Geophysical Research Abstracts
Vol. 15, EGU2013-6312-1, 2013
EGU General Assembly 2013


# The effect of melting and crustal production on plate tectonics on terrestrial planets

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In the Solar System, Earth is the only planet to be in a mobile-lid regime, whilst it is generally accepted that all the other terrestrial planets are currently in a stagnant-lid regime, showing little or no surface motion. A transitional regime between these two, showing episodic overturns of an unstable stagnant lid, is also possible and has been proposed for Venus (e.g. Armann and Tackley, JGR 2012). In recent years a number of studies have focused on the feasibility of plate tectonics on large (1-10 Earth masses) extra-solar terrestrial planets; so-called super-Earths, with some studies concluding that these bodies should be in a mobile-regime mode (Valencia et al., ApJ 2007; van Heck and Tackley, EPSL 2011), but others predicting that they should be in a stagnant-lid regime (O'Neill and Leonardic, GRL 2007; Stein et al., GRL 2011).

Using plastic yielding to self-consistently generate plate tectonics on an Earth-like planet with strongly temperature-dependent viscosity is now well-established, but such models typically focus on purely thermal convection, whereas compositional variations in the lithosphere can alter the stress state and greatly influence the likelihood of plate tectonics. For example, Rolf and Tackley (GRL, 2011) showed that the addition of a continent can reduce the critical yield stress for mobile-lid behaviour by a factor of $\sim$2, while Armann and Tackley (JGR, 2012) found that bursts of crustal production caused by partial melting my trigger lithospheric overturn events, suggesting that laterally-heterogeneous crustal production in earlier studies (e.g. papers by Nakagawa and Tackley) may also play an important role in facilitating plate tectonics. Complicating matters is the finding that the final state of the system (stagnant- or mobile-lid) can depend on initial condition (Tackley, G3 2000 – part 2); Weller and Lenardic (GRL, 2012) found that the parameter range in which two solutions are obtained increases with viscosity contrast, leading to Lenardic and Crowley (ApJ, 2012) proposing a bistability of the system, introducing bifurcation theory to predict the tectonic state of a planet.

Here we thus test (i) whether melting-induced crustal production changes the critical yield stress needed to obtain mobile-lid behaviour as a function of governing parameters (particularly Rayleigh number and viscosity contrast (Moresi and Solomatov, GJI 1998) as well as internal heating rate), and (ii) whether, under these conditions, there is an initial-condition dependence (bimodality) to the state of the system Weller and Lenardic (GRL, 2012). We study these using StagYY (Tackley, PEPI 2008), which uses a finite-volume scheme for advection of temperature, a multigrid solver to obtain a velocity-pressure solution at each timestep, tracers to track composition, and a treatment of partial melting and crustal formation.