The Osservatorio Geofisico Sperimentale marine magnetic surveys in the Antarctic Seas

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Abstract
About 40 000 km of marine magnetic and gradiometric data have been collected during eight geophysical surveys conducted since the Austral summer 1987/1988 in the circum-antarctic seas, by the research vessel OGS-Explora. For the most surveyed areas (Ross Sea, Southwestern Pacific Ocean, and Southern Scotia Sea), the analysis of the acquired data have contributed to clarify important aspects of their geological structure and tectonic evolution. The main scientific results, obtained combining other available geophysical data (multichannel seismic profiles and satellite-derived data), will be briefly illustrated.

Key words *marine magnetic and gradiometric profiles – sea-floor magnetic anomalies – tectonic reconstructions*

1. Introduction

Since 1987, the R/V OGS-Explora has conducted several geophysical cruises in the Ross Sea region, Southwestern Pacific Ocean, Scotia Sea, Pacific margin of the Antarctic Peninsula, and Southern Chile margin (fig. 1).

The amounts of marine magnetic data (acquired with a proton magnetometer and a proton gradiometer in the four last cruises, fig. 2) for each geophysical survey are summarized in table I.

All the surveys were conducted in the frame of the Italian «Programma Nazionale di Ricerche in Antartide», and some of them were performed in collaboration with international scientific institutions.

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The majority of the ship-track magnetic data have been processed (table II), and for the areas of the Southwestern Pacific/Northern Ross Sea and for the South-Western Scotia Sea/Powell Basin, tectonic reconstructions mainly based on magnetic anomaly identifications, in conjunction with multichannel seismic reflection data, have been proposed (Lodolo *et al.*, 1996, 1997; Lodolo and Coren, 1997; Coren *et al.*, 1997). The main scientific results from our studies in the three areas are summarized below.

2. Southwestern Pacific/Northern Ross Sea

Magnetic and bathymetric measurements carried out during three geophysical cruises in the South-Western Pacific between New Zealand and Antarctica south of 60°S, combined with the satellite-derived gravity map, allowed us to delineate the gross structural fabric and tectonic development of this remote region.

The Pacific-Antarctic plate boundary includes in its northern part a series of short spreading centers offset by NNW-SSE trending fracture zones. Towards the south, it appears to be formed

