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Simulation of Lithosphere- Asthenosphere Deformation at Plate Subduction Zones using FEM

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The subduction of an oceanic plate beneath a continental plate causes uplift of island arc due to mechanical effect. The deformation pattern depends on the geometry of the plate interface, relative plate motion, and the crustal structure of the subduction zone.

We modeled the subduction process and numerically simulated long-term crustal deformation due to steady plate subduction using FEM. In this simulation, first, we constructed a finite element model, composed of the elastic oceanic plate, the elastic continental plate and the underlying viscoelastic asthenosphere. Second, we obtain the solution of the viscoelastic problem directly from the solution of the associated elastic problem based on the corresponding principle of linear viscoelasticity. Third, the steady slip at the plate interface is treated with the split-node technique by Melosh and Raefsky (1981).

As a result, we obtained the subsidence of the lithosphere around the trench and uplift of the island arc. This deformation can be interpreted as bending of an elastic plate. At the same time, we obtained the upward motion of the asthenosphere, which can be interpreted as a compensation flow caused by the uplift of the lithosphere. Due to advection by this upward movement, temperature rises in the uplifted region (e.g., Fukahata and Matsu'ura, 2000), and consequently the elastic lithosphere of the region become thinner. Given this elastic-viscoelastic structure, we numerically simulated the subsequent process. As a result, the deformation concentrated in the uplifted region, and a remarkable peak of uplift emerged in the island arc. This pattern can be interpreted as a bending of elastic plate with a thinner part. The mechanical deformation of the lithosphere changes the internal thermal structure due to thermal advection and the change of thermal structure affects the mechanical deformation through the change of crustal rheology. In other words, the mechanical deformation and thermal structure interact each other. Thus, a non-linear physical process progresses in plate subduction zones.