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Imaging the lithosphere-asthenosphere boundary of southern Africa integrating elevation, surface heat flow, magnetotelluric and petrological data

Javier Fullea (1), Mark Muller (1), Alan Jones (1), Juan Carlos Afonso (2), and Sergio Zlotnik (3)

(1) Dublin Institute for Advanced Studies, Geophysics Section, Dublin, Ireland (jfullea@cp.dias.ie), (2) GEMOC, Dept. Earth and Planet. Sci., Macquarie University, Sydney, Australia, (3) LaCaN, Univ. PolyTech. Catalunya, Barcelona, Spain.

The determination of the present-day thermal and compositional structure of the lithospheric and sub-lithospheric upper mantle is one of the fundamental goals in modern lithospheric modelling. In this context, a detailed knowledge of the thermophysical properties of mantle minerals, their temperature and pressure dependence, and their equilibrium assemblages within the lithospheric mantle is crucial. The lithosphere-asthenosphere boundary (LAB) can be defined in various ways depending on the proxy used to constrain it: seismic velocity, seismic anisotropy, electrical resistivity, composition or temperature. The extent to which these alternative definitions can be made compatible is still a matter of much debate.

In a case-study from southern Africa we examine the Proterozoic Rehoboth Terrane and the Archaean Kaapvaal Craton. Although the presence of many kimberlite pipes within the Rehoboth Terrane has been reported, none of them has yet proved to be diamondiferous, suggesting variations in the LAB depth and/or mantle composition between the two lithospheric domains. The LAB of the two terranes has been investigated using the software package LitMod. This software combines petrological and geophysical modelling of the lithosphere and sub-lithospheric upper mantle within an internally consistent thermodynamic-geophysical framework, where all relevant properties are functions of temperature, pressure and composition. In particular, LitMod is used in this work to define realistic temperature, pressure, density and electrical conductivity distributions within the upper mantle, and to characterize the mineral assemblages given bulk chemical compositions as well as water contents. This allows us to determine the topography (local isostasy), surface heat flow and magnetotelluric responses for different models of lithospheric composition and structure. Critically, we also assess the extent to which the lithospheric and sub-lithospheric mantle might be wet or dry within each terrane and the implications of the (potentially depth-variable) hydration state with respect to the lithospheric evolution of each terrane.

Finally, as part of a work in progress, we analyze the study region within the framework of a new multi-observable probabilistic inversion method particularly designed for high-resolution (regional) thermal and compositional mapping of the lithosphere and sublithospheric upper mantle.