Basement topography and sediment thickness beneath Antarctica's Ross Ice Shelf imaged with airborne magnetic data

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Key Points:

- Aeromagnetic analysis reveals basement topography beneath Antarctica's Ross Ice Shelf
- Sediment-filled extensional basins underlie the ice shelf, with continuity northward into the Ross Sea and southward to the Siple Coast
- Narrow, deep basins beneath Siple Coast suggest active rifting, with associated elevated geothermal heat flow and rapid GIA

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Abstract

New geophysical data from Antarctica's Ross Embayment illuminate the structure and subglacial geology of subsided continental crust beneath the Ross Ice Shelf. We use airborne magnetic data from the ROSETTA-Ice Project (2015-2019) to locate the basement-cover contact and map the extent of sedimentary basins. We delineate a broad, segmented high with thin (0-500 m) sedimentary cover which trends northward into the Ross Sea's Central High. Before subsiding below sea level, this feature likely facilitated early glaciation in the region and subsequently acted as a pinning point and ice flow divide. Flanking the high are wide basins, up to 3700 m deep, parallel with Ross Sea basins, which likely formed during Cretaceous-Neogene intracontinental extension. NW-SE basins beneath the Siple Coast grounding zone, by contrast, are narrow, deep, and elongate. They suggest tectonic divergence upon active faults that would localize geothermal heat and/or groundwater flow, both important components of the subglacial system.

Plain Language Summary

The bedrock geology of Antarctica's southern Ross Embayment is concealed by 100s to 1000s of meters of glacial deposits, seawater, and the floating Ross Ice Shelf. Our research stripped away those layers to discover the shape of the consolidated bedrock below, which we refer to as the basement. We used the basement topography to obtain information about past continental landscapes of the Ross Embayment, and the manner of interaction of the basement – now subsided below sea level – with the Antarctic Ice Sheet. To do this, we used the contrast between non-magnetic sediments and magnetic basement rocks to map out the depth of the basement surface under the Ross Ice Shelf. Our primary data source was airborne measurements of the variation in Earth's magnetic field across the ice shelf, from flight lines spaced 10-km apart. We discovered contrasting basement characteristics on either side of the ice shelf, separated by an N-S trending basement high. The West Antarctic side basement features suggest active continental extension, which may localize high geothermal heat and dynamic responses of the earth to changes in the size of the Antarctic Ice Sheet. Our work addresses the connection between geology, tectonics, and glaciation in this region.

1 Introduction

Since the formation of Antarctic ice sheets in the Oligocene, the land surface of Antarctica has changed significantly (Paxman et al., 2019). For the Ross Embayment, this landscape evolution has been dominated by post-rift thermal subsidence following Cretaceous (Jordan et al., 2020) and Paleogene (Wilson & Luyendyk, 2009) continental extension, isostatic compensation of glacial erosion and sedimentation, and continued divergence across the western embayment (Granot et al., 2010). Accounting for these processes, topography reconstructions of Ross Embayment for past times show areas with elevation >500 m above sea level, including mountain ranges that hosted valley glaciers (e.g. De Santis, 1999; Sorlien et al., 2007). Now submerged, the Oligocene paleo-landscape of the Ross Sea sector was revealed by marine seismic data and drilling that penetrated the basement (e.g. Brancolini et al., 1995; Pérez et al., 2021) (Figure 1). This brought recognition that elevated topography of the Oligocene paleo-landscape played a role in the formation of the Antarctic Ice Sheet (DeConto & Pollard, 2003; Wilson et al., 2013), and subglacial topography still influences ice volume fluctuations caused by climate (Austermann et al., 2015; Colleoni et al., 2018).

