

RESEARCH LETTER

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Key Points:

- We present a new 1.5-km grid of Antarctic near surface magnetic anomalies
- The compilation contains more than 3.5 million line-km of airborne and shipborne data
- The magnetic anomaly compilation is a new tool to investigate the Antarctic lithosphere and subglacial geology

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New Magnetic Anomaly Map of the Antarctic

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Abstract The second generation Antarctic magnetic anomaly compilation for the region south of 60°S includes some 3.5 million line-km of aeromagnetic and marine magnetic data that more than doubles the initial map's near-surface database. For the new compilation, the magnetic data sets were corrected for the International Geomagnetic Reference Field, diurnal effects, and high-frequency errors and leveled, gridded, and stitched together. The new magnetic data further constrain the crustal architecture and geological evolution of the Antarctic Peninsula and the West Antarctic Rift System in West Antarctica, as well as Dronning Maud Land, the Gamburtsev Subglacial Mountains, the Prince Charles Mountains, Princess Elizabeth Land, and Wilkes Land in East Antarctica and the circumjacent oceanic margins. Overall, the magnetic anomaly compilation helps unify disparate regional geologic and geophysical studies by providing new constraints on major tectonic and magmatic processes that affected the Antarctic from Precambrian to Cenozoic times.

Plain Language Summary Given the ubiquitous polar cover of snow, ice, and seawater, the magnetic anomaly compilation offers important constraints on the global tectonic processes and crustal properties of the Antarctic. It also links widely separated areas of outcrop to help unify disparate geologic studies and provides insights on the lithospheric transition between Antarctica and adjacent oceans, as well as the geodynamic evolution of the Antarctic lithosphere in the assembly and breakup of the Gondwana, Rodinia, and Columbia supercontinents and key piercing points for reconstructing linkages between the protocontinents. The magnetic data together with ice-probing radar and gravity information greatly facilitate understanding the evolution of fundamental large-scale geological processes such as continental rifting, intraplate mountain building, subduction and terrane accretion processes, and intraplate basin formation.

1. Introduction

The extensive cover of snow, ice, and seawater makes magnetic surveying very effective for obtaining insights into the crustal geology of the Antarctic. Multinational efforts since the 1957–1958 International Geophysical Year have collected a considerable amount of magnetic data, despite the formidable logistical challenges of surveying in the Antarctic. The recognition that a continental-scale compilation of regional magnetic surveys further enhances their geological utility spawned supporting resolutions from the Scientific Committee on Antarctic Research (SCAR) and the International Association of Geomagnetism and

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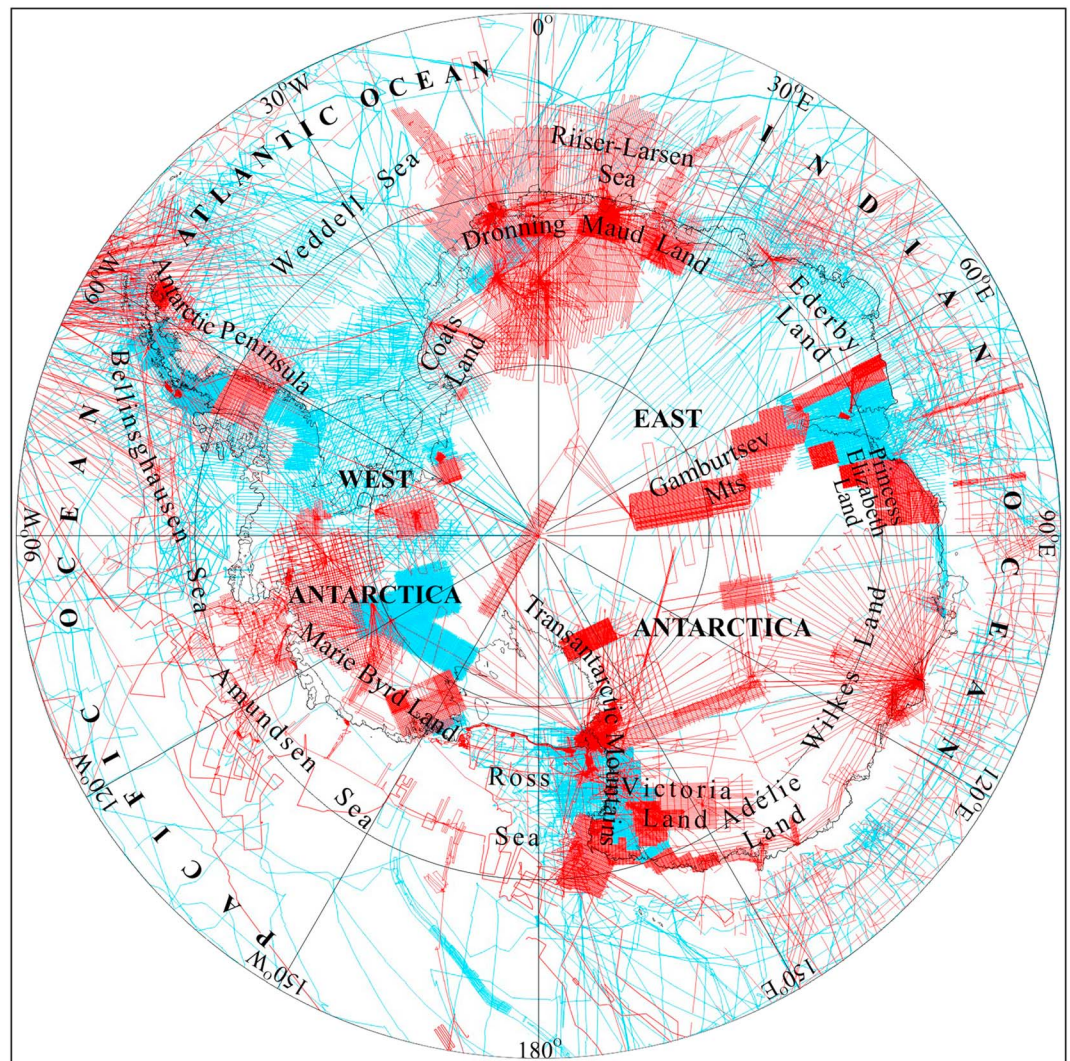


