T34A CC: 516 D Wednesday 1530h

Plate Reorganization Events: Observations and Models II *(joint with GP, S)*

Presiding: **S King,** Purdue University**;** **J Lowman,** University of Leeds

T34A-01 1530h INVITED

Changing Plate Configurations in Models of Mantle Convection

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In the Plate Tectonic model, continents are carried as passive rafts on lithospheric plates, eventually arriving at subduction zones where they accumulate, an idea first suggested by Vening-Meinez in 1962. A subsequent reorganization of plate motions is required to carry continental fragments away in new directions. Paleogeographic reconstructions of the changing locations of continents in the past can act as a proxy for the history of plate motions for the past several hundred My. This history is episodic and has repeatedly assembled large continental masses, or supercontinents. Convection models with buoyant continents can mimic this Wilson cycle type of activity, and internal heating in two- and three-dimensional models with plates can spontaneously reverse, or alter, spreading directions. Kinematic models can also be employed to examine the times required to assemble continents into a single supercontinent. The timescales for supercontinent assembly are found to depend most strongly on the total fraction of the Earth covered with continental material. For current continental masses, the typical assembly time is found to be approximately 400 My while for smaller amounts of continental material supercontinent assembly may require over 1,000 My.

T34A-02 1550h

Convection with Mobile Plates: Testing Plate Formulations with Complex, Time-Dependent Fluid Systems

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Lowman et al. (2001) presented results of 2D convection with mobile plates where the plate velocities reverse due to the evolution of the flow in the fluid beneath them. Lowman et al. used a force balance method to implement mobile plates and we reproduce their results using a 'weak zone' based rheological plate method. For the unit aspect ratio domain with a stiff plate with a thickness of 0.05d, where d is the depth of the domain, we find linear relationships between the surface velocity and size of the weak zones and the surface heat flux and the size of the weak zones. To match the results of Lowman et al. requires square weak zones that are 0.09d in length/depth. The results are less sensitive to the viscosity contrast between the fluid and the weak zone. For the case where Lowman et al. find plate motions that reverse on a periodic time scale we also find periodic, reversing plate motions. Using a T-R periodogram (Scargle 1982; Benson et. al 2003), we find that the periods are extrememly similar, with main peaks near periods of 0.02 and 0.05 diffusion time. However, our results show an apparently more complex behavior than those of Lowman et al. (2001), as demonstrated by the difference in periodicity between the two datasets, and the amplitude modulation in our results. There are additional low-amplitude, short-period phases in our time series that are not present in the Lowman et al. results. We suspect this is a result of small-scale flow differences due to the weak zones. Using these simple 2D systems, we systematically build toward a plate formulation with a temperature and stress dependent olivine rheology, then investigate the effects of damage and history. Lowman, J.P., S.D. King and C.W. Gable, The influence of tectonic plates on mantle convection patterns, temperature and heat flow, Geophysical Journal International, 146, 619-636, 2001. Scargle, J.D., Studies in Astronomical Time Series Analysis II. Statistical Aspects of Spectral Analysis of Unevenly Spaced Data, Astrophysical Journal, 263, 835-853, 1982. Benson, J.L., B.P. Bonev, P.B. James, K.J. Shan, B.A. Cantor, and M.A. Caplinger, The seasonal behavior of water ice clouds in the Tharsis and Valles Marineris Regions of Mars: Mars Orbiter Camera Observations, Icarus, 165, 34-52, 2003.

T34A-03 1605h

Evolving Tectonic Plates in Convection Models: Investigating the Feedback Between Sources of Deep Mantle Buoyancy and Plate Motion

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Understanding the feedback between the dynamically coupled systems of mantle convection and plate tectonics is an important geodynamical problem. In particular, how does the time-dependence associated with tectonic plate velocity and morphology affect other time-dependent features such as plume motion and longevity, surface heat flux and core-mantle boundary heat flux? Previous authors have specified plate-like behaviour in mantle convection models with evolving plate velocities but static plate geometries over time periods approximating billions of years. These studies have led to a greater understanding of the role of plates on mantle convection including flow patterns, mantle temperature and plate velocities, however, the extent to which the temporal evolution of the plate geometry affects such models remains poorly understood. We systematically explore the effect of dynamic migrating plate boundaries in mantle convection models featuring increasing complexity by using a numerical two-dimensional mantle convection model in a Cartesian geometry incorporating stiff tectonic plates, in which the plate velocities and plate boundaries evolve dynamically in response to the buoyancy distribution within the convecting system. We implement two simple migration rules: divergent plate boundaries migrate to simulate symmetric sea-floor spreading and convergent plate boundaries migrate to simulate the subduction of older plate by younger plate, thus modelling asymmetric subduction. We investigate the effects of plate size and number, mantle internal heating rate and mantle viscosity stratification on time-dependent features of our calculations such as the plate velocities, plate ages and plate sizes. We also investigate how plate boundary migration constrains parameters such as mean mantle temperature and surface heat flux. Study of these time-dependent features will help us to further answer questions about plate reorganization events and flow reversals, and to what extent deep mantle processes may be expressed in the history of plate motion.

