I will propose a mechanism of aqueous fluid migration through this layer based on the physical modeling in 2D.

I consider two-phase flow, which allows us to treat the movement of solid phase (rock) and fluid phase (pore fluid) simultaneously. Under the assumption that fluid phase does not affect the movement of solid phase, I take the following two step approaches. First, solid flow and dynamic pressure gradient are computed within the LVL. In this step I assume that solid flows parallel to the subduction direction. Then using the results obtained in the previous step I compute the time evolution of fluid volume fraction in and around the LVL using finite element approach. Fluid production rate is fixed in both time and space.

In the case where the solid shear viscosity within the LVL is constant, we find that a large amount of fluid is trapped within the layer for geological time scale. This is caused by the effects of compaction, that is, the cold and stiff overriding mantle wedge works as a barrier to the upward fluid migration. We also find that dynamic pressure associated with shear deformation of the rock increases with depth within the LVL and it facilitates the fluid migration in the up-dip direction. When we take into account the effects of non-linear viscosity within the LVL, which may be appropriate for the deformation of serpentine, the solid viscosity becomes highest in the central part of the LVL where the strain rate is low. The high viscosity region works as a barrier to the upward fluid migration and the fluid tends to stay near the basal part of the LVL.

The proposed mechanism of fluid migration is likely to be applied to relatively warm subduction zones where major dehydration reactions occur beneath the fore-arc mantle. In contrast, in cold subduction zones a large amount of fluid is released beneath arc or back-arc, not beneath the LVL. Therefore, the fluid will simply migrate upward or move with the slab.