論文の内容の要旨

論文題目　Numerical study of the effect of water upon subduction dynamics
(水が沈み込み帯のダイナミクスに与える影響についての数値的研究)

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Water plays crucial roles to the subduction zone dynamics through the thermal-flow structure and the fluid processes, including dehydration of the subducting slab, hydration of the overlying mantle wedge, and melting.
In this thesis, we aim to understand the relationship between the thermal-flow structure, fluid process, and melting based on a series of calculations. We also aim to quantitatively evaluate thermal structure, especially how sufficient hot materials are supplied to the near-corner region just beneath the volcanic front, based on comparison between the model results and the observations such as spatial distribution of melting-magmatism and serpentinite in addition to surface heat flow and seismic tomography as supporting evidences.

First, we construct the model to solve consistently with the phase relation including fluid generation, fluid transport, its reaction with the solid and distribution of serpentinite. A computational scheme with Direct Method for momentum equation has been applied to the 2-D asymmetric geometry to solve stably the system with fluid advection and a high viscosity contrast in subduction zones.

Second, we focus on η_{serp}, f_v, C_{H_2O} as important model parameters, where η_{serp} indicates effective viscosity of serpentinite, f_v is the viscosity reduction factor between dry ($f_v = 1$) and wet olivine ($f_v = 100$), and C_{H_2O} is initial water content in the oceanic crust before subduction, through which water distribution in mantle wedge is controlled. The effect of these parameters on the relationship between the thermal-flow structure, fluid process, and melting is estimated systematically. In order to extract the essential features from the numerous results, we first focus on several specific cases by changing the main parameters, gradually increasing the complexity and combinations: first η_{serp}, second f_v, and then C_{H_2O} to eventually go through all the combinations. The following points have been clarified.

(1) Thermal structure and serpentinite distribution, especially those just above the subducting slab build the following feed back loop: corner flow reduction induced by weaker coupling between the serpentine layer and the mantle wedge makes the temperature of mantle wedge cooler at which serpentine is stabilized more, so that serpentinite area expands and suppresses influx of hot materials into the corner region. When η_{serp} is greater than 10^{21} Pa s, the thermal-flow structure reaches a steady state. On the other hand, when η_{serp} is less than 10^{19} Pa s, the feed back loop continues to a quasi-steady state. (2) The effect of olivine rheology (f_v) is as significant as serpentine rheology, in that water may significantly reduces the viscosity of a hot part of the mantle wedge where serpentine is unstable and hot materials are promoted to flow into the corner region. (3) Thermal-flow structure is mainly controlled by the above feed back loop, and mildly depends on C_{H_2O} and f_v. (4) The extent of melting region is sensitive to C_{H_2O} and η_{serp}. In the case of $\eta_{serp} \geq 10^{20}$ Pa s, the spatial extent of melting region expands until C_{H_2O} reaches 2 to 3wt.%, and in the case of $\eta_{serp} \leq 10^{19}$ Pa s, no melting or slight melting occurs only beneath the backarc region. Therefore combination of these different parameters and their comparison to the observations may provide useful constraints on the actual thermal-flow structure, including water distribution in the mantle wedge.

Finally, based on the model results, we specify the realistic range of the model parameter values. When $C_{H_2O} = 1$ wt.%, no or slight melting occurs, which does not fit the observations in all models tested in this study. On the other hand, increasing C_{H_2O} from 3 to 6 wt.% does not appreciably modify the melting as well as thermal-flow structure. Accordingly, we focus on the model results with $C_{H_2O} = 2$ wt.% or 3wt.% and compare them with the observed data in NE Japan. In the model case of

$\eta_{serp} = 10^{21}$ Pa s and $f_v = 1$ or $\eta_{serp} = 10^{20}$ Pa s and $f_v = 100$, thermal-flow structure reaches a steady state, and the serpentinite layer develops just above slab interface. In this case, hot materials flow into the region just beneath volcanic front. These model cases reproduce the volcanic chain located at 170 to 260 km in horizontal distance from the trench, together with the serpentinite layer possibly extending to 260 km from the trench (150 km in depth), which coincides well with the observations. These results indicate that a significant amount of water may be carried down to the mantle transition zone, being hosted by nominally anhydrous mineral phases.