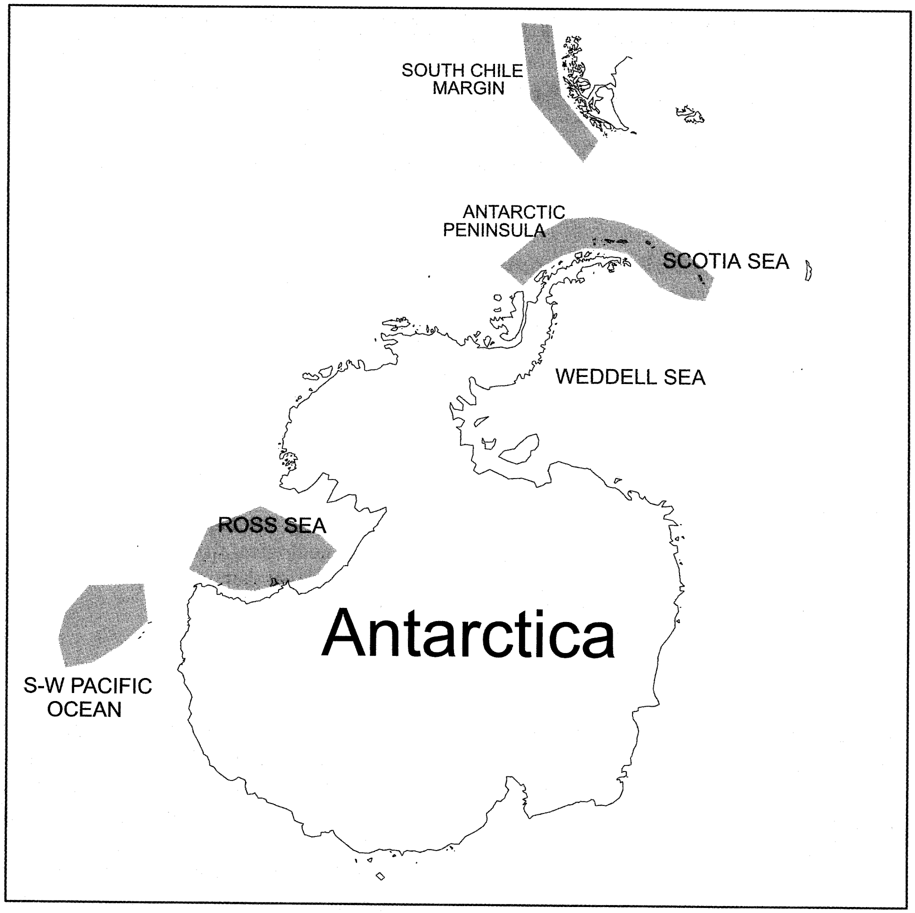

Fig. 1. Areas (dashed pattern) where the R/V OGS-Explora collected geophysical data in the frame of the Italian PNRA.

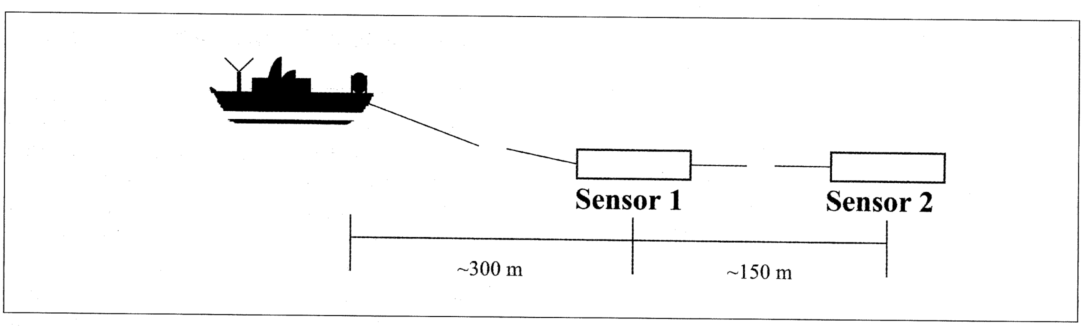

Fig. 2. Acquisition geometry for the gradiometer used since the 1990/1991 OGS-Explora marine magnetic surveys.

Table I. Data gathered during the OGS-Explora geophysical cruises in the Antarctic region.

	1987/88	1988/89	1989/90	1990/91	1991/92	1993/94	1994/95	1996/97
Ross Sea	2317 km	4080 km	2516 km	554 km		1575 km		
S-W Pacific Ocean		3042 km	1273 km	2510 km		1194 km		
Scotia Sea Pacific margin Antarctic Peninsula South Chile margin			3478 km	3561 km	3391 km		7801 km	1723 km

Table II. Acquisition geometry and processing steps adopted for the OGS-Explora magnetic data.

Acquisition geometry (proton gradiometer)
Operating depth (at 5 knots): ~30 m
Sampling rate: 6 s
Data processing
Data editing (to eliminate bad points)
Box-car filtering
Resampling to shot point interval
Removal of the IGRF from field measurements to obtain the magnetic anomaly field

