Evolution and dynamics of subduction zones from 4-D geodynamic models

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Modeling the time-evolution of subduction in a 3-D geometry has a first order effect on nearly every aspect of understanding plate tectonics, in particular on the interpretation of geochemical signatures of the mantle [1,2].

We present models of free subduction (plates subducting due to their own negative buoyancy without the aid of imposed surface velocity boundary conditions or plate reconstructions) in which the subducting trench is allowed to migrate and evolve into curvatures which are fully consistent with the dynamics. A large emphasis has been put on communicating these results through the use of movies of the simulations.

We report the effect of the lateral width of subduction zones on the curvature of oceanic arcs (evolving towards either a concave or convex geometry) and trench migration rates (e.g. hinge rollback or hinge advance). We also observe a range of slab morphology in the upper mantle depending on the relative motion of the hinge during progressive subduction. For example, fast-retreating hinges result in a backward draping of a flat-lying slab atop the lower mantle. However, hinges which are stable in a time-averaged sense (oscillating between phases of slow hinge retreat and slow hinge advance) result in the accumulation of slab material at the 660 km disconituity alternating between forward- and backward-draping recumbent folds.

We quantify the energetics of these systems and provide a relation between the resultant plate kinematics (e.g. the speed of backwards trench migration vs. the forward velocity of the subducting plate) to plate driving forces (i.e. slab pull) and the resistive forces such as generation of the accompanying return flow. A significant component of this return flow is of a toroidal nature, which likely explains the preferred orientation of mantle fabric around slab edges as observed by shear wave splitting directions [3] and geochemistry of volcanic rocks from arc and back-arc environments such as Tonga and Scotia.

References

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