Geodynamics of MARGINS

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An important accomplishment of the Suduction Factory Initiative has been the development of thermal structure models of subduction zones that are consistent with geophysical observations and accessible to the MARGINS community. At the Subduction Factory TEI in Eugene, OR (2000) it became clear that the constant viscosity slab/wedge thermal structure models widely-used in the subduction factory community were not consistent with a number of geophysical observations, including heat flow, gravity, and geochemical constraints of slab surface temperature. After the meeting, a number of groups developed high-resolution temperature- and stress-dependent rheology models showing that the rheology of the wedge critically controls the slab-wedge thermal environment due to the difference between isoviscous and temperature-dependent viscosity mantle wedge flow patterns (1-3). This new class of kinematic-dynamic slab thermal models has been extensively benchmarked (4) and extended to consider compressible convection (5), time-dependent flow (6), and 3D wedge flow (7-8). Additionally, slab thermal structure models have been linked with petrologic models to predict arc lava compositions (9-13).

While significant progress has been made over the last decade, the majority of the thermal models are 2D and only partly dynamic (i.e., the downgoing slab does not deform). Most models also neglect the generation or transport of fluids/magma. Shear-wave splitting observations (e.g., 14-15) and the along-strike variation of arc petrology and subduction zone geometry show that subduction dynamics are 3D and time-dependent and these effects are only beginning to be explored (7-8,16-18). Shear-wave splitting observations have lead to the development of a conceptual model where trench-parallel flow in the mantle wedge results from mantle material flowing around the edges of the slab driven by slab rollback (19). Kneller and van Keken (7-8) examined another mode of trench parallel flow driven by the pressure gradient due to wedge geometry with a fixed slab. Both laboratory (20-22) and numerical studies (23) have examined slab-rollback and trench migration however, the thermal and wedge structures from these calculations have not been examined at the same level of detail as the thermal structure calculations described in the first paragraph. The results presented by Schmeling et al. document the importance of the free surface for dynamic slab evolution. This has not been investigated in the current generation of slab thermal structure models and whether the free surface formulation impacts slab and wedge thermal structure is unknown.

Testing whether trench parallel flow results from trench migration, the hypothesis developed to explain the shear wave splitting observations, has proven to be quite challenging (23). At present, the resolution of the 3D calculations is significantly coarser than the grids used in 2D calculations, raising concerns that the thermal structure in the 3D models is not as well resolved. A decade ago a number of codes capable of solving 2D non-Newtonian wedge flow were already in use and had been benchmarked. It still took most of the decade to complete a subduction zone thermal structure benchmark that most codes could reproduce because the geometry of the wedge was something many codes were not designed to handle and, the nature of the coupling at the top of the slab in the seismogenic zone proved challenging for many codes. The current state of benchmarking of 3D convection codes is not as advanced as was the case for the 2D codes in 2000 and there are significantly fewer 3D codes available.

Adding to the challenges described above, subduction flow calculations need to couple melt, water (volatiles), and solid flow (9,24-25). This is important understanding the hydrous state of the mantle wedge and for better integration of geochemical data with geodynamic models. Inclusion of fluids are critical for understanding the development of serpentine in the corner of the mantle wedge and identifying the proper deformation mechanism for olivine (i.e., hydrous or anhydrous conditions), which is critical to interpret the shear wave splitting observations (26). Transport and reactive flow of fluid and magmas in the wedge also control geochemical cycling through the subduction system and into the deep mantle as well as the fundamental observation of the location, composition and volume of arc volcanics.

Presently most slab thermal structure calculations assume a rheological structure in the wedge that is loosely based on seismic and EM observations and the interpretation that these indicate a significant component of serpentine in the corner of the wedge. This is translated into reduced viscosity *a priori*. Topography and geoid can be used to constrain the rheological structure of the wedge (16-17) and future calculations could be used to test various assumptions regarding regions of serpentinization. At present dynamic topography and geoid are underutilized observational constraints.

The next generation of MARGINS will require a significant contribution from geodynamic modeling. This will require supporting geodynamics projects, such as coupling melt, volatile, and solid flow and may require coordination between MARGINS and CIG (Computational Infrastructure for Geodynamics) to ensure that critical functionality necessary to address goals relevant to the MARGINS program is incorporated into geodynamic tools.

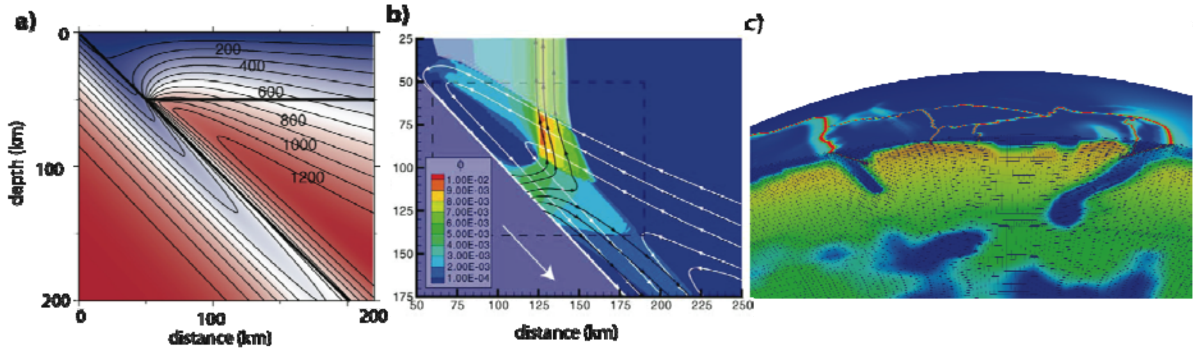

Figure 1 (a) 2D high-resolution calculation with dislocation creep in the mantle wedge from (4). (b) Fluid distribution (color contours), fluid flow (black lines) and solid flow (white lines) from a 2D wedge calculation from (9). C) Cross-section through New Hebrides and Tonga from 3D global model with variable resolution (27).

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