The southern sector of Ross Embayment beneath the Ross Ice Shelf (RIS; area ∼480,000 km^2) is poorly resolved, by comparison, because the region is not easily accessible to conventional seismic or geophysical surveying. The RIS region is of high interest from the standpoint of regional ice sheet dynamics because its grounding zone (GZ) and pinning

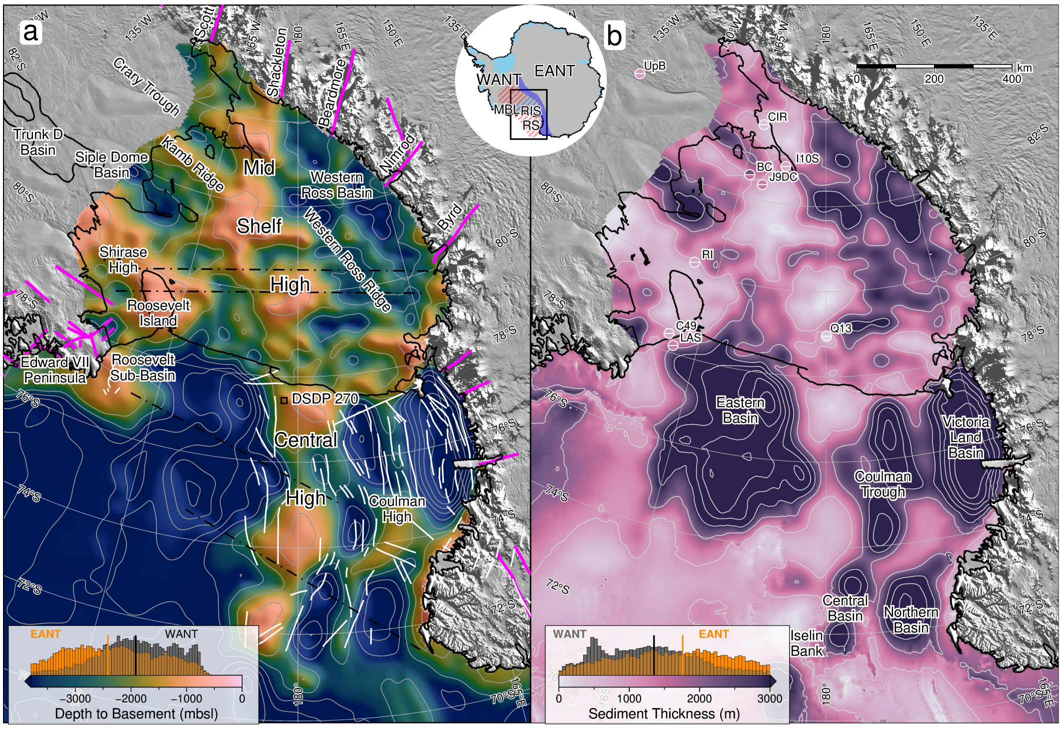

Figure 1. **(a)** Filtered depth to basement (magnetic for RIS, seismic elsewhere) contoured at 1 km. Pink lines are onshore mapped and inferred faults (Goodge, 2020; Siddoway, 2008; Ferraccioli et al., 2002). White lines are offshore faults (Salvini et al., 1997; Luyendyk et al., 2001; Chiappini et al., 2002). Dotted-dashed lines are OIB flight paths referred to here as 404.590, 404.650, 403.1, 403.3, from south to north. **(b)** Sediment thickness, contoured at 1 km, calculated as the difference between (a) and Bedmachine2 bathymetry (Morlighem et al., 2020) (Figure S1e). Previous basement-imaging RIS seismic surveys (Table S1) are plotted with upper and lower uncertainty ranges as circle halves, where reported. Colorbar histograms show data distribution for sub-RIS, separated into East and West Antarctic sides by a line down the center of the MSH (Figure S4). Vertical lines denote average values. Inset map shows figure location, ice shelves (blue), West Antarctic Rift System (hatched red), Transantarctic Mountains (dark blue), Abbreviations: WANT: West Antarctica, EANT: East Antarctica, MBL: Marie Byrd Land, RIS: Ross Ice Shelf, RS: Ross Sea. Shelf edge, grounding line and coastlines in black.

points buttress Antarctica's 2nd largest drainage basin (Tinto et al., 2019). Alongside the relevance of basement elevation for paleotopography, there is a need to delimit the extent of competent basement versus cover sediments. This is because the properties of the ice-bed interface influence the motion of the overriding ice by partitioning flow into sliding at the ice bed interface, deformation of the ice column, and deformation of the underlying substrate (e.g. Alley et al., 2004). Subglacial properties, including bed permeability and distribution of geothermal heat, also contribute to boundary conditions that influence ice sheet dynamics (e.g. Alley et al., 1986; Bell et al., 1998), control the resistance of GZ pinning points (Still et al., 2019), and promote the high flow velocities of West Antarctic ice streams (Blankenship et al., 2001; Tulaczyk et al., 1998). Here we present the first map of magnetic basement topography and sediment thickness for the southern Ross Embayment, developed using ROSETTA-Ice airborne magnetic data (Tinto et al., 2019). Our Werner deconvolution techniques reveal three major sedimentary basins and a broad basement ridge that separates crust of contrasting basement characteristics. This work provides the first holistic view of Ross Embayment crustal geology and structure at a scale appropriate to subglacial boundary conditions.