Figure 1. Near-surface magnetic survey tracks processed for the ADMAP-2 compilation from the ADMAP-1 (blue) and new (red) surveys.

Aeronomy (Johnson et al., 1997). Accordingly, the first Antarctic magnetic anomaly compilation (ADMAP-1) was produced in 2001 from more than 1.5 million line-km of shipborne and airborne measurements and 5.6 million line-km of satellite magnetic observations from the Magsat mission (Golynsky et al., 2001; Golynsky, Chiappini, et al., 2006; von Frese et al., 2002).

The ADMAP-1 compilation merged the near-surface magnetic survey data collected between the International Geophysical Year and 1999 (Figure 1). It provided new insights into the structure and evolution of Antarctica, including some of its Proterozoic-Archean cratons and Proterozoic-Paleozoic orogens, Paleozoic-Cenozoic magmatic arcs, continental rift systems, and rifted margins, as well as large igneous provinces and the surrounding oceanic gateways (e.g., Ferraccioli & Bozzo, 1999; Ferraccioli, Bozzo, & Capponi, 2002; Ferraccioli, Bozzo, & Damaske, 2002; Finn et al., 1999; Golynsky et al., 2000; Golynsky, Masolov, et al., 2006). These data were also released to the World Data Centers in 2008 and incorporated into the first World Digital Magnetic Anomaly Map (Maus et al., 2009).

Since the release of ADMAP-1, the international geomagnetic community has been very active acquiring more than 2 million line-km of new air- and shipborne data (Figure 1). The new coverage more than doubles the amount of near-surface magnetic anomaly data used in ADMAP-1. Many of these new data sets were

obtained within the scope of the International Polar Year 2007–2008 in multidisciplinary projects that also acquired airborne laser altimetry, radio echo sounding, and gravity anomaly data for comprehensive studies of the surface, thickness, and internal features of the ice sheets and the subglacial geology and hydrology. The new surveys targeted coverage gaps in ADMAP-1 such as over the Gamburtsev Subglacial Mountains (Ferraccioli et al., 2011), Dronning Maud Land (e.g., Ferraccioli, Jones, Curtis, Leat, & Riley, 2005; Ferraccioli, Jones, Curtis, & Leat, 2005; Mieth & Jokat, 2014; Shepherd et al., 2006), Wilkes Land (e.g., Aitken et al., 2014; von Frese et al., 2009, 2012), the Wilkes Subglacial Basin and the Transantarctic Mountains (e.g., Ferraccioli, Armadillo, Jordan, et al., 2009; Studinger et al., 2003, 2004, 2006), and other regions (e.g., Damaske et al., 2003; Damaske & McLean, 2005; Ferraccioli et al., 2006; Golynsky, Masolov, et al., 2006; Golynsky, Golynsky, et al., 2006; Jokat et al., 2003; Leinweber & Jokat, 2012; Stagg et al., 2004). The compilation procedures and resultant ADMAP-2 magnetic anomaly grid are presented in the next sections, followed by selected examples of the compilation's utility for geological studies of the most poorly understood crust on Earth.

2. Compilation Procedures

The new magnetic anomaly data could not be easily combined with the ADMAP-1 data, and therefore, all survey lines were processed into regional grids that were subsequently merged into the final Antarctic compilation. All survey lines were visually inspected to identify and mitigate the effects of data gaps, spikes, tip-tank errors, residual diurnal variations (e.g., Damaske, 1989; Saltus & Kucks, 1992), and incomplete or incorrect magnetic compensation noise from the airborne electromechanical systems. Residual high-frequency noise along the survey lines was further suppressed using low-pass Butterworth filters. All survey lines were then leveled, and in several cases also microleveled (e.g., Ferraccioli et al., 1998) within regional clusters (Figure 1) covering (1) the Antarctic Peninsula and adjacent marine regions, (2) Dronning Maud Land, (3) Enderby Land, (4) the Prince Charles-Gamburtsev Mountains, (5) Wilkes Land, (6) Victoria Land, (7) the Amundsen Sea Embayment-Marie Byrd Land, (8) the Indian Ocean, (9) the Atlantic-Pacific Oceans, and (10) interior East and West Antarctica.

All profiles within overlapping survey areas were used to recover as much magnetic anomaly detail as possible. Initially, these profiles defined possible level misfits or systematic biases between adjoining surveys. Variance analysis was used to define the required profile adjustments. Regional data sets were adjusted to essentially zero dispersions. All determined corrections were applied as necessary and subsequent cross-over analysis of the adjusted profiles leveled them with the overlapping surveys. As a rule, the corrections were applied predominantly to the older, poorer quality survey profiles.

