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Antarctica's Continent-Ocean Transitions: Consequences for Tectonic Reconstructions

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ABSTRACT

Antarctica was the centerpiece of the Gondwana supercontinent. About 13,900 km of Antarctica's 15,900-km-long continental margins (87 percent) are of rifted divergent type, 1600 km (10 percent) were converted from a subduction type to a passive margin after ridge-trench collision along the Pacific side of the Antarctic Peninsula, and 400 km (3 percent) are of active convergent type. In recent years the volume of geophysical data along the continental margin of Antarctica has increased substantially, which allows differentiation of the crustal characteristics of its continent-ocean boundaries and transitions (COB/COT). These data and geodynamic modeling indicate that the cause, style, and process of breakup and separation were quite different along the Antarctic margins. A circum-Antarctic map shows the crustal styles of the margins and the location and geophysical characteristics of the COT. The data indicate that only a quarter of the rifted margins are of volcanic type. About 70 percent of the rifted passive margins contain extended continental crust stretching between 50 and 300 km oceanward of the shelf edge. Definitions of the COT and an understanding of its process of formation has consequences for plate-kinematic reconstructions and geodynamic syntheses.

INTRODUCTION

About 13,900 km of the 15,900-km-long continental margins of the Antarctic plate are of rifted divergent type, 1600 km were converted from a subduction-type to a passive margin after ridge-trench collision along the Pacific side of the Antarctic Peninsula, and 400 km are of active convergent type. The structure and composition of continental margins, in particular those of rifted margins, can be used to elucidate the geodynamic processes of continental dispersion and accretion. The margins of Antarctica have mostly been subject to regional studies mainly in areas near research stations in the Ross Sea, Prydz Bay, Weddell Sea, and along the Antarctic Peninsula near national research facilities. In recent years—mainly motivated by the United Nations Convention on the Law of the Sea—large volumes of new offshore geophysical data have been collected, primarily along the East Antarctic margin. For the first time this provides the opportunity to make a comprehensive analysis of the development of these continental margins over large tracts of extended continental crust that were previously unknown. The coverage of circum-Antarctic multichannel seismic lines from the Antarctic Seismic Data Library System for Cooperative Research (SDLS) of the Scientific Committee on Antarctic Research (SCAR) (Wardell et al., 2007) (Figure 1) is, with the exception of some areas in the central Weddell Sea, off western Marie Byrd Land and off the Ross Sea shelf, dense enough for quantifying basement types and volcanic and nonvolcanic characteristics of the margins. The track map (Figure 1) shows that deep crustal seismic data, necessary for a complete and accurate characterization of the marginal crust to upper mantle level, are still absent over most margins.

In this paper I first present a compilation of the structural types of the circum-Antarctic continental margins based on a review of relevant published data of diverse types together with new data. Then I contemplate implications of the knowledge of margin crustal types and properties for plate-kinematic and paleobathymetric reconstructions and for isostatic response models.

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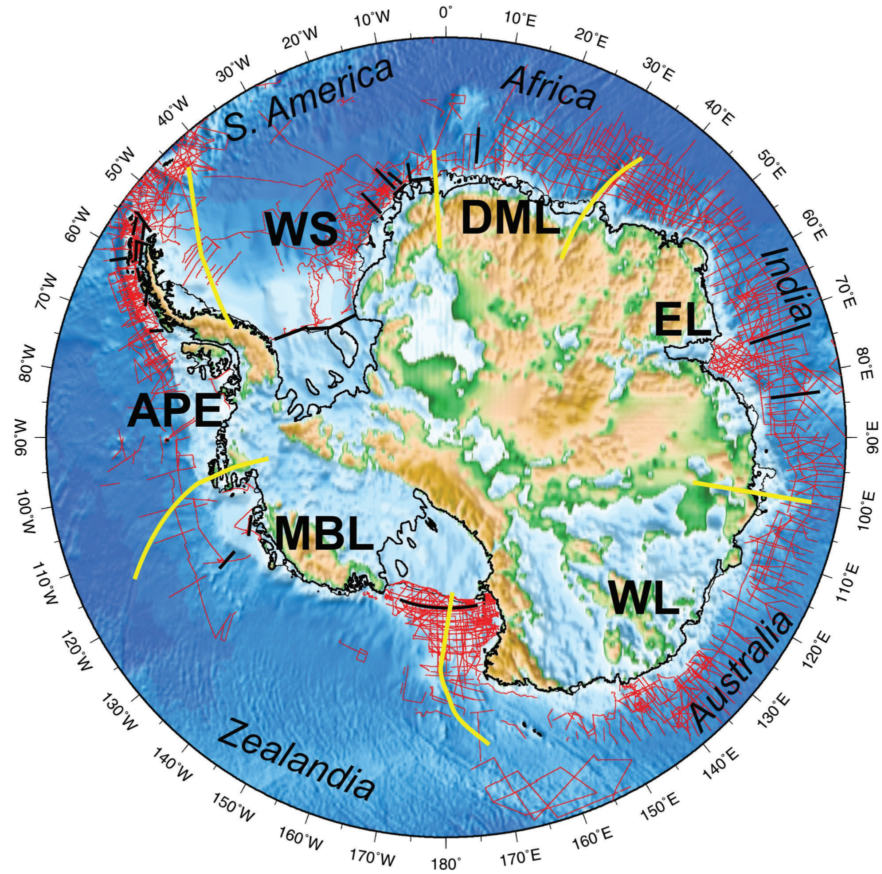