2 Data and Methods

We applied Werner deconvolution (Werner, 1953) to estimate the depth to the top of the magnetic crust along ROSETTA-Ice flight lines at 10-km spacing. The approach assumes that sediments and sedimentary rocks produce significantly lower amplitude magnetic anomalies than the underlying crystalline basement. Werner deconvolution can be performed on a 2D moving window of aeromagnetic line data by isolating anomalies and solving for their source parameters (Birch, 1984). The resulting solutions are non-unique; each observed magnetic anomaly can be solved by bodies at multiple locations and depths by varying the source's magnetic susceptibility and width. The result is a depth scatter of solutions (black dots in Figure 2). To estimate a basement surface, we filtered out the shallow solutions and clustered the remaining solutions (open circles in Figure 2) to produce a continuous distribution of points representing the top of the magnetic basement (orange crosses in Figure 2). The filtering was based on two parameters; Werner deconvolution window width (W) and a parameter (S) representing the product of the source's magnetic susceptibility and width. Clustering was performed by binning solutions (B, vertical grey lines in Figure 2) and retaining bins according to the count of solutions (C). See Text S1 for more details of magnetic data processing and Werner deconvolution.

We implemented a 2-step tuning process which ties our results to well-constrained ANTOSTRAT seismic basement in the Ross Sea (Brancolini et al., 1995). To facilitate this tie, we used Operation Ice Bridge (OIB) airborne magnetics data (Cochran et al., 2014) which flew over both the RIS and the Ross Sea. First, for a wide range of parameter values (W, S, B, and C) we calculated magnetic basement depth over the Ross Sea along OIB transect 403 and compared the result to ANTOSTRAT seismic basement depths (Figures 2&S2, Text S2). This allowed us to pick the parameter values which minimized the difference between the calculated aeromagnetic basement depths and ANTOSTRAT basement depths. With the optimized parameters, we calculated basement depths for OIB flight 404 (Figure S3) over the RIS. Using ROSETTA-Ice lines 590 & 650, coincident with OIB flight 404, we optimized the filtering and clustering parameters to minimize the difference between OIB and ROSETTA-Ice magnetic basement depths (Text S3). We then calculated magnetic basement for all ROSETTA-Ice flight lines and gridded the results (Figure S4, Text S4). Our resulting basement grid is the depth to the shallowest magnetic signal. Note that in some instances, such as igneous bodies intruded into sedimentary basin fill, Werner-determined solutions fall upon the crest of the intrusion, and the actual top of the crystalline basement could be at a deeper level. For intrusions of small lateral extent, these solutions will be excluded by our filter process, and the deep basement sources will still be recognized. Results from this study are merged with ANTOSTRAT data (Brancolini et al., 1995, Text S4) and smoothed with an 80 km Gaussian filter (Figure 1a) to match the characteristic wavelengths of the Ross Sea basement. The combined grid was then subtracted from Bedmachine2 bathymetry (Morlighem et al., 2020) (Figure S1e), which contains ROSETTA-Ice sub-RIS modeled bathymetry (Tinto et al., 2019), to obtain the sediment thickness distribution for the entire Ross Embayment (Figure 1b).