The 10 regional grids were stitched together with the more detailed grids based on targeted aeromagnetic surveys with flight-line intervals varying from 0.5 to 5 km. Geosoft, Inc.'s suturing tool, GridKnit™ (Oasis montaj, 2014) was applied to merge the detailed and reconnaissance grids. Fast Fourier transforms of the grid differences yielded differential wave number by wave number corrections that smoothly joined the grid edges. The more irregular networks of regional profiles were initially merged to provide a framework into which the new and more strongly weighted detailed anomaly grids could be fitted. Before stitching, each individual grid was masked to exclude extrapolated values along the boundaries. All gridding was performed by the minimum curvature technique (Briggs, 1974).

The aeromagnetic and marine grids were merged into a grid at an interval of 1.5 km and low-pass filtered for wavelengths roughly ≥ 7 km to produce the final compilation in Figure 3. To honor the anomaly resolution of the original data sets as fully as possible, the terrestrial survey grids were not continued to a common elevation. However, along the Antarctic Peninsula margins, downward continuing the aeromagnetic profiles collected by the ICEGRAV, USAC, and Magnet projects (Forsberg et al., 2018; LaBrecque et al., 1986; Hittelman et al., 1996) from altitudes varying over 5,000 to 10,000 m above sea level significantly improved the magnetic anomaly patterns in the offshore sea level grids.

Figure 2 quantifies the data coverage for the ADMAP-2 compilation that includes a number of data gaps and poorly mapped areas. Some of these, including the Ross Ice Shelf, Princess Elizabeth Land, the Recovery Basin (Forsberg et al., 2018), and the gap around the South Pole, have been flown recently by the international geomagnetic community and will be incorporated into future ADMAP compilations. Other areas, including coastal Marie Byrd Land and inland Terre Adelie, have yet to be surveyed.

