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Mapping Antarctic Crustal Thickness using Gravity Inversion and Comparison with Seismic Estimates

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Using gravity anomaly inversion, we produce comprehensive regional maps of crustal thickness and oceanic lithosphere distribution for Antarctica and the Southern Ocean. Crustal thicknesses derived from gravity inversion are consistent with seismic estimates. 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, 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.

Crustal thicknesses from gravity inversion are compared with independent seismic estimates, which are still relatively sparse over Antarctica. Our gravity inversion study predicts thick crust (> 45 km) under interior East Antarctica, which is penetrated by narrow continental rifts featuring relatively thinner crust. The largest crustal thicknesses predicted from gravity inversion lie in the region of the Gamburtsev Subglacial Mountains, and are consistent with seismic estimates. The East Antarctic Rift System (EARS), a major Permian to Cretaceous age rift system, is imaged by our inversion and appears to extend from the continental margin at the Lambert Rift to the South Pole region, a distance of $\sim$2500 km. Offshore an extensive region of either thick oceanic crust or highly thinned continental crust lies adjacent to Oates Land and north Victoria Land, and also off West Antarctica around the Amundsen Ridges. Thin crust is predicted under the Ross Sea and beneath the West Antarctic Ice Sheet and delineates the regional extent of the broad West Antarctic Rift System (WARS). Substantial regional uplift is required under Marie Byrd Land to reconcile gravity and seismic estimates. A mantle dynamic uplift origin of the uplift is preferred to a thermal anomaly from a very young rift. The new maps produced by this study support the hypothesis that one branch of the WARS links through to the De Gerlache sea-mounts and Peter I Island in the Bellingshausen Sea region, while another branch may link to the George V Sound Rift in the Antarctic Peninsula region.

Crustal thickness and lithosphere thinning derived from gravity inversion also allows the determination of circum-Antarctic ocean–continent transition structure and the mapping of continent–ocean boundary location. Superposition of illuminated satellite gravity data onto crustal thickness maps from gravity inversion provides improved determination of Southern Ocean rift orientation, pre-breakup rifted margin conjugacy and continental breakup trajectory. The continental lithosphere thinning distribution, used to define the initial thermal model temperature perturbation, is derived from the gravity inversion and uses no a priori isochron information; as a consequence the gravity inversion method provides a prediction of ocean–continent transition location, which is independent of ocean isochron information.