T34A-04 1620h INVITED

Periodic Variations in Subduction Zone Configuration in Spherical Models of Mantle Convection With Plate Tectonics

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Paleogeographic reconstructions indicate that several cycles of oceanic opening-closing and continental collision-break-up have occurred. A more detailed understanding of the physical processes responsible for these cycles requires a consideration of mantle dynamics and the associated surface subduction-zone distributions.

Here we present a 3-D spherical model of mantle convection which incorporates surface tectonic plates which are dynamically coupled to the buoyancy-driven mantle flow. The formalism used to take into account the plates is the same as the one used by Monnereau and Quéré (2001). These time-dependent convection models reveal a cyclical re-organization of the subduction zones, alternating between two stable configurations around the same barycenter. The three main ingredients we employ in the models are: the present-day plate geometry; a multi-layer, geophysically constrained viscosity profile; and a large amount of distributed internal heating in the mantle.

As we have used a fixed plate geometry, one might expect that it would only provide stable subduction zone configurations. As we discover, this geometry will enable subduction zones to move from one state to another. A geometry with fixed boundaries is not, therefore, a restricting factor for the movement of the surface subduction patterns. We have also incorporated a multi-layer viscosity profile inferred from simultaneous inversions of convection and glacial isostatic adjustment (GIA) data (Mitrovica and Forte, 2004). This viscosity profile possesses a strongly defined low-viscosity layer at 670 km depth. The last main input corresponds to the amount of internal heating, and we assume 21 TW of radiogenic heating, as estimated by Stacey (1992).

In these numerical convection simulations, the cycling between the two stable subduction zone configurations is characterized by a period between 500 and 700 Ma. This periodic behaviour is manifested in a relatively restricted range of model parameter space. Several model simulations have allowed us to focus on the main parameters which are able to provide this cyclicity. In this presentation, we will specifically explore the use of both a complex plate geometry, a multi-layer viscosity profile with a low-viscosity channel, and a large amount of mantle internal heating.

T34A-05 1640h

Mantle Convection Models Including Continents and Self Consistent Plates

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Estimates of mantle heat flux under stable continental shields are low, around one tenth of the mean oceanic heat flux, which indicates a strong insulating effect of continents on mantle heat loss. This thermal blanketing effect is studied using numerical models of convection. Rigid conductive lids are set on top of the mantle to represent continents. A previous study had been carried out using an isoviscous fluid for the mantle (Grigne, PhD Thesis, 2003). A scaling law for the mean heat flux, oceanic heat flux, and mantle heat flux underneath the continent, as a function of the Rayleigh number of the mantle and of the width and thickness of the continent was constructed. It was shown that the continental lid strongly modified the pattern of convection in the mantle, producing a large wavelength in the flow. A temperature-dependent viscosity is now introduced, combined with a viscoplastic yielding. This combination was shown to produce plate tectonic-like behavior (e.g. Tackley, 2000). Models thus include self-consistently generated oceanic lithospheric plates and more artificially imposed continents. The study focuses on the effect of continents, with variable geometries and insulating effects, on the heat transfer of the mantle, on the pattern of convection and on the localization of plate boundaries.

T41A CC: 220 C-E Thursday 0830h

Mineral Physics Perspectives on the Structure, Composition, and Dynamics of Earth's Deep Interior Posters *(joint with S, V, MR, SEDI)*

Presiding: **J Badro,** Institut de Physique du Globe, Universite Paris VI**;** **D Farber,** Lawrence Livermore National Laboratory

T41A-01 0830h POSTER

Defective Grain Boundary Structures in MgSiO3

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Grain boundary processes are central to a wide range of geological phenomena, including deformation process by diffusional creep. In this project we employ computational modelling to study surface and grain boundary processes at an atomistic level, knowledge that is vital for the progress of our understanding of the rheological processes in the lower mantle. In our study we have performed calculations on the perovskite structure of MgSiO3, which is believed to comprise more than 70% of the lower mantle (Ringwood AE (1991) Geochim. Cosmochim. Acta 55: 2083-2110). By studying different types of grain boundary structures and domain wall motions in MgSiO3, we calculate the activation energy for the domain wall motions to between 1.4 and 2.0 eV for the grain boundary structures that are described as MgO-types, while for the SiO-terminated grain boundaries the activation energies are predicted to exceed 6 eV, due to the formation of stable ring and cage structures at the grain boundary. We have also performed calculations on the analouge perovskite structure of CaTiO3, but for this compound we