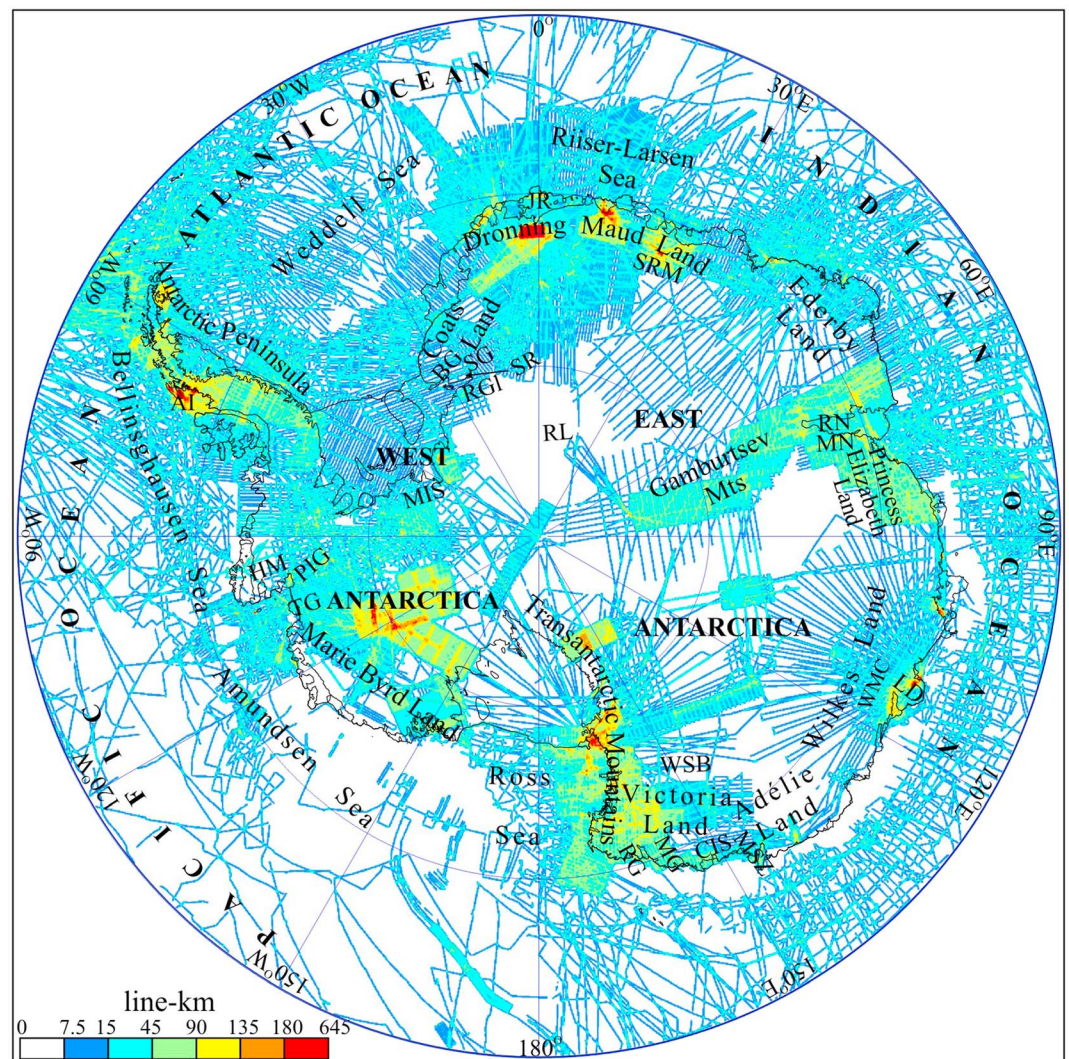


Figure 2. Data density coverage of the magnetic surveys that shows the line-km length of survey data within the window radius of 7.5 km about each gridded anomaly point in Figure 3. Geographic name abbreviations include AI, Adelaide Island; BG, Bailey Glacier; CIS, Cook Ice Shelf; HM, Hudson Mountains; JR, Jutulstraumen Rift; MG, Matusevich Glacier; MIS, Möller and Institute Ice Streams; MN, Manning Nunatak; PIG, Pine Island Glacier; RG, Rennick Graben; RGI, Recovery Glacier; RL, Recovery Lakes; RN, Robertson Nunatak; SG, Slessor; SR, Shackleton Range; SRM, Sør Rondane Mountains; TG, Thwaites Glacier; WSB, Wilkes Subglacial Basin.

To help mitigate some of these limitations, localized spherical harmonic Slepian functions (Kim & von Frese, 2017) are also being developed to integrate the south polar cap's crustal magnetic anomalies from ADMAP-2 and the Swarm satellite mission (Thébault et al., 2016). The Slepian coefficients can also directly update global spherical harmonic coefficients, and thus, ADMAP-2 is poised to substantially upgrade the Antarctic components of the World Digital Magnetic Anomaly Map (Catalán et al., 2016; Meyer et al., 2017). In addition, ADMAP-2 includes magnetic data to extend the Antarctic core field model through 2013 that was developed for extracting crustal anomalies over the 1960–2002 survey period from the ADMAP-1 compilation (Gaya-Piqué et al., 2006; von Frese et al., 2007).

3. Examples of the compilation's Geological Significance

ADMAP-2 (Figure 3) offers the most detailed view to date of the crustal magnetic field over the Antarctic continent and surrounding oceans south of 60°S (e.g., Ferraccioli, Armadillo, Jordan, et al., 2009; Ferraccioli, Armadillo, Zunino, et al., 2009; Golynsky, 2007; Goodge & Finn, 2010; Mieth & Jokat, 2014). It also provides

