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Crustal structure of the Antarctic Peninsula sector of the Gondwana margin around Anvers Island from geophysical data

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ABSTRACT

We investigated the crustal structure of the northern Antarctic Peninsula (AP) — a composite magmatic arc terrane at the Pacific margin of Gondwana. It was formed in Mesozoic–Cenozoic by collision/accretion of allochthonous terranes to the Gondwana margin during subduction and progressive ridge collision of former Phoenix Plate under the AP. The AP is distinguished by belts of high-amplitude, gravity and magnetic anomalies, inferred to indicate the presence of plutons of mafic composition comprising the huge AP batholith. For a better understanding of the lithosphere structure and tectonic processes of the AP continental margin we performed 2D gravity and magnetic modeling along line III-III, which crosses the margin south of Anvers Island. Our model incorporates data on seismic refraction (DSS-13) and reflection (line 8545-03) profiles and physical property data.

Our modeling shows that the crust of the AP margin near Anvers Island is of continental type and comprises two crustal domains, which were welded together during mid-Cretaceous collision. On the east there is a thick (~40 km), high-velocity/density continental crust of the Gondwana margin, which occupies the AP inner shelf and mainland, and Larsen Ice Shelf. The space between the Gondwanian block and oceanic crust of the Bellingshausen Sea is occupied by thinner (~26 km) crust of lower densities of supposed accreted terrane, characterized by gravity anomalies caused probably by accretional tectonics as a result of Cretaceous subduction. Two belts of magnetic anomalies forming the PMA (Pacific Margin Anomaly) probably belong to different crustal domains: the western belt of the PMA relates to accretional block, while the eastern belt of the PMA corresponds to the Gondwana margin block. This may represent an evidence that the PMA relates to a tectono-magmatic event occurred after collision of Gondwana margin and accreted terrane (in mid-Cretaceous) and had been imprinted on already formed continental margin.

1. Introduction

The tectonic history of the Antarctic Peninsula (AP), the largest block of the five blocks of West Antarctica (Dalziel and Elliot, 1982; Storey, 1991; Storey et al., 1988), relates to the interaction between accretionary orogenesis driven by paleo-Pacific plate processes and Gondwana break-up. The Pacific margin of the AP has been an active margin before the break-up of Gondwana (Vaughan and Pankhurst, 2008) and subduction continued through the remainder of the Mesozoic era (Pankhurst, 1982, 1990). During the Cenozoic, ridge crest segments of the Antarctic–Phoenix spreading center arrived progressively to the northeast along the margin (Jin et al., 2002; Larter et al., 1997). The last segment to reach the margin arrived obliquely just southwest of the Hero Fracture Zone between 6.4 and 3.3 Ma (Larter et al., 1997). The Pacific margin of the AP is generally thought to be active to the northeast of the Hero Fracture zone (Fig. 1); to the southwest from this zone the AP margin is considered to be passive, representing a locked-up subduction zone due to the trench being drawn in.

New interpretation for the Mesozoic evolution of the AP geology and new airborne geophysical data (gravity and magnetic) reveal evidences of crustal growth of the AP by Mesozoic arc magmatism and terrane accretion along the paleo-Pacific margin of Gondwana (Ferraccioli et al., 2006; Vaughan and Storey, 2000). The paleo-Pacific margin of Gondwana is now recognized as a long-lived accretionary orogen, active from Neoproterozoic times at least (Cawood, 2005; Vaughan and Pankhurst, 2008). Accretionary orogenesis, driven by paleo-Pacific plate processes, continued right through Gondwana break-up, as argued by Vaughan and Livermore (2005). The main composite terranes are seen in the pattern of potential fields. Satellite, aero and ship-born potential field data have been compiled into publicly available databases of the ADMAP and ADGRAV projects and are published in many papers (Ferraccioli et al., 2006, 2007; Golynsky et al., 2001; Jokat et al., 2003; Kim et al., 2002, 2007; McAdoo and Laxon, 1997). The Pacific margin of the AP is marked by belts of strong gravity and magnetic anomalies attributed to a magmatic arc system consisting of a series of plutons (Garrett, 1990; Garrett and Storey,