FIGURE 1 Overview map of Antarctica and surrounding ocean floor using a combined BEDMAP (bedrock topography with ice sheet removed) (Lythe et al., 2001) and satellite-derived bathymetry grid (McAdoo and Laxon, 1997). White areas on the continent are below sea level if the ice sheet is removed (without isostatic compensation). Yellow lines mark boundaries between the six crustal breakup sectors of respective conjugate continents in this paper. Red lines show the tracks of offshore multichannel seismic profiles of the SCAR Seismic Data Library System (SDLS) (compiled by M. Breitzke, AWI). Black lines mark the locations of offshore deep crustal seismic refraction profiles. WS = Weddell Sea sector; DML = Dronning Maud Land sector; EL = Ellsworth-Lambert Rift sector; WL = Wilkes Land sector; MBL = Marie Byrd Land sector; APE = Antarctic Peninsula-Ellsworth Land sector.

STRETCHING AND BREAKING: PASSIVE MARGIN TYPES

Weddell Sea (WS) Sector Conjugate to South America

The complex tectonic development of the Weddell Sea sector (Figure 2) has more recently been reconstructed by Hübscher et al. (1996a), Jokat et al. (1996, 1997, 2003, 2004), Leitchenkov et al. (1996), Ghidella and LaBrecque (1997), Golynsky and Aleshkova (2000), Ghidella et al. (2002), Rogenhagen and Jokat (2002), and König and Jokat (2006). Deciphering of the crustal types in the central Weddell Sea is still hampered by the lack of deep crustal seismic data. In the southern Weddell Sea seismic refraction data reveal a thinned continental crust of about 20 km thickness beneath the northern edge of the Filchner-Ronne ice shelf (Hübscher et al., 1996a). It can be assumed that this thinned crust extends northward to a boundary marked by the northern limit of a large positive gravity anomaly (Figure 2). König and Jokat (2006) associate an east-west rifting of this crust (stretching factor of 2.5) with the motion of the Antarctic Peninsula from East Antarctica as the earliest event in the Weddell Sea plate circuit at about 167 Ma prior to the early Weddell Sea opening in a north-south direction at about 147 Ma. It is not clear, however, whether some of the crustal extension is also associated with this early Weddell Sea opening. The crust between the northern end of the large positive gravity anomaly and the magnetic Orion Anomaly and Andenes Anomaly (Figure 2) is interpreted as a COT with the Orion Anomaly suggested to represent an extensive zone of volcanics that erupted during the final breakup between South America and Antarctica (König and Jokat, 2006). Deep crustal seismic refraction data across the Orion and Andenes anomalies and the assumed COT south of it are needed in order to constrain their crustal composition and type. Although the Orion Anomaly may provide a hint toward a volcanic-type margin, the few seismic data do not allow a complete characterization of the COT in the southern Weddell Sea. Identified magnetic spreading anomalies (oldest is M17) show evidence that oceanic crust exists north of the Orion and Andenes anomalies with the prominent T-Anomaly marking supposedly the changeover from slow to ultraslow spreading-type crust (König and Jokat, 2006).

The Weddell Sea margin along the east coast of the Antarctic Peninsula is still rather enigmatic due to missing data. König and Jokat (2006) show that it rifted from the western Patagonian margin as part of the earliest plate motion in the Weddell Sea region at about 167 Ma. They follow Ghidella