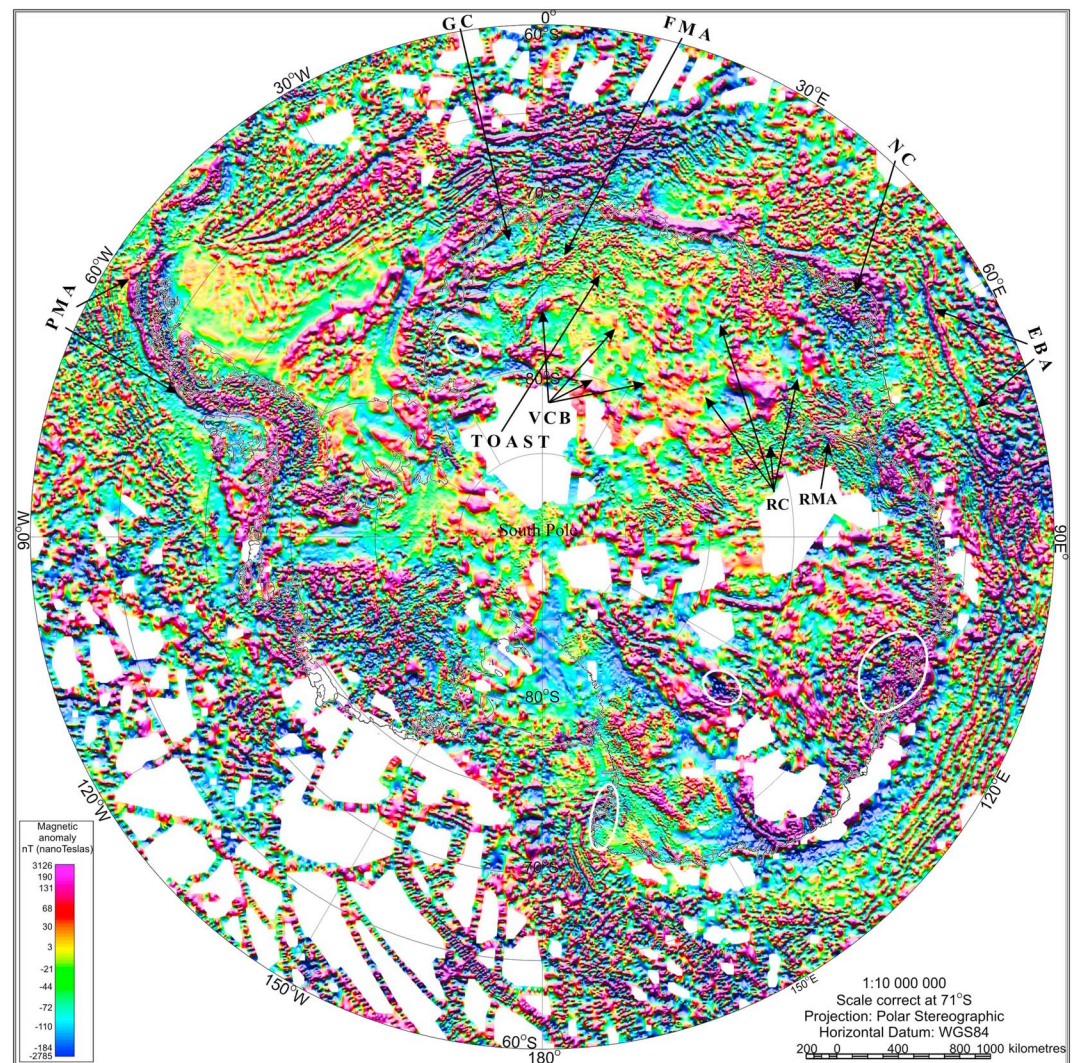


Figure 3. ADMAP-2 compilation of total field magnetic anomalies in shaded-relief on a polar stereographic projection with central meridian = 0°E longitude and standard parallel = 71°S latitude (Golynsky et al., 2017). The 1.5-km grid low-pass filtered for wavelengths ≥ 7 km was generated from more than 3.5 million line-km of airborne and shipborne magnetic observations. Abbreviations include: EBA, Enderby Basin Anomaly; FMA, Forster Magnetic Anomaly; GC, Grunehogna Craton; NC, Napier Craton; PMA, Pacific Margin Anomaly; RC, Ruker Craton; RMA, Robertson Magnetic Anomaly; TOAST, Tonian Oceanic Arc Superterrane; VCB, Valkyrie Cratonic Block. The four white ellipses encircle East Antarctic areas of the strongly negative magnetic anomalies considered in the text.

new insights into Antarctica's continent-ocean transitions (e.g., Davey et al., 2016; Gohl et al., 2013; Granot et al., 2013; König & Jokat, 2006; Leinweber & Jokat, 2012) and the geodynamic evolution of its lithosphere through three cycles of supercontinent assembly and breakup (e.g., Aitken et al., 2014; Aitken, Betts, et al., 2016; Jordan et al., 2017).

We provide below selected examples of crustal interpretations of the new aeromagnetic and marine anomaly surveys in ADMAP-2. They expand previous geological interpretations of the ADMAP-1 compilation (e.g., Chiappini & von Frese, 1999; von Frese et al., 2002; Ferraccioli et al., 2013) and offer initial starting points for using the new ADMAP-2 compilation in Antarctic crustal studies.

3.1. Antarctic Peninsula and West Antarctica

The Antarctic Peninsula's magnetic data sets contain imprints of a protracted history of crustal growth by Mesozoic arc magmatism along the paleo-Pacific margin of Gondwana (Ferraccioli et al., 2006). The

Antarctic Peninsula is a composite crustal block that includes two distinct magmatic arcs, separated by an inferred suture exceeding 1,500 km in length that was likely active during the mid-Cretaceous Palmer Land event (Vaughan et al., 2012). Specifically, combined aeromagnetic, aerogravity, and geological data suggest that a mafic, isotopically juvenile Early Cretaceous western arc marked by the western Pacific Margin Anomaly (Figure 3) may have collided against a more felsic eastern continental arc (Ferraccioli et al., 2006). This aeromagnetic interpretation, however, is subject to debate, with more recent studies favoring long-lived in situ arc to back-arc magmatism in the Antarctic Peninsula throughout the Mesozoic (Burton-Johnson & Riley, 2015). Higher-resolution aeromagnetic surveys across Adelaide Island (Figure 2) also suggest emplacement of extensive Paleogene and Neogene magmatism along part of the inherited Mesozoic arc/fore-arc boundary (Jordan et al., 2014).

ADMAP-2 incorporates significant magnetic data sets over much of the West Antarctic Ice Sheet. These new data provide key constraints into the extent of Cenozoic magmatism in the West Antarctic Rift System (WARS), which extends from the Ross Sea Embayment to the Amundsen (Gohl et al., 2013; Jordan et al., 2010) and possibly Bellingshausen Seas (Eagles et al., 2009). As in the Ross Sea sector (Behrendt, 1999), the Amundsen Sea Embayment was initially affected by distributed Cretaceous rifting related to New Zealand-West Antarctica separation (Gohl et al., 2013) and subsequent Cenozoic narrow-mode rifting (Jordan et al., 2010). The new aeromagnetic compilation reveals the occurrence of several narrow highly magmatic rift basins between the outcrops of Neogene volcanics in the Hudson Mountains (Figure 2), the Pine Island Glacier (Figure 2) catchment, and the Marie Byrd Land Dome (Young et al., 2017). Some of the proposed subglacial rift basins may also enhance glacial flow into the Amundsen Sea (Smith et al., 2013) and Bellingshausen Sea embayments (Bingham et al., 2012). Recent Curie depth estimates derived from magnetic data (Gohl et al., 2013) provide evidence for high geothermal heat flux offshore of the Thwaites Glacier (Figure 2; Dziadek et al., 2017) consistent with proposed Cenozoic tectono-thermal reactivation in this WARS segment (Damiani et al., 2014). ADMAP-2 facilitates extending these results inland into the catchment area of the climatically sensitive glacier and its neighbors.

The Ellsworth-Whitmore Mountains Block to the east forms the uplifted flank of the WARS that was not affected by widespread Cenozoic magmatism. The aeromagnetic data over the adjacent Möller and Institute Ice Streams' (Figure 2) catchments image the inland extent of the older Jurassic Weddell Sea Rift and reveal a major left-lateral strike-slip fault that separates East and West Antarctica (Jordan, Ferraccioli, Ross, et al., 2013). Prior to the opening of the Weddell Sea Rift, this inferred regional shear zone may have facilitated the emplacement of Jurassic granitic intrusions and accommodated southwards motion of the Ellsworth-Whitmore Block toward West Antarctica from a position closer to East Antarctica (Jordan, Ferraccioli, Ross, et al., 2013, 2017).

