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Post-rift sedimentary evolution of the Gebra Debris Valley. A submarine slope failure system in the Central Bransfield Basin (Antarctica)

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ABSTRACT

The combined analysis of paleomorphology, stratigraphy and seismic facies allows us to present new insights into the formation and evolution of the Gebra Valley, located on the lower continental slope of the Central Bransfield Basin (NE Antarctic Peninsula). Repeated large-scale slope failure events were responsible for the cut-and-fill features forming the Gebra Valley. This study revealed a mid-Pleistocene Gebra paleovalley that was progressively and completely infilled. During the last glacial cycle the infilled paleovalley was reoccupied, forming the present day Gebra Valley. Both valley incisions are genetically related to large-scale failures associated with high-energy gravity flows or mass flows. The infilling of the valley involved channelized mass flows of various dimensions and channelized and unchannelized turbidity currents. Alternating erosive periods, during which the valley evacuated sediment from the slope toward the basin, and depositional periods, during which it was fully infilled, allows it to be defined as the "Gebra Debris Valley". Taking into account the presence of faults controlling the headwall locations and the stratigraphic correlation established with glacial periods, the genesis of the Gebra Debris Valley could have been controlled by the interplay of both the tectonic history of the Bransfield Basin and the glacial cycles that allowed grounding events to reach the upper continental slope.

1. Introduction

Large-scale submarine slides have been documented on glaciated or glacially influenced margins (Bugge, 1983; Kenyon, 1987; Evans et al., 1996; Dowdeswell et al., 1998; Vorren et al., 1998; Bart et al., 1999; Laberg and Vorren, 2000; Taylor et al., 2000; Imbo et al., 2003; Taylor and Leventer, 2003; Solheim et al., 2005). During glacial periods large amounts of sediment are delivered to the upper continental slope, forming thick deposits and increasing the likelihood of gravitational instability (Dowdeswell et al., 1998; Bryn et al., 2005; Donda et al., 2008; Lee, 2009). Submarine landslides are influenced by the size, location and sedimentology of migrating depocenters, changes in seafloor pressures and temperatures, variations in seismicity and volcanic activity (Lee, 2009).

In contrast to the Northern Hemisphere, large slides and mass-flow deposits are less common on the Antarctic margins (Rebesco and Camerlenghi, 2008). The best-documented examples are the Gebra Valley (Imbo et al., 2003), the Alexander Channel mega debris flow deposit on the western margin of the Antarctic Peninsula (Diviacco et al., 2006), mass wasting deposits in the Weddell Sea (Bart et al., 1999) and mega debris flow deposits on the Wilkes Land margin (Donda et al., 2008).

The Gebra Valley, located on the lower continental slope of the Central Bransfield Basin (CBB), was discovered in 1993 (Canals et al., 1994; Gracia et al., 1996; Ercilla et al., 1998), and was later associated to a large slide (Imbo et al., 2003). Recently, it has been included in the so-called Gebra–Magia complex (García et al., 2008), defined as a large area of mass wasting that includes two large striking valleys, Gebra and Magia, which are clearly recognizable from bathymetry and probably had a common origin (García et al., 2009) (Fig. 1).

In this article we present new insights into the formation and evolution of the Gebra Valley. In particular, we aim to characterize the morphology and different sedimentary processes which have shaped the Gebra Valley and their relationships with tectonics and climate.

2. Regional framework

The Bransfield Basin (BB) is a young and active rift basin (Barker, 1982; Larter and Barker, 1991) located off the northern tip of Antarctica, between the Antarctica Peninsula (AP) and the South Shetland Islands (Fig. 1). BB is an asymmetric ENE–WSW-trending basin, 230 km long and 125 km wide which can be divided into three sub-basins: the eastern, central and western basins. These basins are separated by structural