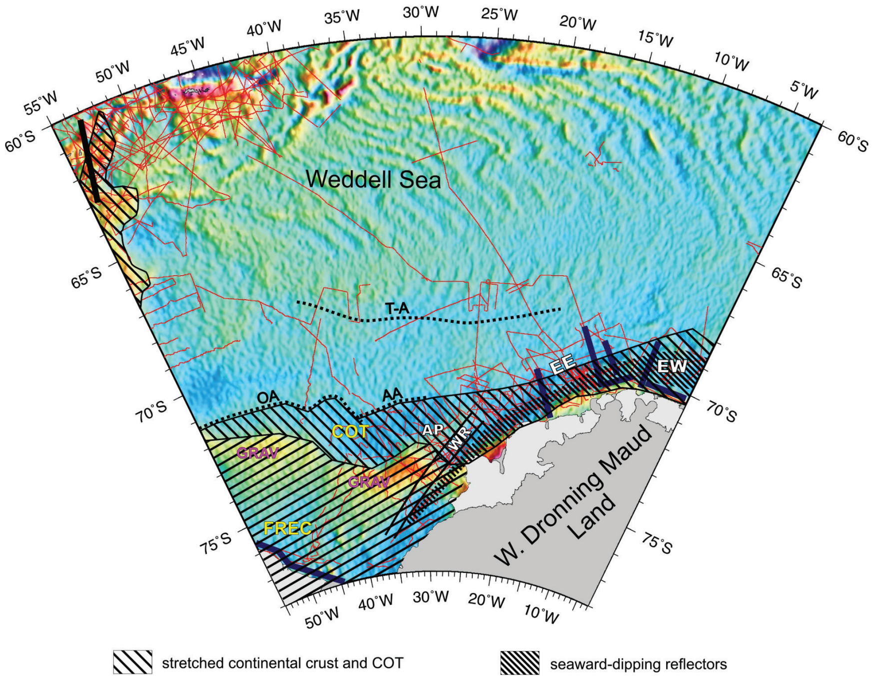

FIGURE 2 Weddell Sea sector with satellite-derived gravity field (McAdoo and Laxon, 1997) and continental margin features. Red lines show the tracks of offshore multichannel seismic profiles of SDLS. Dark blue lines mark the locations of offshore deep crustal seismic refraction profiles. COT = continent-ocean boundary; GRAV = positive gravity anomaly marking northern limit of thinned continental crust; FREC = Filchner-Ronne extended crust; EE = Explora Escarpment; EW = Explora Wedge; AP = Andenes Plateau; WR = Weddell Sea Rift; T-A = T-Anomaly; OA = Orion Anomaly; AA = Andenes Anomaly.

and LaBrecque's (1997) argument for a nonvolcanic margin based on low-amplitude magnetic anomalies and a characteristic bathymetry.

The margin of the eastern Weddell Sea along the western Dronning Maud Land coast is more clearly characterized by the prominent bathymetric expression of the Explora Escarpment and the massive volcanic flows along the Explora Wedge (Figure 2), identified by the abundance of seaward dipping reflectors (SDRs) in the seismic reflection data. A number of deep crustal seismic refraction profiles cross the Explora Wedge and the Explora Escarpment and allow models showing a 70-km to 90-km-wide transitional crust thinning from about 20 km thickness to 10 km thickness toward the north (e.g., Jokat et al., 2004). Relatively high P-wave velocities in the lower crust and in the upper crustal section of the SDRs (Jokat et al., 2004) are evidence for a volcanic-type continental margin.

Dronning Maud Land (DML) Sector Conjugate to Africa

Data and syntheses of the central and eastern Dronning Maud Land (DML) margin stem from work by Hinz and Krause (1982), Hübscher et al. (1996b), Roeser et al. (1996), Jokat et al. (2003, 2004), Hinz et al. (2004), and König and Jokat (2006). The recent plate-kinematic reconstructions by Jokat et al. (2003) and König and Jokat (2006) show that southeast Africa was conjugate to the DML margin (Figure 3) from just east of the Explora Escarpment to the Gunnerus Ridge. However, this DML margin has two distinct parts, separated by the Astrid Ridge. The eastern Lazarev Sea margin is characterized by a COT consisting of a broad stretched continental crust and up to 6-km-thick volcanic wedges clearly identified by SDR sequences. Deep crustal seismic data show that the crust thins in two steps from 23 km to about 10 km thickness over a distance of 180 km (König and Jokat, 2006). Their velocity-depth model reveals high seismic P-wave velocities in the lower crust of this COT, suggesting voluminous underplating and intrusion of magmatic material. A coast-parallel strong positive and negative magnetic anomaly pair marks the northern limit of the COT and is interpreted as the onset of the first oceanic crust generated by spreading processes at chron M12 (136 Ma). The volcanic characteristics of the eastern Lazarev Sea segment is very likely to be related to the same magmatic events leading to the Early Cretaceous crustal accretion of a Large Igneous Province (LIP) consisting of the separated oceanic plateaus Maud Rise, Agulhas Plateau, and Northeast Georgia Rise (Gohl and Uenzelmann-Neben, 2001) and to which also parts of the Mozambique Ridge may have belonged.

At the Riiser-Larsen Sea margin east of the Astrid Ridge, the outer limit of the COB is constrained by densely spaced aeromagnetic data revealing spreading anomalies up to M24 (155 Ma) (Jokat et al., 2003). This is so far the oldest magnetic seafloor spreading anomaly observed along any of the circum-Antarctic margins. Seismic reflection data (Hinz et al., 2004) indicate a COT of stretched continental crust that is with 50 km width much narrower compared with the COT of the Lazarev Sea margin. However, the data do not seem to indicate a strong magmatic influence of the COT as major