We used basement features and geophysical anomaly patterns to infer regional scale faults beneath the RIS. Criteria used to locate faults include 1) high relief on the magnetic basement surface, 2) linear trends that transect zones of shallow basement, 3) high gradient gravity anomalies and 4) large contrasts in modeled sediment thickness. We display the inferred faults upon a base map of crustal stretching factors (β-factor; the ratio of crustal thickness before and after extension, Figure 3a), using an initial crustal thick-

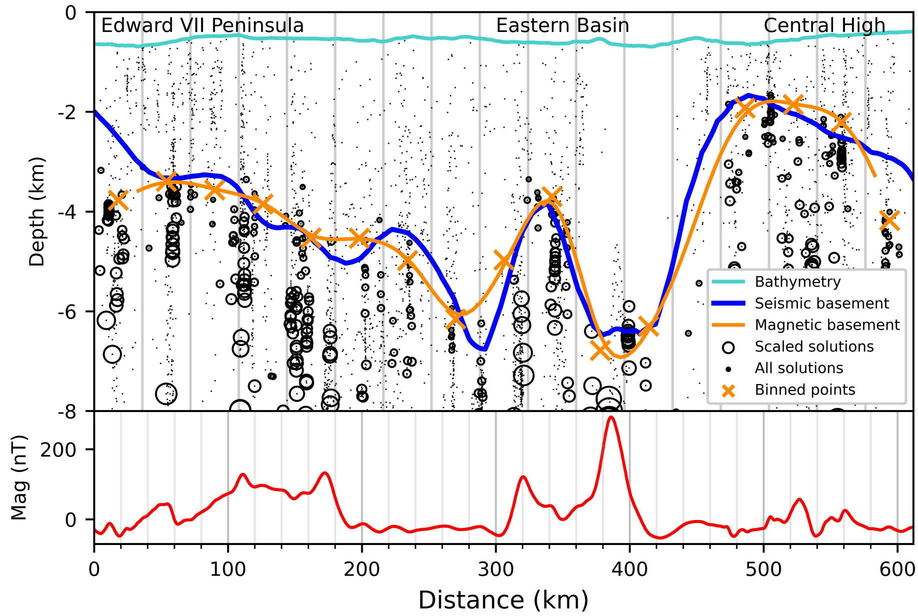

Figure 2. Werner deconvolution solutions for Operation Ice Bridge (OIB) flight 403 over the Ross Sea (line here termed 403-1, location Figure 1a). Bathymetry from Bedmap2 (Fretwell et al., 2013). Seismic basement from ANTOSTRAT (Brancolini et al., 1995). Filtering and clustering are described in Methods and Text S2. Circles are scaled to parameter S. Mean absolute difference between magnetic basement (orange line) and seismic basement (blue line) is 332 m.

ness of 38 km (Müller et al., 2007), a continent-wide Moho model (An et al., 2015), and our basement surface as the top of the crust (Text S5).

3 Results

The basement depths and sediment thickness grids, calculated using the greater data density afforded by ROSETTA-Ice and OIB surveys, provide new resolution of the sub-RIS upper crustal structure. An almost continuous drape of sediment covers the RIS region (Figure 1b), with <1% of the area having <100 m of sediment cover. Our tie between ROSETTA-Ice magnetic basement and Ross Sea seismic is achieved using OIB magnetics data to bridge the gap. The tie between OIB magnetic basement and Ross Sea seismic basement (Figures 2&S2) gives a mean absolute difference of 970 m. The tie between OIB and ROSETTA-Ice magnetic basement (Lines 590&650, Figure S3) give a mean absolute difference of 560 m. On the ice shelf, eight seismic estimates of sediment thickness, independent from our study, gives a mean absolute difference of 470 m from our results (Table S1 & Figure 1b). Three seismic profiles on the RIS report up to several kilometers of sediment, in general accordance with our results (Stern et al., 1991; ten Brink et al., 1993; Beaudoin et al., 1992).

Prominent beneath the midline of the RIS is a broad NNW-SSE trending basement ridge, here-called the Mid-Shelf High (MSH). The MSH is segmented into three blocks, separated by narrow orthogonal valleys. These blocks comprise most of the shallowest (<700 mbsl) sub-RIS basement, with several regions having <50 m sedimentary cover. The southern MSH abuts the TAM in the vicinity of Shackleton Glacier. At the regional scale, basement contrasts are apparent on either side of the MSH, with average basement depths of ∼-2410 mbsl on the East Antarctic side, compared to ∼-1910 mbsl on the West Antarctic side (Figure 1a colorbar). Sedimentary fill is ∼400 m greater and more uniformly distributed on the East Antarctic side than the West Antarctic side (Figure 1b colorbar).