3.2. East Antarctica

Joint interpretation of airborne and satellite magnetic anomaly data helps unveil a mosaic of Precambrian provinces in East Antarctica (Ferraccioli et al., 2011). In the absence of outcrop and drilling information, the age of the individual basement provinces and the tectonic processes that led to their assembly remain both uncertain and controversial. A major collisional suture has been postulated to lie between the Archean Ruker Craton and the inferred Proterozoic Gamburtsev Province (Ferraccioli et al., 2011). The inferred suture may correspond to the southern boundary of a Mesoproterozoic-to-Neoproterozoic orogenic belt that surrounds the Ruker Province. More speculatively, this orogenic belt may link to eastern Dronning Maud Land, where the Tonian Oceanic Arc Superterrane (TOAST; Figure 3), recognized from geochronological and geochemical studies, may encompass a large sector of East Antarctica (Jacobs et al., 2015). Its subglacial extent has been reevaluated using U-Pb zircon analyses of glacial drift to also reveal the presence of older Stenian age oceanic arc-related magmatism (Jacobs et al., 2017).

ADMAP-2 suggests a possible new interpretation concerning the Gamburtsev Province, in the center of which prominent positive anomalies are comparable to anomalies over the Shackleton Range (SR; Figure 2), which lies more than 1,500 km to the west. The relatively lower resolution aeromagnetic data between the Gamburtsev Province and the SR reveal a sinuous alignment of broadly correlative segmented positive anomalies that, with better future coverage, may prove to be a continuous curvilinear belt.

The positive anomalies of the SR Block reach amplitudes of 500 nT in contrast to the more subdued magnetic anomalies of the neighboring Coats Land Block (Golynsky & Aleshkova, 2000). The Precambrian basement

rocks in the SR sustained a strong Ross-age (ca. 500 Ma) overprint and were thrust over unaltered Paleoproterozoic Read basement (Tessensohn, 1997). The SR hosts exposures of the southeastern margin of the East African-Antarctic Orogen (Will et al., 2010). Beneath the Recovery, Bailey, and Slessor glaciers (BG, RGI, and SG; Figure 2) that dissect the region along latitudinal trends lie fault-bounded grabens related to inferred Jurassic and Cretaceous intraplate tectonics (Golynsky & Golynsky, 2012; Paxman et al., 2017) that likely led to reactivation of the inherited basement faults.

Neoproterozoic sedimentary rocks overlying basement in the SR, together with ca. 500 Ma ophiolites (Talarico et al., 1999), high-pressure (up to eclogite facies) metamorphic rocks (Schmädicke & Will, 2006), and thrust faults suggest the presence of a major suture zone. The inferred suture separates the Coats Land Block (Loewy et al., 2011) from the proposed northernmost edge of the Mawson Continent (Will et al., 2010) and may mark ocean closure linked to left-lateral transpressional tectonics (Kleinschmidt et al., 2002). Recent aeromagnetic interpretations suggest that the proposed SR suture extends at least 500 km into the interior of East Antarctica, where it changes orientation from E-W to N-S in the Recovery Lakes (Figure 2) region (Ferraccioli et al., 2016). However, despite the large magnetic susceptibilities of the exposed ophiolites (e.g., $59.0\text{--}350 \times 10^{-3}$ SI), prominent aeromagnetic anomalies do not overlie the proposed suture in the SR (Sergeyev et al., 1999). This implies that relatively small oceanic crustal remnants are preserved within this part of the suture zone.

To the east of the SR, ADMAP-2's compilation of the recent ICEGRAV (Gravity measurements over the ice; Forsberg et al., 2018) and Alfred Wegener Institute (Mieth & Jokat, 2014) magnetic data reveals a curvilinear belt of positive magnetic anomalies. It borders the characteristic NW-trending anomaly fabric of the TOAST on the NE and encircles a poleward-lying province of more subdued magnetic anomalies that may be related to the presence of cratonic lithosphere (Golynsky, 2007; Ruppel et al., 2018). ADMAP-2 allows the first relatively complete mapping of the anomaly province labeled the Valkyrie Cratonic Block (Figure 3) for its partial inclusion of the Valkyrie Dome (Herzfeld, 2012). Notably, several different Archean cratonic blocks in East Antarctica exhibit contrasting magnetic signatures, including the Grunehogna Craton (Figure 3; e.g., Golynsky & Aleshkova, 2000; Ferraccioli, Jones, Curtis, Leat, & Riley, 2005; Riedel et al., 2013), the Napier Craton (Figure 3; Golynsky et al., 1996), and the Ruker Craton (Figure 3; e.g., Golynsky, 2007; McLean et al., 2009).

In central Dronning Maud Land, the Forster Magnetic Anomaly (FMA; Figure 3; Riedel et al., 2013) delineates a major tectonic boundary and/or suture zone within the East African-Antarctic Orogen (Jacobs & Thomas, 2004). The FMA is nearly 400 km long and 65 km wide and consists of segmented linear SW-NE trending anomalies. The lower amplitude SE-trending magnetic anomalies between the FMA and Sør Rondane Mountains (Figure 2) may represent sectors of the TOAST that were partially reworked during the inferred Pan-African age (ca. 600–550 Ma) collision of East Antarctica with Africa and India (e.g., Jacobs et al., 2015; Mieth et al., 2014; Mieth & Jokat, 2014).