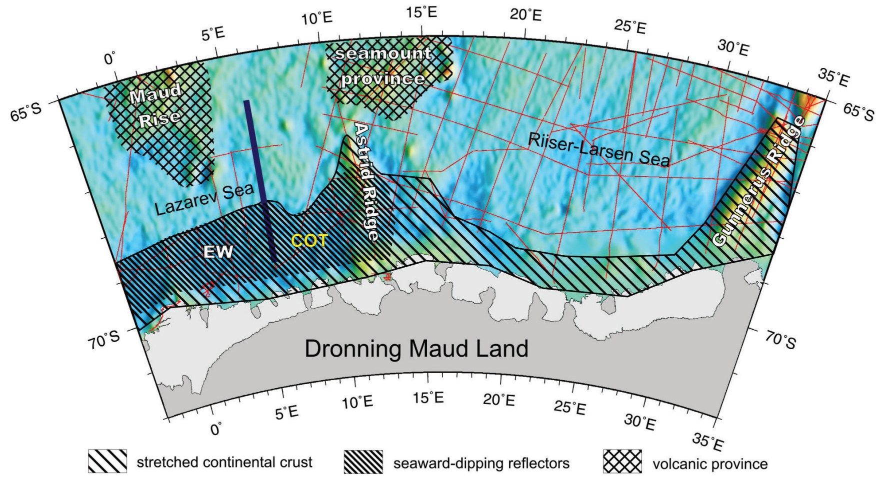

FIGURE 3 Dronning Maud Land sector with satellite-derived gravity field (McAdoo and Laxon, 1997) and continental margin features. Red lines show the tracks of offshore multichannel seismic profiles of SDLS. The dark blue line marks the location of an offshore deep crustal seismic refraction profile. COT = continent-ocean boundary; EW = Explora Wedge.

SDRs are missing (Hinz et al., 2004). Deep crustal seismic refraction data do not exist to better characterize this part of the DML margin and its COT or COB.

Enderby Land to Lambert Rift (EL) Sector Conjugate to India

Most of the crustal and sedimentary structures of the continental margins off Enderby Land (east of Gunnerus Ridge), between Prydz Bay and the Kerguelen Plateau, off Wilhelm II Land and Queen Mary Land (Figure 4) have been revealed by large seismic datasets acquired by Russian and Australian surveys (e.g., Stagg et al., 2004, 2005; Guseva et al., 2007; Leitchenkov et al., 2007a; Solli et al., 2007). Gaina et al. (2007) developed a breakup model between India and this East Antarctic sector based on compiled magnetic data of the southernmost Indian Ocean and the structures of the continental margin interpreted from the seismic data. Despite the large amount of high-quality seismic reflection data, the definition of the COB or COT is equivocal due to the lack of deep crustal seismic refraction data with the exception of nonreversed sonobuoy data. Stagg et al. (2004, 2005) defined the COB as the boundary to a zone by which the first purely oceanic crust was accreted and which shows a changeover from faulted basement geometry of stretched continental crust to a relatively smoother basement of ocean crust. This boundary is often accompanied by a basement ridge or trough.

The Enderby margin can be divided into two zones of distinct character. West of about 58°W the ocean fractures zone terminates in an oblique sense at the margin, thus giving it a mixed rift-transform setting (Stagg et al., 2004). Their defined COB lies between 100 km and 170 km oceanward of the shelf edge. Gaina et al. (2007) identified spreading anomalies from M0 to M9 east of Gunnerus Ridge from relatively sparse shipborne magnetic data. Most of both magnetic and seismic profiles do not parallel the spreading flow lines and may be biased by the structure and signal of crossing fracture zones. The eastern Enderby margin zone has more of a normal rifted margin setting with a COB up to 300 km north of the shelf edge (Stagg et al., 2004). The prominent magnetic Mac Robertson Coastal Anomaly (MCA) correlates with the northern limit of the COT in this eastern zone. Ocean-bottom seismograph data along two seismic refraction profiles were recently acquired in the eastern Enderby Basin and across the Princess Elizabeth Trough (PET) between the Kerguelen Plateau and Princess Elizabeth Land as part of a German-Russian cooperation project (Gohl et al., 2007a) (Figure 4). The western profile confirms an extremely stretched crystalline continental crust, which thins to 7 km thickness (plus 4 km sediments on top), from the shelf edge to the location of the MCA. It is interesting to note that apart from a few scattered observations close to the marked COBs, major SDR sequences do not seem to exist on the Enderby Land margin (Stagg et al., 2004, 2005), suggesting the lack of a mantle plume at the time of breakup at about 130 Ma (Gaina et al., 2007).

The characteristics of the margin off central and eastern Prydz Bay is affected by both the inherited structure of the Paleozoic-Mesozoic Lambert Rift system as well as by magmatic events of the Kerguelen Plateau LIP, probably postdating the initial India-Antarctica breakup by about 10 million to 15 million years (Gaina et al., 2007). Guseva et al. (2007) proposed a direct connection between the volcanic Southern Kerguelen Plateau crust and stretched continental crust of Wilhelm II Land. The recent deep crustal seismic refraction data and a helicopter-magnetic survey, however, provides constraints that the central part of the PET consists of oceanic crust, possibly affected by the LIP event (Gohl et al., 2007a). This result is used to draw a narrow zone of stretched continental crust that widens eastward along the margin of the Davis Sea (Figure 4), where it reaches the width of the COT in the area of Bruce Rise as suggested by Guseva et