There is a single broad and deep basin (200 x 600 km) between the MSH and the TAM, here termed the Western Ross Basin (Figure 1a). The Western Ross Basin parallels the TAM and contains a narrow NW-SE trending ridge that runs the full length of the basin. The linear basement ridge, here termed the Western Ross Ridge, displays ∼1500 m structural relief above the basement sub-basins on either side. The TAM-side basin has the highest-observed sub-RIS basement depths of 4500 mbsl, accommodating sediments that are up to 3800 m thick.

Bordering the MSH on the east, an elongate NW-SE trending basin runs from the RIS calving front to the Siple Coast GZ (Figure 1a). It is segmented by two gentle rises, then deepens abruptly beneath Siple Dome where we discover a 150x200 km depocenter reaching basement depths up to 4000 mbsl, with sediments up to 3700 m thick. We refer to this depocenter as Siple Dome Basin (SDB). SDB's east margin is formed by a basement high that trends southward from Roosevelt Island. Here termed the Shirase High, the feature rises to its shallowest point at the GZ, where its sedimentary cover is less than 100 m. A second deep, narrow basin (50x200 km in dimension) is found along the north margin of Crary Ice Rise, separated from the SDB by an NW-SE ridge (Kamb Ridge) underlying Kamb Ice Stream. The basin, here termed Crary Trough, contains sediments 1800-2700 m thick and the basement reaches depths of 3200 mbsl. At the southernmost region of the RIS is an additional depocenter, up to 2000 m thick, beneath Whillans Ice Stream (location in Figure 3a).

With the criteria outlined in Methods, we identified a series of likely locations for active and inactive sub-RIS faults (Figure 3a). We find active faults are concentrated on the West Antarctic side, where basement basins are narrow, linear, and coincide with high-gradient gravity anomalies (Figure S1a). Inactive normal and strike-slip faults are inferred between the shallow blocks of the MSH, and inline with Transantarctic Mountain (TAM) outlet glacier faults. β-factors show a distinct signature on the east vs west side of the MSH, with the TAM side showing high β-factors (average 1.99) with low variability while the West Antarctic side has lower β-factors (average 1.82), with localized zones of higher values (up to 2.1) (Figure 3a).

4 Discussion

Sub-RIS sedimentary basins align with and show lateral continuity with (from east to west, Figure 1) the Ross Sea's Roosevelt Sub-Basin, Eastern Basin, Coulman Trough, and Victoria Land Basin. The MSH forms the prominent southward continuation of the Ross Sea's Central High (CH). At the southern RIS margin, the narrow SDB has continuity with the previously identified Trunk D Basin (Bell et al., 2006) (Figure 1a). These regional continuations display sub-RIS basement features within the context of the Ross Sea (e.g. Cooper et al., 1995) and central West Antarctica (e.g. Bell et al., 2006) crustal structure.

4.1 West Antarctic Rift System extensional basins

Here we show the first geophysically constrained evidence of large-scale continental rifting beneath the RIS (Figure 3). Our basement map shows that rift basins of the eastern Ross Sea continue southward beneath the ice shelf as far as the Siple Coast, while those of the western Ross Sea terminate along the MSH. The Western Ross Basin has a configuration similar to the western Ross Sea rift basins in that it is a broad and deep basin, separated into distinct depocenters by a low relief ridge. The deeper of the depocenters is on the TAM side of the ridge and coincides with a narrow gravity low (Figure S1a). These similarities to the western Ross Sea basins, and the parallelism in trend between them, suggest these features are the sub-RIS continuations of the Coulman Trough, Coulman High, and the Victoria Land Basin, likely sharing a common tectonic origin. These sub-RIS basins terminate against the southern segment of the MSH (Figure 1a; along 180° meridian). The basin margins are likely fault-controlled (Figure 3a), as in the Ross Sea (e.g. Salvini et al., 1997) (Figure 1a, white lines).

The TAM-side of the Western Ross Basin likely marks and bounds the southward continuation of the Terror Rift, a southward-narrowing graben (Sauli et al., 2021) formed due to Neogene oceanic spreading in the Adare Trough (Henrys et al., 2007; Granot et al., 2010). This Neogene event caused extension in the Ross Sea and is inferred to transition into strike-slip under the RIS (Granot & Dyment, 2018). We infer that the southern limit of the Western Ross Basin, along the MSH, corresponds to a transfer fault between sectors of crust extended to different degrees (Figure 3a). The structure passes southward beneath Shackleton Glacier, which occupies a fault-controlled trough and crustal boundary (Borg et al., 1990).

