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Crustal architecture of the Wilkes Subglacial Basin in East Antarctica, as revealed from airborne gravity data

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ABSTRACT

The Wilkes Subglacial Basin, in the hinterland of the Transantarctic Mountains, represents one of the least understood continental-scale features in Antarctica. Aeromagnetic data suggests that this basin may be imposed on a Ross age back arc region adjacent to the East Antarctic Craton. However, the evolution of the deeper crustal structure is disputed. Here, we present new airborne gravity data that reveals the crustal architecture of the northern Wilkes Subglacial Basin. Our gravity models indicate that the crust under the northern Wilkes Subglacial Basin is 30–35 km thick, i.e. ca 5–10 km thinner than imaged under the Transantarctic Mountains, and ~15 km thinner than predicted from some flexural and seismic models in the southern Wilkes Basin. We suggest that crustal thickening under northern Victoria Land reflects Ross-age (ca 500 Ma) orogenic events. Airy isostatic anomalies along both flanks of the Wilkes Basin reveal major inherited tectonic structures, which likely controlled the basin location, supporting aeromagnetic interpretations of the Wilkes Subglacial Basin as a structurally controlled basin. The positive anomaly along the western margin of the basin defines the boundary between the East Antarctic Craton and the Ross Orogen, and the anomaly along its eastern flank likely reflects high-grade rocks of the central Wilson Terrane. Our models indicate that the crust is ~5 km thinner beneath the northern Wilkes Basin, compared to formerly contiguous segments of the Delamerian Orogen in south-eastern Australia. The thinner crust may be linked to: i) back-arc basin formation or orogenic collapse processes and segmentation within the Ross\Delamerian Orogen, ii) Jurassic to Cretaceous extension prior to break-up between Australia and East Antarctica, iii) Cenozoic glacial erosion or most likely, iv) a combination of these processes.

1. Introduction

Crustal architecture is a first-order parameter of the lithosphere describing the crustal thickness and fundamental geological structures of an area and is a function of a region's tectonic development. A lack of rock exposure and sparse geophysical data mean that the crustal architecture of East Antarctica is the most poorly constrained in the world, limiting our knowledge of the continent's tectonic evolution. East Antarctica is bordered by the Transantarctic Mountains (TAM) (Fig. 1), which are the world's longest and highest rift-related mountain range (ten Brink et al., 1997). In their glaciated hinterland lies the Wilkes Subglacial Basin (WSB), a sub-ice topographic feature of disputed origin ~1400 km long and up to 600 km wide (Ferraccioli et al., 2009a). Recent aeromagnetic data have provided new insights into the evolution of the upper crustal structures and revealed the importance of tectonic inheritance in this region (Damaske et al., 2003; Ferraccioli et al., 2009a, 2009b). However, a range of mutually incompatible models have been put forward for the crustal scale evolution of the WSB, including a rift basin (Steed, 1983), or extended terrane (Ferraccioli et al., 2001). Alternatively the WSB has been interpreted as a flexural down-warp of cratonic lithosphere associated with uplift of the TAM (Stern and ten Brink, 1989; ten Brink et al., 1997).

The WSB was first interpreted as a major sedimentary basin, based on reconnaissance airborne radar and sparse land-gravity measurements (Drewry, 1976). The basin was subsequently linked with continental rifting (Steed, 1983), a hypothesis in part supported by more recent data from a geophysical traverse across the WSB (Ferraccioli et al., 2001). An alternative model depicts the WSB as a flexural down-warp, created in response to Cenozoic rift-flank uplift of the TAM, adjacent to the Ross Sea Rift (RSR) (Stern and ten Brink, 1989; ten Brink et al., 1997). In flexural models of the WSB, thick crust and rigid lithosphere extend across the WSB to the TAM, with the maximum Moho depth predicted beneath the WSB (ten Brink et al., 1997). More recent estimates of Moho depth across the Southern Victoria Land (SVL) sector of the TAM and the southern WSB based on airborne gravity data (Studinger et al., 2004) (Fig. 1) suggested maximum Moho depth of ~40 km in SVL, decreasing to ~35 km beneath the WSB, contrary to predictions of previous flexural models. Wide-angle seismic investigations (Della Vedova et al.,

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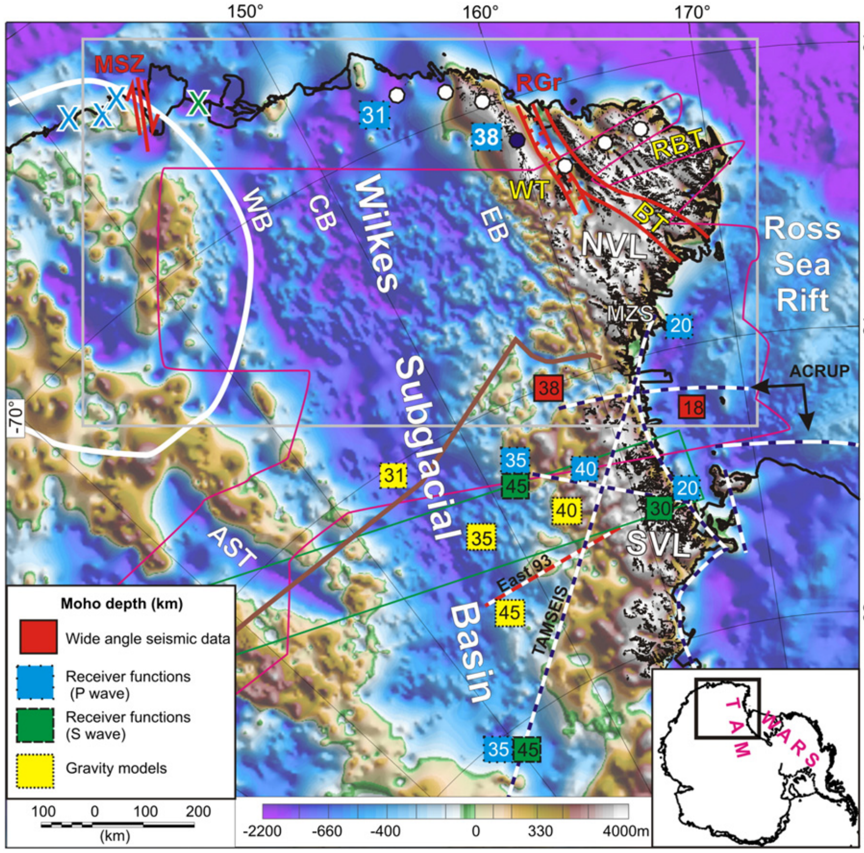