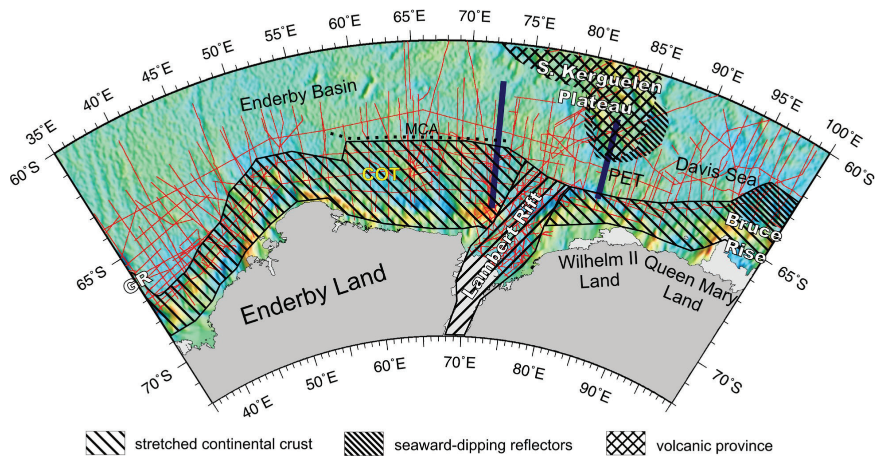

FIGURE 4 Enderby Land-Lambert Rift sector with satellite-derived gravity field (McAdoo and Laxon, 1997) and continental margin features. Red lines show the tracks of offshore multichannel seismic profiles of SDLS. Dark blue lines mark the locations of offshore deep crustal seismic refraction profiles. COT = continent-ocean boundary; PET = Princess Elizabeth Trough; GR = Gunnerus Ridge; MCA = Mac Robertson Coastal Anomaly.

al. (2007). Similar to observations along the Enderby Land margin, major SDR sequences are not observed on the Antarctic margin of the Davis Sea but only around the margins of the Southern Kerguelen Plateau. However, SDRs appear as strongly reflecting sequences at Bruce Rise (Guseva et al., 2007).

Wilkes Land (WL) Sector Conjugate to Australia

A vast amount of seismic reflection, gravity, and magnetic data as well as nonreversed sonobuoy refraction data collected by Australian and Russian scientists in the last few years allows a characterization of the Wilkes Land and Terre Adélie Coast margin east of Bruce Rise (Figure 5) (Stagg et al., 2005; Colwell et al., 2006; Leitchenkov et al., 2007b). Along most of this margin the shelf slope is underlain by a marginal rift zone of stretched and faulted basement. From the northern limit of this marginal rift zone to 90-180 km farther oceanward, Eittreim et al. (1985), Eittreim and Smith (1987), Colwell et al. (2006), and Leitchenkov et al. (2007b) identified a COT consisting primarily of strongly stretched and faulted continental crust with embedded magmatic segments following linear trends parallel to the margin. The interpretation of the COB along parts of the margin is debatable, as mainly basement characteristics were used for the differentiation of crustal types. It cannot be completely excluded that the magnetic anomalies interpreted as magmatic components are actually true seafloor spreading anomalies C33y and C34y, which would move the COB farther south. However, this seems unlikely based on the results of Colwell et al. (2006), Direen et al. (2007), and Sayers et al. (2001) in a comparison of the conjugate magnetic anomalies as well as new theoretical and analogue examples published in Sibuet et al. (2007). Reversed deep crustal refraction data would provide better constraints on the composition of the crustal units but are missing anywhere along this margin. However, in the absence of better data I adopted the interpretation by Colwell et al. (2006) and Leitchenkov et al. (2007b) of an up-to-300-km-wide zone of stretched continental crust (Figure 5).

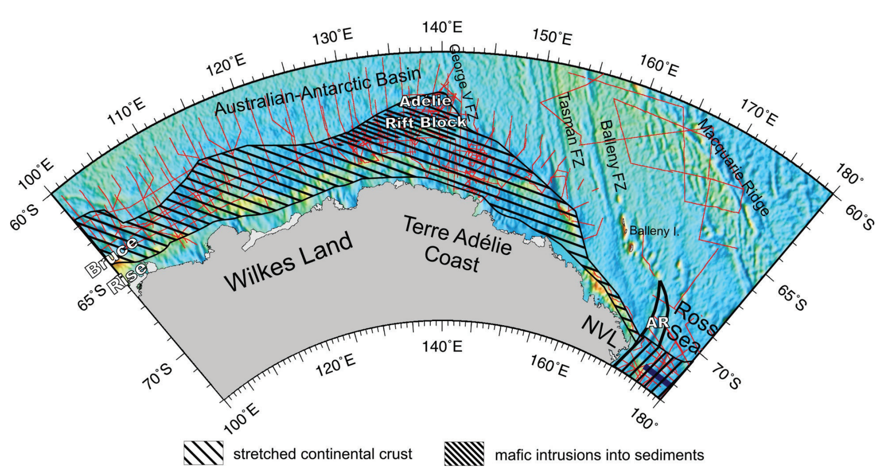

FIGURE 5 Wilkes Land sector with satellite-derived gravity field (McAdoo and Laxon, 1997) and continental margin features. Red lines show the tracks of offshore multichannel seismic profiles of SDLS. The dark blue line marks the location of an offshore deep crustal seismic refraction profile. NVR = Northern Victoria Land; AR = Adare Rift.

