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Refining Gondwana Plate Reconstructions using Antarctic and Southern Ocean Crustal Thickness Mapping from Gravity Inversion

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The breakup of Gondwana and the development of the Southern Oceans during the Mesozoic and Cenozoic have led to the present complex distribution of oceanic crust, micro-continents and volcanic plateaux separating the southern continents.

Using gravity anomaly inversion, we produce comprehensive regional maps of Moho depth, crustal basement thickness and continental lithosphere thinning-factor for Antarctica and the Southern Ocean. From these we determine continent-ocean boundary (COB) location, ocean-continent transition (OCT) structure and the distribution of oceanic lithosphere which are independent of oceanic magnetic isochrons. Crustal cross-sections using Moho depths from gravity inversion, together with regional bathymetry and sediment-thickness information, allow OCT structure (e.g. narrow versus wide, rift versus transform) and margin magmatic-type (i.e. magma poor, "normal" or magma rich) to be determined.

Superposition of illuminated satellite-gravity data onto crustal thickness maps from gravity inversion provides an improved understanding of the pre-breakup conjugacy between the continental margins of Antarctica and those of its Gondwana conjugates. It also illuminates their post-breakup sea-floor spreading trajectory. By restoring maps of crustal thickness & continental-lithosphere thinning-factor to their initial post-breakup configuration, we can highlight the geometry and segmentation of the rifted continental margins at their time of breakup. Such restorations also identify the location of highly-stretched failed-breakup basins and rifted micro-continents, as well as showing the development of deep-ocean connectivity.

We determine Moho depth, crustal basement thickness, continental lithosphere thinning (1-1/β) and ocean-continent transition location using a 3D spectral domain gravity inversion method, which incorporates a lithosphere thermal gravity anomaly correction (Chappell & Kusznir 2008). The gravity anomaly contribution from ice thickness is included in the gravity inversion, as is the contribution from sediments which assumes a compaction controlled sediment density increase with depth. Data used in the gravity inversion are elevation and bathymetry, satellite free-air gravity anomaly, the Bedmap 2 ice thickness and bedrock topography compilation south of 60 degrees south and relatively sparse constraints on sediment thickness. Ocean isochrons are used to define the cooling age of oceanic lithosphere to determine the lithosphere thermal gravity anomaly correction. Antarctic crustal thicknesses derived from gravity inversion are consistent with the seismic estimates of An et al. (2015).

Our results and analysis suggest a re-appraisal is required of our present understanding of the tectonic development of the Weddell Sea, the West Antarctic Rift, the India-East Antarctica breakup and the Balleny region.