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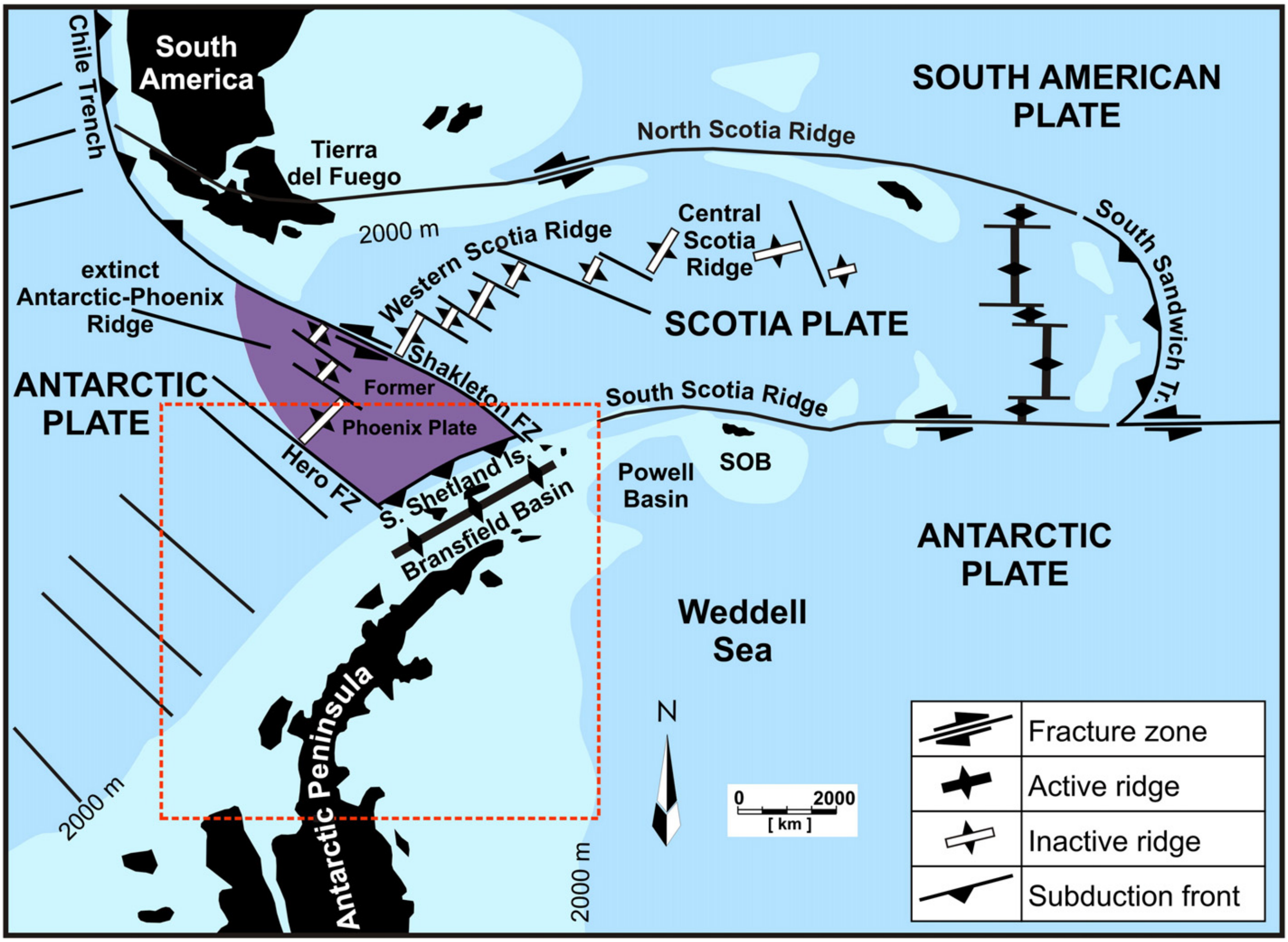

Fig. 1. Main tectonic elements of Antarctic Peninsula and Scotia Sea (Larter and Barker, 1991). Dashed red line rectangle shows the study region (Figs. 2, 3 and 5). Light blue shows bathymetry shallower than 2000 m. Abbreviation SOB — South Orkney Block.

1987; Renner et al., 1985) comprising the giant AP batholith (Leat et al., 1995).

The shelf of the AP is the best-studied region in Antarctica by seismic refraction study. Here a network of more than 20 seismic profiles was acquired using the explosions in the sea of between 25 and 120 kg of TNT that made it possible to investigate the structure of the crust and upper mantle and to compile a Moho map for the region (Grad et al., 1992, 2002; Guterch et al., 1998; Janik et al., 2006; Środa et al., 1997). The AP margin was covered by a dense network of seismic reflection lines carried out within the framework of the Antarctic Offshore Acoustic Stratigraphy (ANTOSTRAT) Project (Cooper and Webb, 1992, 1994). Interpretation of ANTOSTRAT Project data allowed subdivision of the AP shelf into an inner shelf, shelf basins and the basement high on the mid-shelf, and a prograded outer shelf (Jin et al., 2002; Larter et al., 1994, 1997). As a result, the AP continental margin is well-characterized by geophysical methods (seismic and potential fields) and is a region of Antarctica that makes it posssible to develop joint geophysical models for the crust and upper mantle using several geophysical parameters (Yegorova et al., 2011).

The main objective of our study was to develop a series of joint geophysical models along the interpretation profiles that cross the continental margin of the AP at the location of DSS profiles (Figs. 2–5). This study was started by setting up of two geophysical models across the AP continental margin (lines I-I and II-II in Fig. 2; Yegorova et al., 2011). Present work extends our analysis further south on the AP and presents a joint geophysical model for the crust structure on line III-III, which crosses the AP south of Anvers Island (for location see Figs. 2–5) at the location of seismic refraction and reflection lines. These seismic data constrained the geometry of 2-D gravity and magnetic models that used satellite-derived free-air gravity anomalies and total field magnetic anomalies.

2. Geological and tectonic setting

The AP was traditionally regarded as a magmatic arc formed along the paleo-Pacific margin on the outer edge of Gondwana (Storey and Garrett, 1985). Paleotectonic reconstructions show that in the Late Cretaceous the Phoenix Plate was subducted at the western AP margin (Larter et al., 2002). During the Late Mesozoic and Cenozoic subduction has stopped progressively from southwest to northeast as a result of a series of ridge–trench collisions (Larter and Barker, 1991). Subduction is only active today in the northern part of the AP adjacent to the South Shetland Islands located between the Skackleton and Hero fracture zones (Fig. 1). Northward subduction of the Weddell Sea floor also occurred until mid-Miocene times beneath the far eastern part of the AP as described by Bohoyo et al. (2002).

Reevaluation of the structural and tectonic Mesozoic evolution of the AP suggest that it is a composite magmatic arc comprising two or three separate terranes that were accreted and sutured in mid-Cretaceous (Ferraccioli et al., 2006; Vaughan and Storey, 2000). Vaughan et al.