Over the eastern shoulder of the Lambert Rift (Harrowfield et al., 2005) that is part of the continental-scale East Antarctic Rift System (Ferraccioli et al., 2011), a prominent alternating system of linear NE-SW trending positive and negative magnetic anomalies may be related to outcropping Precambrian gneiss with both igneous and sedimentary protoliths (Laiba & Kudriavtsev, 2006). Although these rocks are virtually identical in age and geochemistry to Beaver Complex rocks on the western side of the rift (Mikhalsky et al., 2013), the two regions have different magnetic anomaly signatures (Golynsky, Masolov, et al., 2006; Golynsky, Golynsky, et al., 2006). Geochemical analyses indicate island arc and volcanic arc settings for the emplacement of the protoliths (Liu et al., 2014), and geochronological data yield protolith ages ranging from ca. 1,347 to 1,020 Ma, indicating long-lived magmatic accretion within the composite Rayner continental arc. Thus, aeromagnetic surveys over Princess Elizabeth Land image the extent of a continuous Stenian-age accretional orogen in East Antarctica, which preserves geological records of a protracted accretionary history prior to collision (Liu et al., 2016; Mikhalsky et al., 2015). The prominent Robertson Magnetic Anomaly (Figure 3; Golynsky, Masolov, et al., 2006) reflects amphibolite facies rocks that only crop out at Robertson Nunatak (Figure 2; Mikhalsky et al., 2013). These isotopically juvenile rocks may also represent the remnants of an oceanic arc that crosses the Lambert Rift via a dextral offset of about 50–60 km. This displacement more likely occurred during Phanerozoic transtensional tectonics (Läuffer & Phillips, 2007), perhaps during the breakup of India from East Antarctica.

In the Wilkes Land region, Investigating the Cryospheric Evolution of the Central Antarctic Plate (Blankenship et al., 2011) aeromagnetic data enable correlating tectonic provinces of southern Australia with those hidden beneath the East Antarctic Ice Sheet, thereby helping to constrain reconstructions of Australia and Antarctica within the Gondwana, Rodinia, and Nuna supercontinents (Aitken et al., 2014; Aitken, Betts, et al., 2016). These magnetic data also help estimate the thickness of sedimentary fill in the Aurora, Knox, and Sabrina subglacial basins (Aitken et al., 2014; Aitken, Roberts, et al., 2016; Maritati et al., 2016). Further to the east, the new compilation reveals a prominent linear 2,100-km-long magnetic minimum that images the edge of the Archean-to-Mesoproterozoic Mawson continent, which encompassed Australia's Gawler Craton (Payne et al., 2009) and East Antarctica's Terre Adélie Craton (Gapais et al., 2008).

Within the Wilkes Subglacial Basin (WSB; Figure 2) and Transantarctic Mountains region, the combination of aeromagnetic, airborne radar, and aerogravity observations delineates the regional subglacial geology and deeper crustal architecture at the margin of the composite East Antarctic Craton (e.g., Ferraccioli, Armadillo, Jordan, et al., 2009; Jordan, Ferraccioli, Armadillo, et al., 2013; Studinger et al., 2004). Specifically, aeromagnetic interpretations identify the subglacial distribution of Beacon sediments and Ferrar tholeiites and reveal uplifted, presumed Precambrian and Ross age (ca. 550–460 Ma) basement blocks in the WSB. Magnetic modeling also suggests that post-Jurassic grabens underlie the central basins of the WSB, perhaps structurally similar to the Rennick Graben (Figure 2) in Northern Victoria Land (Ferraccioli, Armadillo, Jordan, et al., 2009). ADMAP-2 reveals that these grabens may also extend beneath the ice streams of the Cook Ice Shelf (Figure 2).

A significant tectonic feature identified along the eastern side of the WSB is the Exiles Thrust Fault System under the Matushevich Glacier (Figure 2; Ferraccioli et al., 2003). Combined aeromagnetic data and structural geology indicate that the Exiles Thrust and other thrust faults further to the east were active during the Ross Orogen (Ferraccioli, Bozzo, & Capponi, 2002) and were reactivated during much later intraplate Cenozoic strike-slip faulting that affected Northern Victoria Land (Ferraccioli & Bozzo, 2003).

ADMAP-2 also reveals nearly 60 negative anomalies with amplitudes reaching $-2,650$ nT in East Antarctica (Figure 3, white ellipses). In Northern Victoria Land, these anomalies are possibly related with reversed thermoremanent magnetization of Late Cenozoic McMurdo Volcanics (Ferraccioli, Armadillo, Zunino, et al., 2009; Tonarini et al., 1997). Southward of Law Dome (Figure 2), pronounced negative anomalies form a continuous ~ 650 -km-long belt consisting of eight anomalies with varying shapes, trends, and intensities in a terrane that Aitken et al. (2014) interpreted as "low-mag intrusions" linked with Australia's Albany-Fraser Province and the West Mawson Craton (Figure 2). Three additional anomalies over Law Dome appear to map a continuous source with an extent of about $9,500$ km². These anomalies could potentially mark one of the world's largest mafic/ultramafic intrusions, similar in extent to Norway's Bjerkreim-Sokndal layered intrusion (McEnroe et al., 2001).

