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New insights on the post-rift seismic stratigraphic architecture and sedimentary evolution of the Antarctic Peninsula margin (Central Bransfield Basin)

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ABSTRACT

A seismic stratigraphic study of the Antarctic Peninsula margin of the Central Bransfield Basin was conducted using seismic and bathymetric data. The study focused on seismic sequences and units deposited after the basin opened, and yield a record of the evolution of the northern-most Antarctic Peninsula Ice Sheet. Two seismic sequences compose the post-rift stratigraphic succession on the Central Bransfield Basin slope platforms. Both sequences are composed of seismic units that record glacial/interglacial cycles and show evidence of the Antarctic Peninsula Ice Sheet having grounded on the continental shelf and slope platform on several occasions in the past. This evidence includes glacial and glaciomarine related sedimentary and erosional features within the seismic units (glacial unconformities, glacial troughs, till wedges, prograded wedges, trough mouth fans, glaciomarine sheet deposits and moraines), which are bounded by glacial unconformities. The Antarctic Peninsula lower slope also registered in its eastern sector the deposition of gravity flow deposits during ice sheet retreat and interglacial stages. The deposition of seismic units on the middle slope produced the present-day step-like profile of the margin composed of wide flat slope platforms and narrow and steep upper and lower slopes. Seismic units show changes in thickness and distribution that record the effect of the physiography and climatic changes on margin sedimentation. These variations produced an overall change from more line-sourced deposition to more point sourced deposition as ice streams evolved.

The stacking of units shows a change in the stratigraphic architecture through time, from dominantly progradational (S2) to progradational/aggradational (S1). This change is correlated with a change in the frequency of ice sheet grounding events which was probably driven by a higher rate of eustatic rise and fall in relation with the Mid Pleistocene global climatic change.

1. Introduction

Glacial and glaciomarine sedimentary processes have dominated on the Antarctic Peninsula since the Oligocene (Barker and Camerlenghi, 2002). The Antarctic Peninsula (AP) is considered a key region for the study of glacial cyclicity, due to its high sensitivity to climatic changes (Anderson, 1999; Barker et al., 1999). Its thick Plio-Quaternary sediment fill makes the Bransfield Basin particularly well suited for examining the stratigraphic record of climate change and glacial evolution in the northern Peninsula region (Fig. 1).

Previous studies dealing with the seismic stratigraphy of the Central Bransfield Basin (CBB) provided the framework for this investigation (Jeffers and Anderson, 1990; Banfield and Anderson, 1995; Prieto et al., 1999), which focuses on the analysis of seismic sequences of the continental shelf to slope and the study of the factors that control the stratigraphic architecture in the basin. This work also aims to establish a new constraint on the chronology of glacial cyclicity and to interpret the global and local factors that have controlled deposition on the Antarctic Peninsula margin of the CBB after its opening.

2. Geological setting

The Bransfield Basin is located in the northernmost part of the AP (Fig. 1). It is defined by a narrow NE-SW oriented strait which separates the AP to the southeast and the South Shetland Islands (SSI) to the northwest. The Bransfield Basin developed in a complex tectonic setting, after the cessation of the spreading of the Phoenix–Antarctic Ridge approximately 4 Ma (Barker and Burrell, 1977; Anderson et al., 1990; Jeffers and Anderson, 1990; Barker, 2001; Galindo-Zaldívar et al., 2004). The opening of the basin began approximately 3.3 Ma and is related to roll-back processes (Barker and Dalziel, 1983; Larter and Barker, 1991; Maldonado et al., 1994; Galindo-Zaldívar et al., 2004) that resulted in northwestward migration of the South Shetland Block and the propagation along its SE boundary of structural features associated with the Scotia/Antarctic plate boundary (Galindo-Zaldívar et al., 1996, 2004). Regional left-lateral strike-slip motion related to convergence between the Phoenix and Antarctic plates and ongoing subduction by a rollback

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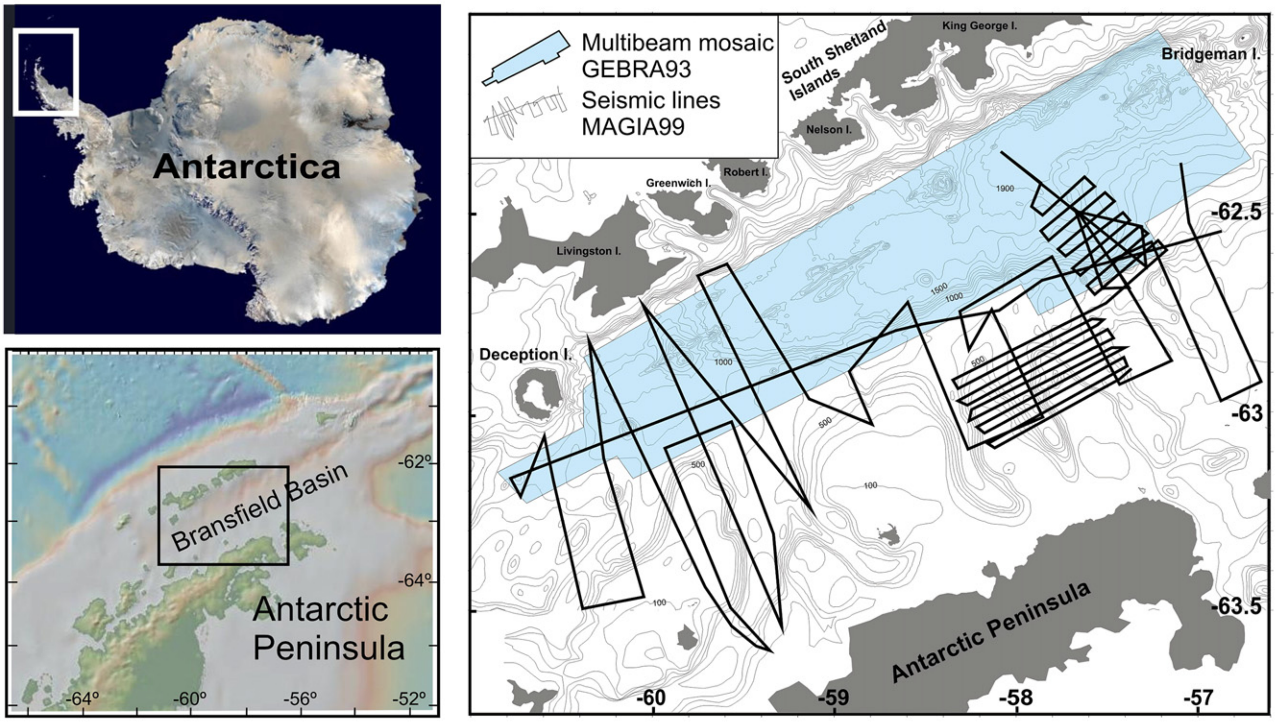