Off the Terre Adélie Coast margin the Adélie Rift Block, which is interpreted as a continental crustal block, is part of the stretched marginal crust. Major sequences of SDRs are not observed along the margin of the Wilkes Land sector, although Eittreim et al. (1985), Eittreim and Smith (1987), and Colwell et al. (2006) describe significant volumes of mafic intrusions within the sedimentary sequences of the landward edge of the Adélie Rift Block. The margin east of about 155°E toward the Ross Sea is characterized by prominent oblique fracture zones (e.g., Balleny FZ) reaching close to the shelf edge. This is similar to the rift-transform setting as observed in the western Enderby Basin but in an opposite directional sense. Stock and Cande (2002) and Damaske et al. (2007) suggest that a broad zone of distributed deformation was active at the margin, affecting the continental crustal blocks of Northern Victoria Land even after the initiation of ocean spreading.

The continental margin in the western Ross Sea underwent a rather complex development that makes a clear delineation of the COB difficult. A major proportion of the Ross Sea crustal extension is associated with a 180 km plate separation between East and West Antarctica when the Adare Trough was formed in Eocene and Oligocene time (Cande et al., 2000; Stock and Cande, 2002). The southward extension of this rift dissects the continental shelf region of the western Ross Sea (Davey et al., 2006).

Marie Byrd Land (MBL) Sector Conjugate to Zealandia

The eastern Ross Sea margin (Figure 6) is conjugate to the southwesternmost margin of the Campbell Plateau of New Zealand. Unlike the western Ross Sea margin, this margin can be considered a typical rifted continental margin with the oldest identified shelf-edge parallel spreading anomaly being C33y just east of the Iselin Rift (Stock and Cande, 2002). Seismic refraction data from a profile across the Ross Sea shelf by Cooper et al. (1997) and Trey et al. (1997) show a crust of 17-km to 24-km thickness with the thinnest parts beneath two troughs in the eastern and western region. It can be assumed that this type of stretched continental crust extends to the shelf edge at least. Whether crustal thinning is a result of the New Zealand-Antarctic breakup or extensional processes of the West Antarctic Rift System or both cannot be answered due to insufficient data in this area. It is also not known whether magmatic events affected the structure of the marginal crust.

Structural models of the continental margin of western Marie Byrd Land also suffer from the lack of seismic and other geophysical data. The only assumption for a sharp breakup structure and a very narrow transitional crust is derived from the close fit of the steep southeastern Campbell Plateau margin to the western MBL margin and coastal gravity anomaly (e.g., Mayes et al., 1990; Sutherland, 1999; Larter et al., 2002; Eagles et al., 2004). The same approach was applied for the closest fit between Chatham Rise and eastern MBL. However, new deep crustal seismic data from the Amundsen Sea indicate that the inner to middle shelf of the Amundsen Sea Embayment consists of crust thinned to about 21- to 23-km thickness with a pre- or syn-breakup failed rift structure (Gohl et al., 2007b). Here the continental margin structure is rather complex due to the propagating and rotating rifting processes between the breakup of Chatham Rise from the western Thurston Island block at about 90 Ma (Eagles et al., 2004), the opening of the Bounty Trough between Chatham Rise and Campbell Plateau (Eagles et al., 2004; Grobys et al., 2007), and the initiation of the breakup of Campbell Plateau from MBL at about 84-83 Ma (e.g., Larter et al., 2002; Eagles et al., 2004). The analysis of a crustal seismic refraction profile (Gohl et al., 2007b) and a seismic reflection dataset (Gohl et al., 1997b) between the

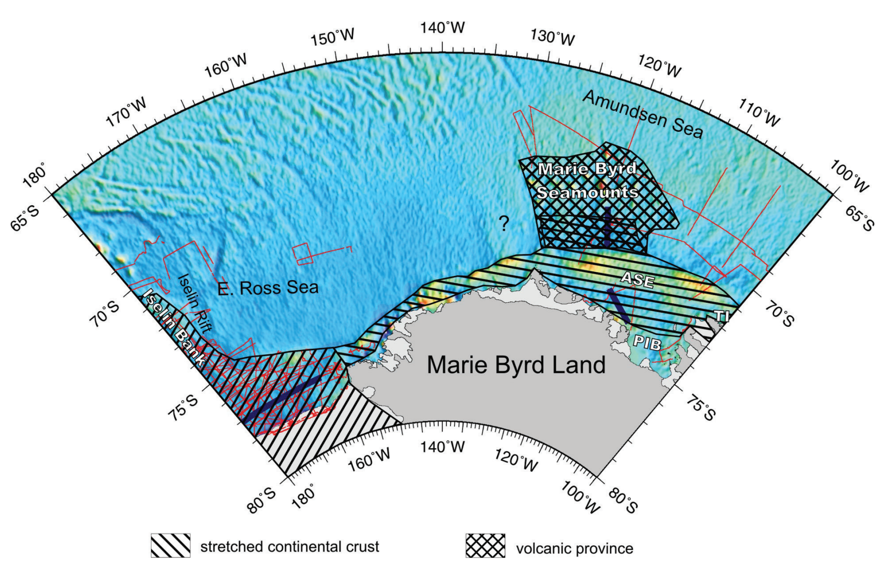

FIGURE 6 Marie Byrd Land sector with satellite-derived gravity field (McAdoo and Laxon, 1997) and continental margin features. Red lines show the tracks of offshore multichannel seismic profiles of SDLS. Dark blue lines mark the locations of offshore deep crustal seismic refraction profiles. ASE = Amundsen Sea Embayment; PIB = Pine Island Bay; TI = Thurston Island.

