Geophysical Research Abstracts
Vol. 16, EGU2014-14986, 2014
EGU General Assembly 2014

Advanced computation for modeling fluid-solid dynamics in subduction zones

Marc Spiegelman (1), Cian Wilson (1), Peter van Keken (2), Peter Kelemen (1), and Bradley Hacker (3)
(1) Columbia University, LDEO, Palisades, NY, US (mspieg@ldeo.columbia.edu), (2) University of Michigan, Ann Arbor, MI, US, (3) UCSB, Santa Barbara, CA, US

Arc volcanism associated with subduction is generally considered to occur by a process where hydrous fluids are released from the slab, interact with the overlying mantle wedge to produce silicate rich magmas which are then transported to the arc. However, the quantitative details of fluid release, migration, melt generation and transport in the wedge remain poorly understood. In particular, there are two fundamental observations that defy quantitative modeling. The first is the location of the volcanic front with respect to intermediate depth earthquakes (e.g. 100 ± 40 km). This observation is remarkably robust yet insensitive to subduction parameters. This contrasts with new estimates on the variability of fluid release in global subduction zones which suggest a significant sensitivity of fluid release to slab thermal conditions. Reconciling these results implies some mechanism for focusing fluids and/or melts toward the wedge corner. The second observation is the global existence of thermally hot erupted basalts and andesites that, if derived from flux melting of the mantle requires sub-arc mantle temperatures of 1300 degrees C over shallow pressures of 1–2 GPa comparable to P-T estimates for the dry solidus beneath mid-ocean ridges.

These observations impose significant challenges for geodynamic models of subduction zones, and in particular for those that do not include the explicit transport of fluids and melts. We present a range of high-resolution models that include a more complete description of coupled fluid and solid mechanics (allowing the fluid to interact with solid rheological variations) together with rheologically consistent solution for temperature and solid flow. We discuss how successful these interactions are at focusing both fluids and hot solids to sub-arc regions worldwide. We also evaluate the efficacy of current wet melting parameterizations in these models.

When driven by buoyancy alone, fluid migrates through the mantle wedge along nearly vertical trajectories. Only interactions with the solid flow at very low values of permeability or high values of fluid viscosity can cause deviations from this path. However, in a viscous, permeable medium, additional pressure gradients are generated by volumetric deformation due to variations in fluid flux. These pressure gradients can significantly modify the fluid flow paths. At shallow depths, compaction channels form along the rheological contrast with the overriding plate while in the mantle wedge itself porosity waves concentrate the fluid. When considering multiple, distributed sources of fluid, as predicted by thermodynamic models, interaction between layers in the slab itself can also cause significant focusing. As well as permeability, rheological controls and numerical regularizations place upper and lower bounds on the length-scales over which such interactions occur further modifying the degree of focusing seen. The wide range of behaviors described here is modeled using TerraFERMA (the Transparent Finite Element Rapid Model Assembler), which harnesses the advanced computational libraries FEniCS, PETSc and SPuD to provide the a flexible computational framework for exploring coupled multi-physics problems.