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Rifting Thick Lithosphere – Canning Basin, Western Australia

Karol Czarnota (1,2) and Nicky White (2)

(1) Geoscience Australia, Canberra, Australia (karol.czarnota@ga.gov.au), (2) Bullard Laboratories, University of Cambridge, Cambridge, UK (njw10@cam.ac.uk)

The subsidence histories and architecture of most, but not all, rift basins are elegantly explained by extension of ∼120 km thick lithosphere followed by thermal re-thickening of the lithospheric mantle to its pre-rift thickness. Although this well-established model underpins most basin analysis, it is unclear whether the model explains the subsidence of rift basins developed over substantially thick lithosphere (as imaged by seismic tomography beneath substantial portions of the continents). The Canning Basin of Western Australia is an example where a rift basin putatively overlies lithosphere ≥180 km thick, imaged using shear wave tomography. Subsidence modelling in this study shows that the entire subsidence history of the <300 km wide and <6 km thick western Canning Basin is adequately explained by mild Ordovician extension ($\beta \approx 1.2$) of ∼120 km thick lithosphere followed by post-rift thermal subsidence. This is consistent with the established model, described above, albeit with perturbations due to transient dynamic topography support which are expressed as basin-wide unconformities. In contrast the <150 km wide and ∼15 km thick Fitzroy Trough of the eastern Canning Basin reveals an almost continuous period of normal faulting between the Ordovician and Carboniferous ($\beta < 2.0$) followed by negligible post-rift thermal subsidence. These features cannot be readily explained by the established model of rift basin development. We attribute the difference in basin architecture between the western and eastern Canning Basin to rifting of thick lithosphere beneath the eastern part, verified by the presence of ∼20 Ma diamond-bearing lamproites intruded into the basin depocentre. In order to account for the observed subsidence, at standard crustal densities, the lithospheric mantle is required to be depleted in density by 50–70 kg m-3, which is in line with estimates derived from modelling rare-earth element concentrations of the ∼20 Ma lamproites and global isostatic considerations. Together, these results suggest that thick lithosphere thinned to > 120 km is thermally stable and is not accompanied by post-rift thermal subsidence driven by thermal re-thickening of the lithospheric mantle. Our results show that variations in lithospheric thickness place a fundamental control on basin architecture. The discrepancy between estimates of lithospheric thickness derived from subsidence data for the western Canning Basin and those derived from shear wave tomography suggests that the latter technique currently is limited in its ability to resolve lithospheric thickness variations at horizontal half-wavelength scales of <300 km.