Mantle-lithosphere interaction models: last achievements and new links to geophysical data

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We provide an overview of the current state of the art in geodynamic modelling of mantle-lithosphere interactions. The resent developments are largely focused on introduction of a realistic lithosphere in the large-scale geodynamic models. This includes incorporation of explicit viscous-elastic-plastic formulation for the lithosphere, instead of more common stagnant viscous or visco-plastic lid concept. The new approach takes into account the rheological stratification of the oceanic and continental plates, free upper surface, topography and lateral heterogeneities. The recent models suggest sometimes contra-intuitive results, i.e. the development of short-wavelength topographies as a result of large-scale mantle dynamics, plume-initiated subduction or compression zones, spatially periodic zones of tectonic-style deformation (compression and extension). The account for free surface and surface processes enables comparisons with geodetic, sedimentary and structural geology data. The account for visco-elasto-plastic rheological terms allows one to reproduce localisation of brittle deformation, whence, the distribution of seismic events. The other possible link with seismic studies refers to the coupling of thermo-mechanical models with thermo-dynamic models, which allows one to compute density and elastic property distributions as function of pressure and temperature (pressure and temperature are also proxies for depth). This allows one to generate synthetic seismic models such as synthetic seismic tomography or synthetic reflection/refraction profiles. The preliminary tests (Figure 1) suggest that seismo-tomographic images of some mantle processes are not necessarily those that are commonly expected. For example, some plumes may become virtually undetectable due the smoothing of the boundaries of thermal anomalies associated with establishment of progressive thermo-dynamic and thermal density transition zones between the plume-head material and environment. The thermo-dynamical consistency also refers to the possibility of confrontation with petrology, geochermistry and magnetotelluric data, i.e. via modelled metamorphic P-T-t paths and reproduced zones of crystallization, partial melting and hydration-dehydration. The energy consistent approach requires, however, a thorough treatment of energy transformations within the system (viscous dissipation, latent heat and so on), and a number of questions are still to be solved before energy conservation can be accurately treated in the models. Finally, deep mantle rheology still remains enigmatic in a number of aspects, since flow laws at high

pressure-temperature conditions are not well constrained. In this relation, a number of studies have recently tested Pearl's plasticity as an alternative of ductile flow laws. Dynamic grain-size variations, grain-boundary sliding and the associated mechanical and seismic anisotropies constitute another important direction of investigation that can be tackled with dynamic numerical models.

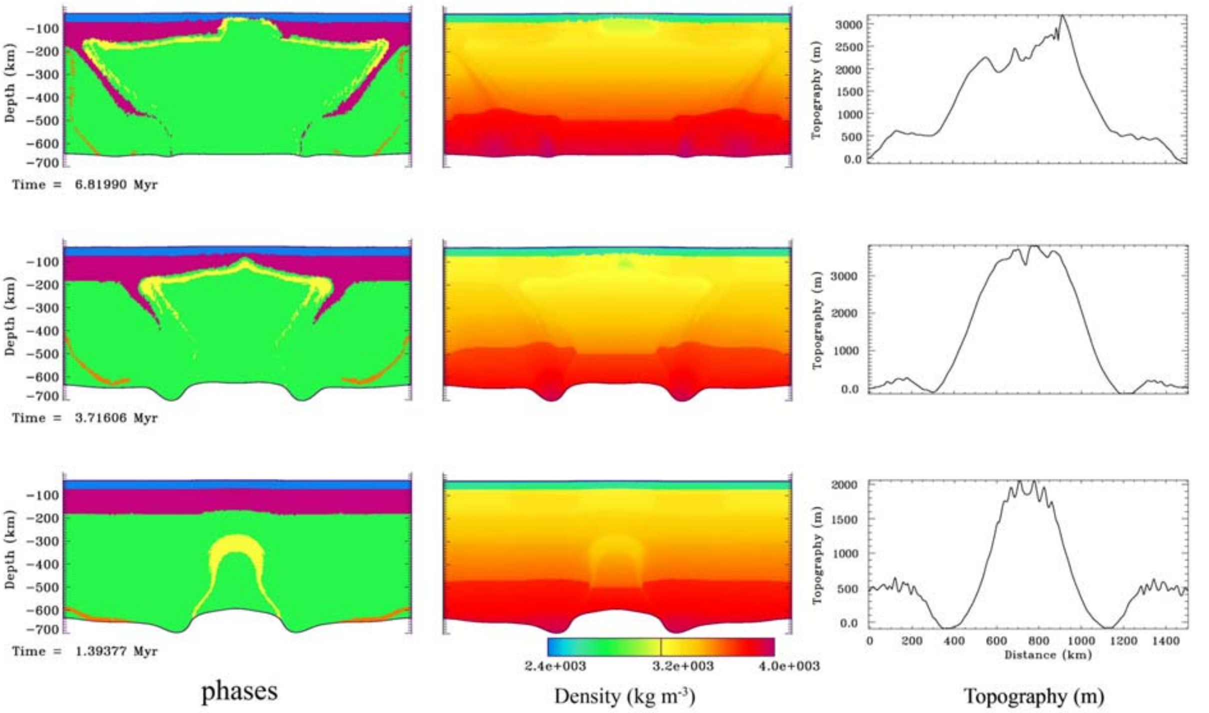

Figure 1. Example of a thermoèmechanically and thermo-dynamically consistent model of plume-lithosphere interaction, (viscous-elastic-plastic rheology, free-surface upper boundary condition) Left: A 200 km wide plume (yellow) translates through ductile olivine-dominated mantle (green) towards the base of a visco-elasto-plastic lithosphere with quartz-dominated crust (blue) and olivine-dominated lithosphere mantle rheology (purple). Middle : dynamic density changes associated with mineralogical phase transforms and pressure-temperature variations (computed using PERPLEX data base from J. Conolly). Right: topographic variations (note short-wavelength deformation superposed with long-wavelength deformation). Note also large-scale lithosphere mantle down-thrusting that under certain conditions turns to a subduction-like process.