Fig. 1. Location of the study area at the northern extreme of the Antarctic Peninsula. The dataset includes seismic lines obtained during the MAGIA99 cruise and a multibeam survey conducted during the GEBRA93 cruise, both on board the R/V Hespérides.

mechanism are the main processes that controlled extension in the basin (Maestro et al., 2007).

The CBB is separated from the western and eastern basins by morphological steps that occur approximately in line with Deception and Bridgeman Islands, respectively (Jeffers and Anderson, 1990; Fig. 1). These steps have been interpreted as the morphological expression of tectonic scarps caused by NW-trending faults (Gràcia et al., 1996; Prieto et al., 1999), or as the result of regional doming in association with submarine edifices (Lawver et al., 1996). The structure of the CBB is dominated by two families of faults, northeast- and northwest-trending (Gràcia et al., 1996; Prieto et al., 1998). It is argued that incipient seafloor spreading of the CBB (Prieto et al., 1998) has resulted in the formation of up to 25 km of new crust (Barker and Burrell, 1977; Gràcia et al., 1996; Galindo-Zaldívar et al., 2004). A linear chain of volcanic edifices located along the axis of the basin has been attributed to this spreading (Gràcia et al., 1996). The most prominent of these are Volcanic Edifice A, Three Sisters, Orca and Volcanic Edifice F (Gràcia et al., 1996; Lawver et al., 1996).

The first seismic stratigraphic investigation of the CBB led to the recognition of two major onlapping stratigraphic units on the continental slope, designated S2 and S1, from older to younger (Jeffers and Anderson, 1990). These were interpreted as representing two complete third order glacial/eustatic cycles that occurred since approximately 1.6 Ma. This work was followed by a stratigraphic study by Banfield and Anderson (1995), which identified at least three glacial and interglacial cycles based on an acoustic facies analysis. Prieto et al. (1999) studied a larger dataset, which led to recognition of additional stratigraphic units. They interpreted the overall stratigraphic package as being composed of two main sequences, lower and upper, overlying the deformed acoustic basement. The lower sequence is interpreted as a syn-rift sequence and the upper sequence as a post-rift sequence. The upper sequence is divided into eight seismic units: four slope progradational units, interpreted as glacial units, and four basinal aggradational units, interpreted as interglacial units.

Other relevant studies have focused on geomorphic features and sediment cores that provide compelling evidence for the Antarctic Peninsula Ice Sheet having grounded at depths below approximately 900 m in the CBB during the Last Glacial Maximum (LGM). The evidence includes morainal ridges, drumlins, megaflutings and glacial lineations (Canals et al., 2002; Heroy and Anderson, 2005; García et al., 2006). The glacial lineations show a marked change of direction, from a trough-parallel trend (NNW-N) at the troughs' bottoms to an almost basin axis-parallel (N-NE) trend at the slope platforms (García et al., 2006). Sediment cores provide radiocarbon ages, which indicate that the retreat of the ice sheet from the continental shelf began around 17340 cal yr B.P (Heroy and Anderson, 2005).

3. Methods

This work is based on the study of single-channel airgun seismic reflection profiles acquired during the MAGIA99 cruise on board the R/V Hespérides (Fig. 1). Most lines were oriented perpendicular to the margin, from the continental shelf to the slope. The data were collected using four 40 in^3 in sleeve-guns, located at a depth of 3.5 m and with a shot frequency of 8 s. The penetration of the acoustic signal was 2–3 s two-way travel time, and the resolution was tens of meters (i.e., an average resolution of 10/15 m). Data were acquired with a SIG streamer with a 150 m active section, including three independent channels with 40 hydrophones each. A GeoAcoustics Sonar Enhancement System (SES) was used for data acquisition and processing. Sampling frequency was 1 ms and the recording window was from 4 to 8 s. Navigation was with a Global Positioning System (GPS). Kingdom Suite software has been used to analyze and interpret the seismic profiles and also to extract the thickness of the different seismic sequences and units. The latter information has been converted into isopach maps with Surfer software.

Swath bathymetry data were obtained during the GEBRA 93 and MAGIA 99 cruises on board the R/V Hespérides (Fig. 1) with SIMRAD EM12 and EM1000 systems. These data were processed with NEPTUNE and Caraibes software. The regional bathymetric map published by the Polish Polar Academy of Sciences (1990) was used for the physiographic characterization of the study area.