by extension along an ancient strike-slip lineation. A new map of Chrons (C1-C20), spanning the region comprised between the easternmost Australian-Antarctic ridge segment and the Western Ross Sea, has been compiled, and rates of oceanic crustal accretion have been computed. The resulting instantaneous velocities testify that spreading processes in this sector of the Southern Ocean are not uniform. Substantial asymmetry of spreading between the northern and southern flanks of the Australian-Antarctic ridge axis was revealed in the 2.15-4.29 Ma time interval. A 20 Ma period in the spreading velocity trend was found, with maximum values positioned at 10 Ma (4.8 cm/yr) and 31 Ma (6.1 cm/yr); the minimum coincides with 21.5 Ma (1.5 cm/yr). These results are in agreement with those obtained by computation of instantaneous velocities for the conjugate northern flank of the Australian-Antarctic ridge segment. The identification of marine magnetic lineations crossing the Pacific-Antarctic plate boundary testifies that a general tectonic reorganization occurred as a consequence of a change in the Pacific-Antarctic relative motions that resulted in a geometric readjustment of the plate boundary. The newly created crust is not older than Late Miocene and is currently surrounded by oceanic regions where the magnetic anomalies range from 19 to 24 (~41-53 Ma) northeastward, and from 7 to 9 (~24.5-28 Ma) southwestward. This segment of the plate boundary formed along an older fracture zone that was pulled-apart by the new plate motions, and the segmented ridge-transform system then evolved.

3. Southwestern Scotia Sea/Powell Basin

The southwestern part of the Scotia Sea and the Powell Basin have been extensively surveyed during three geophysical cruises, acquiring marine magnetic profiles, multichannel seismic reflection profiles, and marine gravity profiles. The western sector of the Scotia Sea developed since about 30 Ma as a consequence of the pulling away of the two major plates of South America and Antarctica and definitively separated Antarctica from the other continental masses. Marine magnetic identifications revealed that spreading processes stopped along the WSW-ENE-trending spreading system at about 7 Ma. Also in the central part of the Scotia Sea the spreading system is fossil, but its evolution is still speculative. The only active ridge system in the entire Scotia Sea is in its easternmost part, where back-arc processes related to South Atlantic oceanic lithosphere subduction occur (see Tectonic map of the Scotia Arc, 1985). The Powell Basin, located near the Scotia-Antarctica strike-slip plate boundary, is a restricted basin almost entirely surrounded by continental crustal blocks, and separates the South Orkney microcontinent from the Northeastern Antarctic Peninsula.

At the corner of the Shackleton Fracture Zone with the South Scotia Ridge, we identified and mapped the oldest part of the oceanic crust in this sector, whose age is older than chron C10 (28.7 Ma). Combining multichannel seismic profiles, satellite-derived gravity measurements and magnetic profiles, we postulated that this area represents a relict of oceanic crust formed during an earlier, possibly chaotic episode of spreading at the onset of the Drake Passage opening (Lodolo *et al.*, 1997), that definitively cleared South America from Antarctica.

The morphology, crustal structure, and sedimentary setting of the Powell Basin have also been investigated, combining bathymetric, gravity, magnetic, and multichannel seismic reflection data (Coren *et al.*, 1997). On the basis of the entire geophysical data set, we identified the main structural and geological elements of the basin. The northern domain is characterised by an oceanic-like environment, with the presence of a ridge axis in the centre of the basin. The southern domain is mainly floored by transitional crust and presents rift-related structures (graben) in the basement. The identification of marine magnetic anomalies in the oceanic area disclosed three main evolutionary phases for its development, that explain the different geological setting of the Powell Basin. An early phase of separation between the Powell Basin and the South Orkney microcontinent produced stretching and progressive continental lithospheric thinning. This phase was followed by a northward movement, possibly accomplished with a clockwise rotation, of the South Orkney microcontinent (drift phase spanning 30-18.5 Ma, as determined from the marine magnetic anomalies). A successive clockwise rotation of the South Orkney microcontinent determined the complete development of the northern sector of the basin, with possible reactivation of spreading and final structuration of the margins encircling the basin plain.

Future interpretative work will focus on the southern part of the Central Scotia Sea north of the South Orkney microcontinent, where the Protector Basin and Pirie Bank (Tectonic map of the Scotia Arc, 1985) are located. The origin of these basins is enigmatic. Some authors propose that these areas were created by N-S-trending spreading centers, others suggest alternative hypotheses such as older ocean lithosphere capture or the presence of pre-Drake Passage opening crust. The analysis and interpretation of the acquired magnetic anomaly data will probably allow to identify the main events responsible for Central Scotia Sea tectonic development.

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