THE DYNAMICS OF HYDROUS COLD PLUMES SEEN THROUGH ONE BILLION TRACERS

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Recently the role of water in geodynamics is receiving greater and greater attention, driven by laboratory experiments, seismic analysis and numerical modeling. Introducing water into the dynamical models changes the nature of the equations to a complex system characterized by multiple components with many different intrinsic scales. We have modeled the dynamics of hydrous plume development above subducting slabs. Our 2-D model incorporates the effects of thermal-chemical buoyancy as well as the combined effects of both hydration and melting. We have used up to ONE BILLION tracers to delineate the evolution of the lithological, rheological and deformation structure of subduction zone with resolution down to between 10 and 50 meters. Tracers are integrated simultaneously with a Lagrangian energy equation and the solution is interpolated back to an Eulerian system for the solution of the thermal-chemical momentum equation. The rheologies of the different components are explicitly included. We have found the following interesting result. In contrast to common dogmatic thought that hot rising mantle flows prevail in the mantle wedge above the subducting slab our results suggest that partially molten hydrated upwellings (WET COLD PLUMES) in the mantle wedge are characterized by a colder thermal anomaly of 300 to 400 degrees! This rather unique process is produced by the subduction of buoyant crustal rocks and infiltration of aqueous fluids releasing from the slab, particularly due to decomposition of serpentine at depths >100 km. Low viscosity of these silicate bearing fluids under subsolidus conditions results in a rapid upward transport of water from the slab toward the melting front that forms within the mantle wedge. This melting front lies nearly parallel to the slab and is located just a few kilometers atop the slab. Higher viscosity and slower infiltration of hydrous basaltic melts formed above the melting front produces a slab-parallel layer of partially molten peridotite which is the source layer for the unmixed cold plumes transporting magmas of peridotitic origin. Mixed cold plumes responsible for transportation of crustal and mixed magmas starts directly from the slab and consist of hydrated, partially molten both mantle and subducted crustal rocks mixed over hundreds to tens of meter scale. Unmixed and mixed wave-like structures were also observed and they propagate upward along the descending slabs. Both cold plumes and cold waves may have an upward velocity >1 m/year, thus rapidly transporting thousands of cubic kilometers of rocks and magmas. Visualizing one billion tracers is indeed a daunting task and a grand challenge problem. Currently there exists is
no single display device available for unveiling all of the minute details in one fell swoop. In order to address this serious obstacle in visualization, we have developed two solutions for remote visualization and for local visualization. Our remote visualization solution is based on the web, and is a zoomed-in image service (WEB-IS3, available on http://tomo.msi.umn.edu/~max/webis) that requires minimal bandwidth, while allowing the user to explore our data through time, across many thermo-physical properties, and through different spatial scales. For local visualization, we found it optimal to use 2 bandwidth-intensive, high-resolution display walls for performing parallel visualization in order to best comprehend the causal and temporal dynamics produced by the multiple physical and chemical properties in subduction zone dynamics.

Figure: Results of numerical experiment of the developing mixed and unmixed hydrous cold plumes during oceanic subduction over hundred million tracers were employed in this run. Subduction of 120 million year old oceanic slab is modeled for a rapid subduction speed of 8 cm/a, characteristic of the Japanese subduction zone. We visualize here the multi-component compositional field at a time of 7.8 Myr after the onset of subduction.