Fig. 1. Subglacial topography of the Wilkes Subglacial Basin and Transantarctic Mountains. Pink outline marks the extent of the ISODYN/WISE aerogeophysical survey (this study). Green outline marks the AEROTAM aerogeophysical survey (Holt, 2001; Studinger et al., 2004). Other topographic data is from BEDMAP (Lythe et al., 2001). Brown line marks ITASE traverse (Ferraccioli et al., 2001). Red and white line marks EAST93 traverse (ten Brink et al., 1997). Blue dashed lines show seismic profiles in Southern Victoria Land (SVL) (Della Vedova et al., 1997; Lawrence et al., 2006). Circles mark seismic stations in Northern Victoria Land (NVL) (Agostinetti et al., 2004) (blue dot marks Moho tie value used in our gravity models). Boxed numbers show previous estimates of Moho depth, based on different geophysical methods. Solid red lines mark faults and proposed terrane boundaries. Outcrops are outlined in black. Rock exposures to the west of the Mertz Shear Zone have ages of ~1.7 Ga (blue crosses), while rocks to the east are ~500 Ma (green crosses). MSZ = Mertz Shear Zone; RGr = Rennick Graben; WT = Wilson Terrane; BT = Bowers Terrane; RBT = Robertson Bay Terrane; WB, CB, EB = Western, Central and Eastern basins; AST = Adventure Subglacial Trench. White line denotes inferred extent of the Terre Adélie Craton (Finn et al., 2006). Grey box locates Fig. 2. Inset shows study area. TAM = Transantarctic Mountains; WARS = West Antarctic Rift System. MZS = Mario Zucchelli Station.

1997), passive seismic studies and gravity models (Lawrence et al., 2006), (Fig. 1) support Moho depths of ~40 km beneath SVL. A remarkably uniform Moho depth of ~35 km has been modelled beneath the southern WSB suggesting that although major extension is unlikely beneath this part of basin, root-like thickening of the crust under the TAM is viable (Bialas et al., 2007; Lawrence et al., 2006). However, a more recent seismic model using improved S-wave receiver function techniques along the same transect shows no evidence for a crustal root beneath the TAM and ~45 km thick crust beneath the WSB (Hansen et al., 2009). Within northern Victoria Land (NVL) receiver function estimates (Agostinetti et al., 2004) suggest a Moho depth of ~38 km beneath the TAM decreasing to ~31 in the north-eastern WSB (Fig. 1).

Direct information about the geology and origin of the WSB is limited by sparse rock exposure along the coast. To the East, over the RSR, drill cores and seismic investigations (Hamilton et al., 2001) have shown that widespread Cretaceous rifting was followed by narrow-mode Cenozoic extension close to the TAM rift flank (Huerta and Harry, 2007). Geological investigations over NVL have revealed three terranes with contrasting geological and metamorphic histories (Fig. 1), that were affected by the ~500 Ma Ross Orogen (Tessensohn and Henjes-Kunst, 2005). These terranes form part of the active margin of the East Antarctic Craton (Ferraccioli et al., 2002; Finn et al., 1999; Rocchi et al., 2011). However, the boundary between these terranes and the craton, and their relationship with the WSB, are less well-constrained. West of the WSB, beyond the Mertz Glacier, ~1.7 Ga rocks, have been recognised within the Terre Adélie Craton (Fig. 1) that is conjugate to the Gawler Craton in Australia (Di Vincenzo et al., 2007; Fitzsimons, 2003; Ménot et al., 2007). East of the Mertz Glacier, 500 Ma granites have been mapped along the coast, suggesting that the Ross Orogen may extend across the width of the WSB (Di Vincenzo et al., 2007), an inference that is supported by recent provenance studies (Cook et al., 2011; Goodge and Fanning, 2010). Satellite and airborne magnetic data have also been used to infer that the boundary of the East Antarctic Craton is close to the western margin of the WSB (Damaske et al., 2003; Ferraccioli et al., 2009a; Finn et al., 2006) (Fig. 1).

Aeromagnetic studies indicating that tectonic inheritance plays a role in the present day development of the WSB (Ferraccioli et al., 2009a) are directly complemented by our new aerogravity data, which reveal the deeper crustal architecture across the northern WSB. Here we present recent airborne gravity data, collected as part of a collaborative UK/Italian ISODYN/WISE aero-geophysical survey across the WSB (Ferraccioli et al., 2007; Jordan et al., 2007). Our analysis includes an interpretation of a new Bouguer gravity anomaly map of the WSB, and 2D gravity and isostatic models of crustal structure across the WSB and NVL. Additionally, a new regional Airy isostatic residual gravity anomaly map is presented. Our study provides new insights into variation in Moho depth and structural controls in the WSB region, and we propose a new interpretation for the origin of the thinner crust we observed under the northern WSB, compared to the southern WSB.