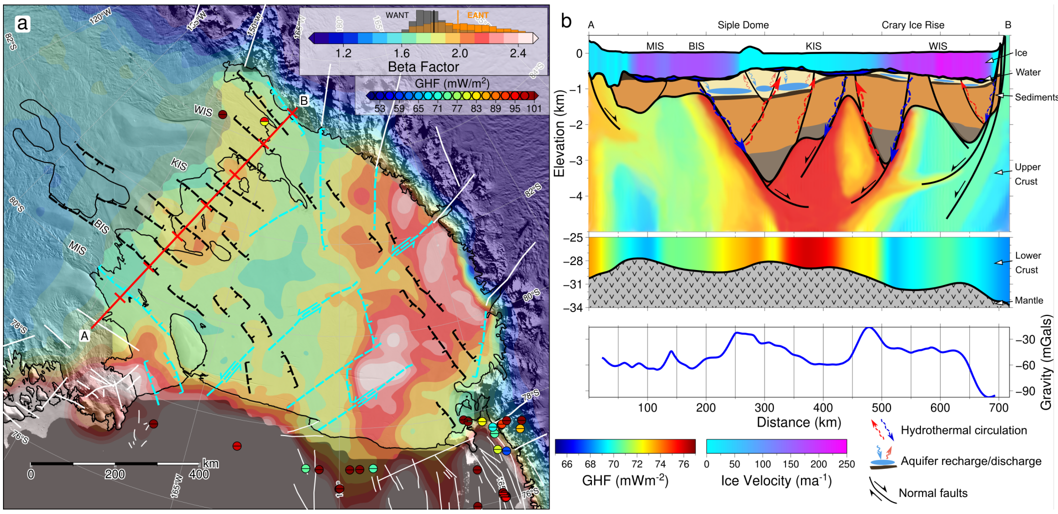

Figure 3. Tectonic interpretation of the sub-RIS. **(a)** β stretching factors (Text S5). Colorbar histogram shows east vs west data distribution, same as Figure 1. White faults and black basin outline same as Figure 1a, black and cyan dashed lines indicate inferred active and inactive faults, respectively, with kinematics shown. GHF point measurements plotted with upper and lower uncertainty ranges as circle halves, if reported (Burton-Johnson et al., 2020). Profile location in red, with 100 km ticks. **(b)** Siple Coast cross-section from A-B. Ice surface, ice base, and bathymetry from Bedmachine2 (Morlighem et al., 2020). Basement surface merged to bed outside of data coverage. Ice colored by velocity (Mouginot et al., 2019). Sediment layer shows interpreted faults, offset beds, aquifers, and water transport. Upper crust shows theoretical GHF guided by inferred faults and GHF models (Burton-Johnson et al., 2020), which color the lower crust, from Moho (Shen et al., 2018) to –25km. Lower panel shows ROSETTA-Ice gravity. Abbreviations: MIS: MacAyeal Ice Stream, BIS: Bindschadler Ice Stream, KIS: Kamb Ice Stream, WIS: Whillans Ice Stream.

Beneath the GZ at the southeastern RIS margin, ridges and narrow basins define a prominent NW-SE trend. The narrow, deep basin profiles, thick sediments, and strong definition of high-gradient gravity anomalies (Figure S1a) suggest the presence of NW-SE-oriented normal faults accommodating active divergent tectonics in this domain. Our Siple Coast cross-section (Figure 3b) displays these inferred faults associated with the SDB and Crary Trough formation. Local gravity surveys have imaged portions of the basin-bounding faults, with contrasting sediment thicknesses indicating up to 600 m of throw along the Whillans Ice Stream flank (Muto et al., 2013) (Figure 3a) and J9DC (Greischar et al., 1992) (Figure 1b). The sharp definition of Crary Trough and Siple Dome Basin signifies that this domain of Neogene extension is distinct from the southward-narrowing mid-Cenozoic divergence recognized for the Ross Sea (e.g. Cande et al., 2000; Davey et al., 2006). There is continuity from the narrow SDB into the previously identified Trunk D Basin (Bell et al., 2006) (Figure 1a) indicating the significant areal extent of the active tectonic domain into West Antarctica. A decrease in β-factors from the well-constrained RIS into West Antarctica, where sediment basins haven't been removed from the crustal thickness calculation, shows that knowledge of basement topography significantly changes β-factor estimates.