3.3. Oceanic Basins

The first-order magnetic difference between oceans and continents is well expressed in Figure 3 by the contrast between complex magnetic anomaly patterns over continental crust and simpler linear seafloor spreading patterns over the younger and thinner oceanic crust. Along the Pacific continental margin of the Antarctic Peninsula, the magnetic anomaly patterns were significantly enhanced by downward continuing anomaly profiles of the ICEGRAV (Forsberg et al., 2018), US-Argentine-Chile (LaBrecque et al., 1986), and U. S. Navy's Project Magnet surveys (Hittelman et al., 1996) from altitudes of 5,000–10,000 m above sea level to sea level. Linear seafloor spreading anomalies and fracture zones, in particular, are more clearly expressed in the compilation to better constrain the tectonic evolution of the Phoenix and Pacific plates (Eagles, 2003).

The new data yield further details on the early spreading history between the West Antarctic and Phoenix plates (e.g., Eagles, 2003). They also constrain the initial position of the Campbell Plateau relative to Iselin Bank and western Marie Byrd Land, as well as that of the Chatham Rise relative to eastern Marie Byrd Land and Thurston Island (e.g., Cande et al., 2000; Eagles et al., 2004; Wobbe et al., 2012).

High-resolution aeromagnetic data from a recent German campaign over the Adare and Northern Basins have been modeled to further constrain middle-Eocene to late-Oligocene East-West Antarctic plate motions (Granot et al., 2013). The calculated rotations imply that Cenozoic seafloor spreading in the Adare Basin gave way to transcurrent motion in the central WARS via a zone of about 95 km of continental extension within the Victoria Land Basin (Davey et al., 2016).

Alfred Wegener Institute's aeromagnetic data along the continental margins of the eastern Weddell Sea and Riiser-Larsen Sea help define the timing and kinematics of early Gondwana breakup (Jokat et al., 2003; König & Jokat, 2006). In the Riiser-Larsen Sea/Mozambique Basin, the first oceanic crust between Africa and Antarctica formed by ca. 159 Ma, whereas to the west, the oceanic Weddell Rift is interpreted to have propagated eastward with a velocity of about 63 km/Myr between ca. 146 and 143 Ma (Jokat et al., 2003; Leinweber & Jokat, 2012).

More than 430,000 line-km of airborne and marine magnetic observations provide enhanced anomaly detail and important new constraints on the breakup processes and igneous activity along East Antarctica's passive margin. The pronounced Enderby Basin Anomaly (Figure 3) extends for roughly 1,680 km from the continental rise of the Kerguelen Plateau toward the Cosmonaut Sea (Golynsky et al., 2007). This high-amplitude, positive anomaly lies approximately 300 km outboard of the continental shelf over a basement rise at the inboard edge of unequivocal oceanic crust (e.g., Golynsky et al., 2013; Stagg et al., 2004).

Most published age models for the Enderby Basin and Australian sector of the East Antarctic continental margin still need to include the new magnetic anomaly constraints compiled in ADMAP-2 (Golynsky et al., 2013, 2017). This is particularly true for the Enderby and Shackleton Basins and, to a lesser degree, the conjugate Australia region. However, the Southern Ocean magnetic survey coverage in ADMAP-2 remains rather sparse and hence of limited value for constraining the region's seafloor spreading history and kinematics.

4. Summary

The ADMAP-2 compilation (Figure 3) contains more than 3.5 million line-km of airborne and shipborne data and provides the most complete and coherent view to date of the magnetic properties of the Antarctic crust (Golynsky et al., 2017). The map reveals a wide variation of magnetic anomalies reflecting crustal terranes of different lithologies and rock magnetic properties, ages, geothermal attributes, and tectonic affinities.

For example, the magnetic anomaly patterns of the East Antarctic continental margin have been enhanced considerably by the availability of 430,000 line km of new airborne and marine magnetic data. On the continent, the new compilation helps to map Proterozoic-Archean cratons, Proterozoic-to-Paleozoic orogenic belts, Paleozoic-Cenozoic magmatic arcs, the tectonic boundary between East and West Antarctica, continent-ocean transitions, and other regional Antarctic crustal features. In East Antarctica, the compilation helps to infer distinct Precambrian basement provinces, suture zones, and intracontinental and continental margin rifts. It also reveals the extent of arc rocks in the Antarctic Peninsula, rift-related Cenozoic magmatism buried beneath the West Antarctic Ice Sheet, as well as the subglacial extent of the Ferrar Large Igneous Province in the Transantarctic Mountains' hinterland, and the Jurassic granitoids in the Ellsworth-Whitmore Mountains.

Augmented by available gravity (e.g., Scheinert et al., 2016) and other geophysical and geological constraints, ADMAP-2 will stimulate new insights into Antarctica's geological evolution by plate subduction, terrane accretion and collision, continental rifting, intraplate basin formation, continental margin development and seafloor spreading, and other tectonic and geodynamic processes. The magnetic compilation also provides a new tool for assessing the influence on Antarctic ice sheet dynamics of geothermal heat flux (e.g., Leat et al., 2018; Martos et al., 2017), the distribution of subglacial sedimentary basins (Aitken, Roberts, et al., 2016), and other geological boundary conditions.

The new Antarctic magnetic anomaly grid is a key contribution toward the development of the next generation World Digital Magnetic Anomaly Map. Together with global geological and geophysical data sets, it has considerable potential for providing novel insights into the evolution of the Antarctic lithosphere during the Earth's supercontinent cycles (e.g., Li et al., 2016). The ADMAP-2 databases and grids are freely available for public download from the ADMAP websites maintained by the Korea Polar Research Institute (<http://admap.kopri.re.kr>), the British Antarctic Survey (<https://www.bas.ac.uk>), and the AWI (<https://www.pangaea.de/>).

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