Geophysical Research Abstracts
Vol. 21, EGU2019-11135, 2019
EGU General Assembly 2019

Thermal convection in a « soft » planetary mantle : plates, plumes, subduction and accretion, and their interactions.

Anne Davaille
FAST, CNRS / Univ. Paris-Sud / Univ. Paris-Saclay, ORSAY, France (davaille@fast.u-psud.fr)

The planets and rocky satellites of our solar system show very different evolutions and present-day dynamics. These result from the convective regimes prevailing in their mantle. However, the conditions necessary for convection to generate Plate Tectonics on Earth, episodic resurfacing on Venus, heat pipes on Io, or no resurfacing on Mars, remain strongly debated. The difficulty comes from the complexity of rocks rheology : viscous at high temperature and on long time-scale, brittle at low temperature and short time-scale. This « soft matter » behaviour can be recovered in the laboratory using aqueous colloidal dispersions, whose rheology varies from viscous to elasto-visco-plastic to brittle when their temperature, and/or their water or ionic content, vary. We therefore have investigated the physics of thermal and solutal convection in those systems. They show a diversity of convective regimes, including the ones encountered in rocky mantles; and the conditions under which heat pipes, plates, plumes, subduction and accretion develop self-consistently from convection, can now be systematically studied in a fish-tank.

For exemple, we observed that one-sided subduction can be induced by lithosphere buckling, or by the impingement of a hot plume under the lithosphere. Scaling laws show that this strong association between plumes and subduction initiation could explain on Venus the association of large coronae (created by hot upwelling mantle plumes) with trenches that have topographic signatures similar to the Earth's subduction zones. Moreover, the same mechanism may have been instrumental in the nucleation and growth of cratons on Earth and the onset of continuous Plate Tectonics. On the other hand, the characteristics of mid-ocean ridges (morphology, segmentation, mechanical instabilities such as transform faults, overlapping spreading centers or microplates) not only depend on spreading velocity but also on the mechanical properties and structure of the axial lithosphere. There again, scaling suggests that a hotter Archean Earth could have shown similar accretion structures to present-day Venus. Finally, every experiment always shows an evolution through time, passing through several convective regimes as it cools or dries: similarly a planet will not stay in the same convective regime for ever.

These aqueous colloidal dispersions are so far the only laboratory fluids capable of producing the sufficient shear localization to generate self-consistently asymmetric subduction and/or plate tectonics. It is worth noting that such strong and rapid deformation localization is due to their biphasic nature (water and a skeletton of silica nano-particles). This suggests that fluids, and especially partial melting, may be a key-parameter to produce Earth's dynamics.