4.2 Solid-Earth-cryosphere interactions

Glacioisostatic adjustment following deglaciation in a region such as the Siple Coast, with low mantle viscosities (Whitehouse et al., 2019) and a landward-deepening bed (Adhikari et al., 2014), results in a negative feedback that can stabilize the ice sheet (Coulon et al., 2021). This rebound-driven ice sheet re-advance has been suggested for the region during the Holocene (Kingslake et al., 2018) and is dependent on mantle viscosity and its variability (Lowry et al., 2020). Active graben-bounding faults, as suggested here, and the elevated geotherm from recent extension would result in the rapid crustal responses to ice volume changes.

Groundwater reservoirs within sedimentary basins are estimated to store up to half of subglacial water, which enables the fast flow of the Siple Coast ice streams (Christoffersen et al., 2014). As this water is discharged or recharged, via fault damage zones (Jolie et al., 2021), it concentrates geothermal heat flux (GHF), drawing it up to the ice-bed interface or suppressing it to lower depths (Gooch et al., 2016). This vertical groundwater flow is modulated by pressure from the overriding ice sheets (Piotrowski, 2006; Siegert et al., 2018). High heat flux has been observed at one of the depocenters we defined at the GZ beneath Whillans Ice Stream (Fisher et al., 2015) (Figure 3a) and estimated seismologically along the Siple Coast (Shen et al., 2020) (Figure 3b). The steeply dipping normal faults and the potential basinal aquifers likely affect the localization and magnitude of GHF and subglacial water fluxes (Figure 3b).

4.3 Central High - Mid-Shelf High

Based on contrast in crustal characteristics, including magnetic anomalies, Tinto et al. (2019) suggest a mid-Ross Embayment north-south trending major geologic boundary separating crust of East and West Antarctic affinity. Geological substantiation comes from basement rock samples recovered from the CH at DSDP 270 (Ford & Barrett, 1975), and at Iselin Bank (Mortimer et al., 2011) (Figure 1), which have lithologic affinities to the TAM. This N-S boundary is coincident through the entire embayment with the CH-MSH. The distinct geologic properties on either side of the MSH related to West versus East Antarctic type crust have likely controlled the respective responses to West Antarctic Rift System extension (Tinto et al., 2019). High and homogeneous β-factors on the TAM-side indicate distributed crustal extension, while the West Antarctic side's β-factors are representative of localized intense rifting within a region of generally less thinned crust (Figure 3a). The greater amount of extension on the East Antarctic side is corroborated with the deeper bathymetry (Tinto et al., 2019) and deeper basement (Figure 1a).

Under the RIS, this CH-MSH feature trends southward from the calving front to the TAM. At the intersection with the TAM, the western edge of the high aligns with Shackleton Glacier which occupies a major fault separating the distinct geologic domains of the central and southern TAM (Borg et al., 1990; Paulsen et al., 2004; Miller et al., 2010). Previous workers noted that the Shackleton Glacier Fault trends into a 250-km long fault that passes from the south side of the TAM (Drewry, 1972) into a prominent magnetic lineament at the South Pole (Studinger et al., 2006). This N-S sequence of structures from Shackleton Glacier to the South Pole may be an expression of the East Antarctic craton margin or a major intracontinental transform (Studinger et al., 2006) (Figure 3a). The spatial correspondence of the East-West Antarctic geologic boundary, the N-S series of linear features, and the prominent basement highs suggest the CH-MSH is a major tectonic feature which through tectonic inheritance has influenced the rift architecture and development of Ross Embayment (Corti et al., 2007).

