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Temperature and compositional variation in the Australian lithospheric mantle

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To discern temperature and compositional variations of the Australian upper mantle, we apply an iterative technique, which jointly interprets seismic tomography and gravity data. In the first step we remove the effect of the crust from the observed gravity field and topography and compute the residual mantle gravity anomalies and residual topography. In the second step, the thermal contribution to the density structure is estimated by inverting the seismic tomography model AusREM, assuming a laterally and vertically uniform "fertile" mantle composition. After removing this effect from the total mantle anomalies, the residual "compositional" fields are obtained. Next, the residual mantle gravity field and residual topography are inverted to obtain a 3-D compositional density model of the upper mantle. In this way, we could improve the initial thermal and compositional models by applying an iterative approach to account for the effect of composition on the temperature variations.
With the inclusion of compositional variation, the estimates of temperature beneath the cratonic zones increases by about 100-150°C, compared to uniform composition. The final estimates of the temperature field show distinct differences between the warm eastern margin of the continent and the cooler zones beneath the Archean and Proterozoic domains. The South Australian craton with Archean to Proterozoic outcrops has much thinner and warmer lithosphere than the other cratons.
Strong depletion is present beneath the Northern and Western Australian cratons with thick and cool lithosphere, likely of mostly Archean provenance with only localized disturbance in the Proterozoic. In central Australia, the thick low temperature lithosphere is somewhat more fertile. The slower shear velocities in the uppermost mantle are not accompanied by any significant seismic attenuation, therefore rather compositional than thermal origin might be expected, for example a low temperature phase such as amphibole. Strong iron depletion is required in Western Australia than elsewhere. Indeed, this depletion appears to extend beneath the lithosphere, which suggests some component of lithospheric erosion due to the rapid northward motion of the Australian Plate. Beneath the Proterozoic terranes, depletion is much reduced below 150 km depth. The Palaeozoic domains display a generally more fertile regime.