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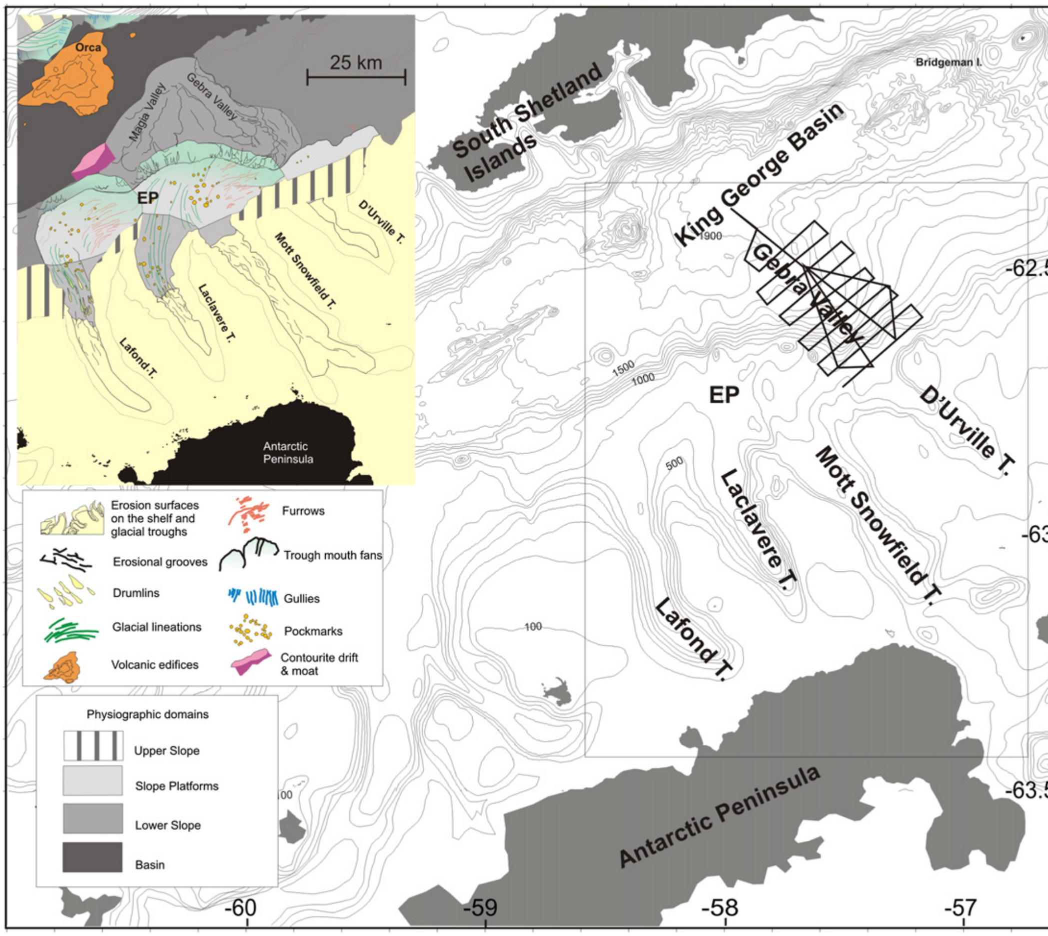

Fig. 1. General bathymetry of Bransfield Basin and morphological map of the study area (modified from García et al., 2008). Location of the available geophysical data is also displayed.

steps produced by NW-trending faults (Jeffers et al., 1991; Gràcia et al., 1996; Prieto et al., 1998).

The physiography of the CBB is atypical in several aspects when compared with other glacial margins (Jeffers et al., 1991; Anderson, 1999; García et al., 2008). The continental slopes of both the Antarctic Peninsula (AP) and South Shetland Islands are characterized by relatively flat slope platforms in their middle slope domains, while the lower slope connects sharply to the basin without defining a continental rise.

The main provinces defined in the AP continental margin in the CBB are the shelf and the upper and lower slopes, locally interrupted by large striking terraces (Ercilla et al., 1998; García et al., 2008). The continental shelf extends down to 200 to 300 mwd, becomes deep and wide (50 km maximum width) toward the southwest and has average gradients of 1.5°. The shelf is eroded by N to NW-trending glacial troughs (Fig. 1). The upper slope (from 200 to 800 mwd) is a narrow (<10 km wide) and steep (up to 15°) scarp. The slope platforms comprise two terraces, up to 35 km wide, known as the Western (WP) and Eastern (EP) Platforms, which develop between 500 and 1100 mwd, with gradients of between 0° and 6°. The lower slope is steeper (up to 20°), is 5 to 10 km wide, and extends down to 1500 mwd. The Gebra Valley is located in the northeastern CBB close to the morphological step that separated the CBB and the Eastern Bransfield Basin, and is surrounded by the EP to the west and the lower continental slope to the east (Fig. 1). The Gebra and the Magia Valleys are the main outstanding erosive features in the area.

The Antarctic Peninsula continental margin connects with the King George Basin, which is a relatively low gradient (2° average) surface that deepens toward the NE, reaching a maximum depth of 1940 mwd.

2.1. Tectonic setting

The BB developed after the spreading of the Phoenix–Antarctic Ridge ceased at about 4 Ma (Barker and Burrell, 1977; Jeffers et al., 1991; Barker, 2001; Galindo-Zaldívar et al., 2004). The opening of the basin began at approximately 3.3 Ma and is related to rollback processes (Barker and Dalziel, 1983; Larter and Barker, 1991; Maldonado et al., 1994; Galindo-Zaldívar et al., 2004). Regional left-lateral strike-slip motion related to convergence between the Phoenix and Antarctic plates and ongoing rollback are the main processes that have controlled extension in this basin (Maestro et al., 2007).

The study area is located at the transition between two morphostructural segments of the AP margin (the central and eastern basins). The distinct morphological changes across this boundary are attributed to a first-order tectonic segmentation of the entire BB (Barker and Austin, 1994). In this context, the main, widely distributed tectonic features identified in the area are extensional as well as a few compressional structures (Prieto et al., 1998). The extensional structures consist of normal faults that bound graben systems. These faults, which appear to have been continuously active during the evolution of the CBB, are NE-trending (50°N to 75°N) and NW-trending faults, ranging in orientation from 135°N to 165°N (Prieto et al., 1998). The NE-trending faults, with vertical offsets from 0.25 to 1.5 s, deepen the acoustic basement basinward producing a step-like morphology (Prieto et al., 1998).