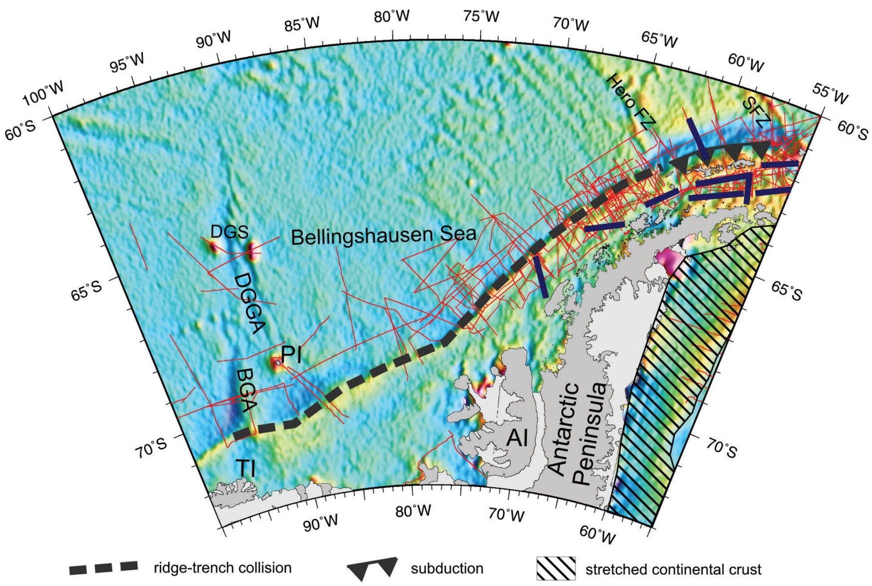

FIGURE 7 Antarctic Peninsula-Ellsworth Land sector with satellite-derived gravity field (McAdoo and Laxon, 1997) and continental margin features. Red lines show the tracks of offshore multichannel seismic profiles of SDLS. Dark blue lines mark the locations of offshore deep crustal seismic refraction profiles. AI = Alexander Island; TI = Thurston Island; PI = Peter Island; DGS = De Gerlache Seamounts; DGGA = De Gerlache Gravity Anomaly; BGA = Bellingshausen Gravity Anomaly; SFZ = Shackleton Fracture Zone.

shelf edge and the Marie Byrd Seamount province reveals that the crust in this corridor is 12-18 km thick, highly fractured, and volcanically overprinted. Lower crustal velocities suggest a continental affinity, which implies highly stretched continental crust or continental fragments, possibly even into the area of the seamount province. SDRs are not observed in the few existing seismic reflection profiles crossing the shelf and margin (Gohl et al., 1997a,b, 2007b; Nitsche et al., 2000; Cunningham et al., 2002; Uenzelmann-Neben et al., 2007).

SUBDUCTION TO RIDGE COLLISIONS: THE CONVERTED ACTIVE-TO-PASSIVE MARGIN

Antarctic Peninsula to Ellsworth Land (APE) Sector—Proto-Pacific Margin

Subduction of the Phoenix plate and subsequent collision of the Phoenix-Pacific spreading ridge resulted in a converted active to passive nonrifted margin along the Ellsworth Land and western Antarctic Peninsula margin between Thurston Island and the Hero Fracture Zone (e.g., Barker, 1982; Larter and Barker, 1991) (see Figure 7). The age for the oldest ridge-trench collision in the western Bellingshausen Sea can be roughly estimated to be about 50 Ma, using a few identified spreading anomalies (Eagles et al., 2004; Scheuer et al., 2006). Oceanic crustal age along the margin becomes progressively younger toward the northeast (Larter and Barker, 1991). Ultraslow subduction is still active in the segment of the remaining Phoenix plate between the Hero FZ and the Shackleton FZ along the South Shetland Trench. The only deep crustal seismic data along this converted margin south of the Hero FZ are from two profiles by Grad et al. (2002), showing that the crust thins oceanward from about 37 km thickness beneath the Antarctic Peninsula to a thickness of 25 to 30 km beneath the middle and outer continental shelf. The remains of the collided ridge segments cannot be resolved by the models. Data are also not sufficient to estimate any possible crustal extension of the western Antarctic Peninsula due to stress release after subduction ceded.

