Geophysical Research Abstracts
Vol. 15, EGU2013-12903, 2013
EGU General Assembly 2013

Lithospheric-Mantle Structure of the Kaapvaal Craton, South Africa, Derived from Thermodynamically Self-Consistent Modelling of Magnetotelluric, Surface-Wave Dispersion, S-wave Receiver Function, Heat-flow, Elevation and Xenolith Observations

Mark Muller, Javier Fullea, Alan G. Jones, Joanne Adam, Sergei Lebedev, and Nicola Piana Agostinetti
Dublin Institute for Advanced Studies, School of Cosmic Physics, Dublin, Ireland (mark.muller@dias.ie)

Results from recent geophysical and mantle-xenolith geochemistry studies of the Kaapvaal Craton appear, at times, to provide disparate views of the physical, chemical and thermal structure of the lithosphere. Models from our recent SAMTEX magnetotelluric (MT) surveys across the Kaapvaal Craton indicate a resistive, 220–240 km thick lithosphere for the central core of the craton. One published S-wave receiver function (SRF) study and other surface-wave studies suggest a thinner lithosphere characterised by a ∼160 km thick high-velocity "lid" underlain by a low-velocity zone (LVZ) of between 65–150 km in thickness. Other seismic studies suggest that the (high-velocity) lithosphere is thicker, in excess of 220 km. Mantle xenolith pressure-temperature arrays from Mesozoic kimberlites require that the base of the "thermal" lithosphere (i.e. the depth above which a conductive geotherm is maintained – the tLAB) is at least 220 km deep, to account for mantle geotherms in the range 35–38 mWm-2. Richly diamondiferous kimberlites across the Kaapvaal Craton require a lithospheric thickness substantially greater than 160 km – the depth of the top of the diamond stability field.

In this paper we use the recently developed LitMod software code to derive, thermodynamically consistently, a range of 1-D electrical resistivity, seismic velocity, density and temperature models from layered geochemical models of the lithosphere based on mantle xenolith compositions. In our work, the "petrological" lithosphere-asthenosphere boundary (pLAB) (i.e. the top of the fertile asthenospheric-mantle) and the "thermal" LAB (tLAB) are coincident. Lithospheric-mantle models are found simultaneously satisfying all geophysical observables: MT responses, new surface-wave dispersion data, published SRFs, surface elevation and heat-flow.

Our results show:
1. All lithospheric-mantle models are characterised by a seismic LVZ with a minimum velocity at the depth of the petrological/thermal LAB. The top of the LVZ does not correspond with the LAB.
2. Thin (∼160 km-thick) lithospheric-mantle models are consistent with surface elevation and heat-flow observations only for unreasonably low average crustal heat production values (∼0.4 μWm-3). However, such models are inconsistent both with the surface-wave dispersion data and youngest (Group I) palaeo-geotherms defined by xenolith P-T arrays.
3. A three-layered geochemical model, with lithospheric thickness in excess of 230 km, is required to match all geophysical and xenolith constraints.
4. The chemical transition from a depleted harzburgitic composition (above) to a refertilised high-T lherzolitic composition (below) at 160 km depth produces a sharp onset of the seismic LVZ and a sharp increase in density. Synthetic SRFs indicate that this chemical transition is able to account for the reported S-to-P conversion event at 160 km depth. In this this instance the 160 km deep SRF event does not represent the petrological/thermal LAB.