Paleotopographic reconstructions of the Late Paleogene depict a proto-Ross Embayment divided by a long, narrow mountain range, emergent above sea level (Paxman et al., 2019; Wilson et al., 2012), that hosted alpine glaciers and small ice caps (De Santis et al., 1995; De Santis, 1999). These represent the initial glacial stage in the region, and, once established, were the centers from which continental ice expanded to the outer Ross Sea continental shelf (Bart & De Santis, 2012). As the CH subsided by up to 500 m through the Neogene (Leckie, 1983) it submerged below sea level, but remained a bathymetric high until the mid-Miocene, before sedimentary deposits covered it (De Santis et al., 1995). The geophysical similarities and continuity between the Ross Sea's CH and the RIS's MSH imply a similar glaciation and subsidence history for the RIS region as for the Ross Sea. The terrestrial/alpine stage for the MSH helps to explain the region's potential to hold the late Oligocene's larger-than-modern ice volumes (Wilson et al., 2013; Pekar et al., 2006). Analysis of subglacial sediment identified a major ice flow divide between East and West Antarctic ice since the Last Glacial Maximum (Li et al., 2020; Licht et al., 2014; Coenen et al., 2019). These findings highlight the CH-MSH as important features for both Oligocene ice sheet development and the subsequent evolution of the ice sheet and ice shelf to the present day.

4.4 Thermal subsidence and sedimentation

Incorporating the updated basement basin extents and geometries into post-rift thermal subsidence modeling will enable better constrained paleotopographic reconstructions. A model for post-Eocene thermal subsidence following rifting of the West Antarctic Rift System predicts sub-RIS subsidence values based on gravity-derived basin geometries, uniform β-factors, and instantaneous extension ages based on plate-circuit data (Wilson et al., 2012; Paxman et al., 2019). They predict a relatively uniform southward decrease in subsidence for the sub-RIS continuation of the Eastern Basin. Instead, we discovered the narrow, deep SDB beneath the GZ, trending directly into Trunk D Basin. The basins' geometry suggests active structures and tectonic subsidence (Figure 3b). Consequently, the paleotopography of Siple Dome should restore to a higher elevation than was determined in paleogeographic reconstructions (Wilson et al., 2012; Paxman et al., 2019).

Our sediment thickness comparison with past models (Decesari et al., 2007) shows the majority of the sub-RIS contains more sediment than previously estimated (Figure S1f). This finding has implications for surface elevation changes due to sediment deposition. According to Paxman et al. (2019), sediment loading in Ross Embayment caused up to 2 km of isostatic response via subsidence in major depocenters since the Eocene, with the degree of subsidence diminishing southward from the Ross Sea to the Siple Coast. Our improved sub-RIS sediment thickness estimates, of up to 4 km along the Siple Coast and Western Ross Basin, imply a late Eocene-Oligocene paleotopography higher than today's. Depending on the age of the sediment, reconstructions for parts of the sub-RIS are therefore likely to be too low.

5 Conclusions

Here we present a depth to magnetic basement for the Ross Ice Shelf from Werner deconvolution of airborne magnetics data. The magnetic basement derived for the RIS is tied to acoustic basement of the Ross Sea, providing the first synthetic view of Ross Embayment crustal structure. Subtracting a bathymetry model (Tinto et al., 2019) we obtain sediment thickness distribution for the region. With these two grids and the magnetics data, we identify the likely positions for crustal faults, basement highs likely to function as pinning points at ice sheet high stands, and sites where the localization of geothermal heat or subglacial groundwater may affect boundary conditions. Sub-RIS sedimentary basins have continuity with Ross Sea basins to the north, and the prominent Mid-Shelf High trends northward into the Ross Sea's Central High. The High separates crust of contrasting geophysical character, affected by different stages of continental extension. The Mid-Shelf High was likely subaerial in the Oligocene, facilitating the formation of ice caps in early Antarctic glaciation, and subsequently acted as an ice flow divide between East and West Antarctic Ice Sheets. Newly identified narrow, linear, and deep sedimentary basins provide evidence for active extension beneath the Siple Coast grounding zone. The thinned crust likely experiences elevated geothermal heat flow promoting the formation of subglacial water. Fault motions may accommodate a rapid glacioisostatic response to ice sheet volume changes along the RIS's Siple Coast. Groundwater storage and transport to the ice-bed interface are likely controlled by permeable basin fill and fault-controlled basement interfaces, with possible localization of geothermal heat. Our work contributes critical information about Ross Embayment subglacial boundary conditions that arise from an interplay of geology, tectonics, and glaciation.

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