GEODYNAMIC AND PLATE-TECTONIC IMPLICATIONS AND COMPLICATIONS

The compilation of circum-Antarctic margin characteristics indicates that only a quarter (3400 km) of the rifted margins is of volcanic type, although uncertainties on volcanic and nonvolcanic affinity exist for about 4900 km (35 percent) of the rifted margins due to the lack of data in the Weddell Sea and along the MBL and Ross Sea margins. Only the eastern WL and western DML sectors as well as some isolated areas such as Bruce Rise of the EL sector and the Adélie Rift Block in the WL sector show well-observed magmatic characteristics that are explained by syn-rift mantle plumes or other smaller-scale magmatic events. Most other margins seem to have been formed by processes similar to those proposed for other nonvolcanic margins, such as the Iberian-Newfoundland conjugate margins (e.g., Sibuet et al., 2007) and the Nova Scotia margin (e.g., Funck et al., 2003), which exhibit widely extended, thinned, and block-faulted continental crust. Whether any updoming of lower continental crust is a possible process, as Gaina et al. (2007) suggest for the Enderby Land margin, is difficult to assess because of a lack of drill information.

Approximately 70 percent of the rifted passive margins contain continental crust stretched over more than 50 km oceanward of the shelf edge. In about two-thirds of these extended margins the COT has a width of more than 100 km, in many cases up to 300 km. The total area of extended continental crust on the continental shelf and beyond the shelf edge, including COTs with substantial syn-rift magmatic-volcanic accretion, is estimated to be about 2.9×10^6 km^2. Crustal stretching factors still remain uncertain for a good proportion of the extended margins due to a lack of crustal thickness measurements in most sectors. However, assuming stretching factors between 1.5 close to the shelf edge and in marginal rifts and increasing to 2 or 3 outboards in the deep sea, the continental crust, which has to be added to the original continent of normal crustal thickness, makes up about 1.5×10^6 km^2. The quantification of extended marginal crust has implications for plate-kinematic reconstructions, paleobathymetric models, and possibly for isostatic balancing of the Antarctic continent in glacial-interglacial cycles.

In almost all large-scale plate-kinematic reconstructions in which Antarctica is a key component, plate motions are calculated by applying rotation parameters derived from spreading anomalies and fracture zone directions, and continent-ocean boundaries are fixed single-order discontinuities, in most cases identified by the shelf edge or the associated margin-parallel gravity anomaly gradient (e.g., Lawver and Gahagan, 2003; Cande and Stock, 2004). This has caused misfits in terms of substantial overlaps or gaps when plates are reconstructed to close fit. For instance, a large misfit occurs when fitting the southeastern Australian margin to the eastern Wilkes Land margin in the area between 142°E and 160°E where extended continental crust reaches up to 300 km off the Terre Adélie Coast (Stock and Cande, 2002; Cande and Stock, 2004). In their reconstruction of the breakup processes of the Weddell Sea region, König and Jokat (2006) accounted for extended continental crust in the southern Weddell Sea and derived a reasonable fit of the conjugate margins of South America, Antarctica, and Africa. An appropriate approach for reconstructing best fits of continents and continental fragments is to apply a crustal balancing technique by restoring crustal thickness in rift zones and plate margins (Grobys et al., 2008). This, however, requires detailed knowledge of pre- and postrift crustal thickness, crustal composition, and magmatic accretion.

Detailed delineations of the COT and COB are important ingredients for paleobathymetric reconstructions. In the reconstruction of the circum-Antarctic ocean gateways (e.g., Lawver and Gahagan, 2003; Brown et al., 2006; Eagles et al., 2006), but also of the bathymetric features along nongateway continental margins, the differentiation between continental crust that was stretched and faulted and possibly intruded by magmatic material on one side and oceanic crust generated from spreading processes on the other side may make a significant difference in estimating the widths and depths along and across pathways for paleo-ocean currents.

Parameters of crustal and lithospheric extensions, depths, and viscoelastic properties are key boundary conditions for accurate calculation of the isostatic response from a varying ice sheet in glacial-interglacial cycles. Ice-sheet modelers still use relatively rudimentary crustal and lithospheric models of the Antarctic continent. Although the tomographic inversion of seismological data has improved the knowledge of the lithospheric structure beneath Antarctica and surrounding ocean basins (e.g., Morelli and Danesi, 2004), its spatial resolution of the upper 60-70 km of the relevant elastic lithosphere (Ivins and James, 2005), and in particular of the boundary between continental and oceanic lithosphere, is still extremely crude. Considering that ice sheets advanced to the shelf breaks of most Antarctic continental margins during glacial maxima, the isostatic response must be directly related to the width and depths of any extended continental crust and lithosphere oceanward of the shelf, which would probably have an effect on estimates of sea-level change. To quantify this effect, good-quality deep crustal and lithospheric data are needed to derive the geometries and rheologies of the extended crust and lithospheric mantle.

CONCLUSIONS

In a comprehensive compilation of circum-Antarctic continental margin types, about 70 percent of the rifted passive margins contain extended continental crust stretching more than 50 km oceanward of the shelf edge. Most of these extended margins have a continent-ocean transition with a width of more than 100 km—in many cases up to 300 km. Only a quarter of the rifted margins seem to be of volcanic type. The total area of extended continental crust on the shelf and oceanward of the shelf edge, including COTs with substantial syn-rift magmatic-volcanic accretion, is estimated to be about 2.9×10^6 km^2. This has implications for improved plate-kinematic and paleobathymetric reconstructions and provides new constraints for accurate calculations of isostatic responses along the Antarctic margin.

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