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3D model of a sector of the South Scotia Ridge (Antarctica)

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Abstract

A three-dimensional geological model was built to show and analyse a northern sector of the Scotia–Antarctica transform plate boundary.

The South Scotia Ridge is a 400 km long submerged continental structural high representing the eastern continuation of the Antarctic Peninsula. South Scotia Ridge runs approximately in the E–W direction, separating Scotia Sea Plate from Antarctica Plates. Structures, due to the transform plate margin, are considered to be concentrated inside this continental high. The three-dimensional model, built using seismic profiles and a digital elevation model, is a powerful tool to visualize and help to understand deep geological structures. Maps and profiles, on the contrary, only give a two-dimensional view, and do not show the structure of the continental–oceanic boundary at depth.

The model shows that the deformation style of the continental–oceanic boundary, and of the oceanic crust nearby, is related to the left-lateral movement of the main transform fault system. Furthermore, it seems to be connected to the orientation and geometry of the South Scotia Ridge with respect to the homogeneous deformation regime, which affects the entire Scotia Plate. Moving from west to east, the NW-dipping main fault surface becomes almost vertical with a sinistral strike–slip movement in the central sector. To the east, a south-dipping plane decreases its inclination and changes orientation (from E–W to ESE–WNW): here shortening features are visible.

The three-dimensional geological model presents a western and central province wherein the continental–oceanic boundary involves the fragmented continental blocks, the continental slope, the oceanic basement and sediments. The sedimentary cover and the oceanic basement are not deformed in the eastern province.

Keywords: Geological modelling; Visualization; Seismic reflection profiles; Transform margin; Scotia Sea

1. Introduction

The goal of this project is to define a method and workflow by which we can create three-dimensional (3D) models in geology. For such purposes we chose to test this method in an area well covered by data, and with scientific and applied interest in the national and international research environments. This paper shows a 3D geological model of the area between the northern flank of the South Scotia Ridge (SSR) and the Scotia Sea (continental–oceanic boundary: COB), and we draw geological conclusions from the model.

3D modelling is a powerful tool to visualize and assist understanding of deep geological structures. On the contrary, maps and profiles give a two-dimensional (2D) view without visualizing and

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interpreting the relationships between complex structures and other important geological features. Using the 3D model we can visualize and analyse the 3D representation of continental and oceanic crusts, sedimentary horizons and their deep structures, and then analyse the geological, structural and geomorphic features, their shape and dimensions.

This paper shows the methods and the workflow we followed during the 3D modelling process. We present new interpretations of the geology and structures derived from examination of the model.

2. Geological setting

The study area is the SSR, a submerged structural high that runs approximately E–W for about 400 km separating the Scotia Plate from the Antarctica Plate (Fig. 1). It represents both structurally and morphologically the eastern sub-sea continuation of the Antarctic Peninsula (Canals et al., 1992; Galindo-Zaldivar et al., 1994) and it is made up mainly of fragments of continental crust. The continental SSR structure is bounded southward and northward, respectively, by the oceanic domains of the Powell Basin and of the Scotia Sea.

The SSR structure presents an axial depression that contains four deep narrow asymmetric troughs (Galindo-Zaldivar et al., 1994). According to Pelayo and Wiens (1989) and Galindo-Zaldivar et al. (2002), the transcurrent plate boundary between Scotia and Antarctic plates is located along these deep troughs.

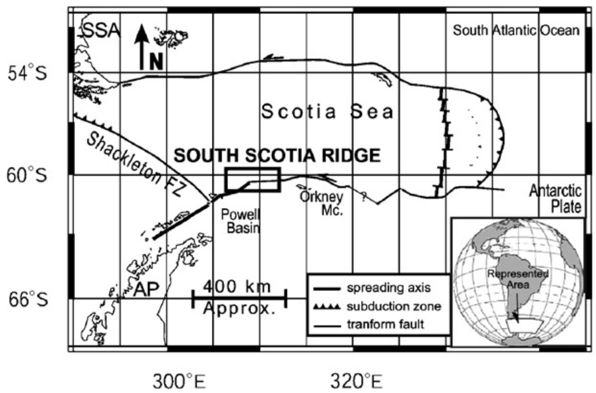

Fig. 1. Tectonic sketch of main geological structures and plate boundaries of Scotia Plate (modified from Giner-Robles et al., 2003). Black box outlines investigated area of South Scotia Ridge (SSR). Rectangle (in bottom right insert) shows Scotia Plate location with respect to globe. SSA: Southern South America; AP: Antarctic Peninsula.

The SSR is composed of fragments of the continental link between South America and the Antarctic Peninsula (Livermore and Woollett, 1993; Barker, 1995, 2001). This old margin was disrupted in the Tertiary period as a consequence of the development of the Scotia Sea (Barker and Burrell, 1977; Barker et al., 1991; Barker, 2001). Later, as a consequence of the new relative motion of the Scotia plate with respect to the South American and Antarctic plates (Barker and Hill, 1981; Larter and Barker, 1991; Barker et al., 1991) it became the site of left-lateral strike–slip movements.

3. Data set

Deep penetrating multi-channel seismic (MCS) measurements were conducted by the Italian R/V OGS-Explora during geophysical surveys in the peri-antarctic region of the Powell Basin and South Scotia Sea (campaigns between 1989 and 1995). The MCS reflection lines were carried out by the Osservatorio Geofisico Sperimentale (OGS) on behalf of the Italian "Programma Nazionale di Ricerche in Antartide". The seismic lines data were processed at the OGS Processing Centre in Trieste and at the CNR-Institute for Marine Research of Bologna (Lodolo et al., 1997; Susini et al., 2007).

The present study is based on the analysis of multi-channel seismic lines crossing the northern edge of the SSR in the area located approximately between South Orkney Island and Elephant Island (Fig. 2).

We used satellite-derived gravity data, downloaded from World Wide Web (Sandwell and Smith, 1997) in order to construct the digital elevation model (DEM).

4. 3D model

4.1. Construction

The 3D model construction used specialized software for geological modelling (2D-Move and 3D-Move produced by Midland Valley Exploration Ltd.), which implements algorithms developed for representing and analysing various structural settings. Seismic lines were interpreted underlining the main geological horizons and tectonic features (faults and folds). According to the interpretation of the seismic lines, the work-flow presented in Fig. 3 includes (i) seismic lines digitization, georeferencing in the UTM system (zone 22, 51°W),