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South Shetland Block – Antarctic Plate boundary: a present- day example of progressive transition from extensional to transcurrent boundary.

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ABSTRACT

The South Shetland Block is a fragment of continental crust that extends between the South Shetland Trench and the Bransfield Basin. Its southern boundary shows present-day tectonic activity and its nature changes along strike from a spreading center in the area between the South Shetland Islands and the Antarctic Peninsula to a transtensional boundary at the northern part of the block. Eastwards, along the South Scotia Ridge, the fault system finally intersects the transcurrent boundary between the Antarctic and Scotia Plate. The variability in the features of the southern boundary of the block is probably a consequence of the variable orientation of active faults in a nearly constant stress field. The study of several transects of the boundary indicates that extensional structures are generally asymmetrical. The Bransfield Strait has been formed by an asymmetrical extension, probably related to a low-angle normal fault dipping towards the NW.

INTRODUCTION

Plate boundaries are best observed within the oceanic realm, where several geophysical methods can be used with success for the identification of their nature. As the plates interact and adjust their relative motions to others, these boundaries can change their nature, as postulated by the plate tectonics theory. Few places, however, offer the opportunity for the study of transition from one type of boundary to another in a clear manner as observed at the South Shetland Block/Antarctic Plate boundary, at the northern tip of the Antarctic Peninsula. In this paper we describe a progressive transition from extensional to transcurrent boundary using geophysical data obtained from Spain, Brazil, China and Japan, integrated with previous work performed adjacent to the Antarctic Peninsula by several other countries and institutions.

GEOLOGICAL SETTING

The Antarctic Peninsula bears many geological similarities to the southernmost South America (Dott, et al., 1982; Thompson et al., 1983; Daziel, 1984). An active magmatic arc extended continuously from the Andes to the Antarctic Peninsula and formed the western margin of Gondwana at least since the Triassic (Herron and Tucholke, 1976; Elliot, 1984). This connection was broken by the opening of the Drake Passage and the formation of the Scotia Plate which isolated the Antarctic continent after the Oligocene (Barker and Burrel, 1977; Figure 1). The Scotia Plate is bounded by sinistral transcurrent faults, which accommodate the strike-slip motion between South America and Antarctic plates. A series of faulted basement highs and lows define the morphology along the east-west trending transform boundaries of the Scotia Plate, named the North Scotia Ridge and the South Scotia Ridge.

The South Shetland Islands are located to the northwest of the Antarctic Peninsula, at the southwestern end of the South Scotia Ridge. Geological and geophysical evidences indicate that the South Shetland Islands were originally part of the Antarctic Peninsula before the formation of the Bransfield Basin (Ashcroft, 1972; Barker and Burrel, 1977; Storey and Garret, 1985; Gamboa and Maldonado, 1990; Barker and Austin, 1998). Until the formation of the Bransfield Basin (Bransfield Strait), a magmatic island arc was situated on the Antarctic Peninsula. The Bransfield Basin separates the South Shetland Islands, the present location of the volcanic arc, from the Antarctic Peninsula. An incipient spreading center is observed along the Bransfield Basin and defines the boundary between the South Shetland Block and the Antarctic Plate.

The South Shetland Block is the piece of crust that extends from the South Shetland Trench to the Bransfield Strait spreading axis. To the south, it is connected to the Antarctic Plate by an area of crustal diffuse deformation located at the extension of the Hero Fracture Zone into the Antarctic Plate. To the north, it continues along the northern half of the South Scotia Ridge. At its northern extremity, the South Shetland Block is bounded to the north by the oceanic crust of the Scotia Sea, and to the south, by the t internal depression of the Scotia Ridge, northeastward continuation of the spreading center of Bransfield Basin (Figure 1). The objective of this work is to show how this boundary progressively changes its nature from an extensional boundary in the South Shetland Archipelago sector, to a transcurrent boundary further north towards the South Scotia Ridge.

The Southern boundary of the South Shetland Block

The nature of the southern boundary of the South Shetland Block changes progressively from the Bransfield Strait to the South Scotia Ridge. The satellite free-air gravimetric data shows that, although some elements interrupt the continuity between the Bransfield Strait and the internal depression of the South Scotia Ridge in the Clarence Island region, both depressions are very well aligned. In addition, a high seismicity is identified in both depressions, that, together with the recent faulting activity identified in MCS profiles suggest that a major crustal boundary is located along them. Earthquake focal mechanisms (Galindo-Zaldívar et al., 1996) indicate that in both sectors the present day stresses are similar, with a well-defined NW-SE extensional trend.
Multichannel profiles reveal that the tectonic style and the degree of development of extensional structures along the southern limit of the South Shetland Block are variable from NE to SW. In the South Scotia Ridge, a deep narrow depression located in continental crust and more than 4000 m deep, defines the NE end of the South Shetland block-Antarctic plate boundary. The depression is formed by conjugated high angle sinistral transtensional faults, and its shape is nearly symmetrical. Towards the SW, the boundary evolves to asymmetrical structures. It is located along a NE-SW trending normal fault that dips towards the SE and defines a half-graben structure. The infilling of the basin has a wedge shape, which thickens towards the northwestern fault. This type of structure is also recognized in the NE end of the Bransfield Strait, where the wedge is deformed by recent open folds.
Further to the south, the Bransfield Strait also shows asymmetrical extensional structures. A major high-angle normal fault bounds the South Shetland Block and is responsible for high slopes identified in this boundary. The spreading axis is located near this fault. The Antarctic Peninsula side is characterized by lower slopes and the development of several normal faults dipping northwestwards. These faults develop half-graben basins with wedge-shaped sediment filling thickening southeastwards, towards the Antarctic Peninsula. This tectonic setting is typical of an asymmetric extension related to a major low-angle normal fault dipping northwestwards, below the South Shetland block. The activity of this system finally should have contributed to the starting of oceanic spreading in the Bransfield Strait. In the southwestern end of the Bransfield strait, the structure is similar, to the NE end, with asymmetrical basins filled by northwestern thickening sediment wedges. In this sector, the sediments are deformed by strike-slip faults and by open folds.

CONCLUSIONS

The nature of the active structures is progressively changing along the southern boundary of the South Shetland Block, probably due to the progressive change in the trend of this structure in a stress field nearly similar throughout the region. The boundary is located along the Bransfield Strait and the internal depressions of the South Scotia Ridge, although some basement highs disrupt in Clarence Island region the continuity between the depressed areas. While the Bransfield Strait is orthogonal to the present-day trend of extension in the region (NW-SE), the Scotia Ridge internal depression is arched and oblique to the extension direction. This relative orientation of the stress field in respect to the boundary trend is responsible of the better development of extensional structures in Bransfield Strait, while in the South Scotia Ridge predominates the transtensional structures, without recent volcanism and mainly affecting continental crust. In addition, the existence of a well-developed subduction zone in the South Shetland trench, also may help the development of extensional structures in the Bransfield Strait that constitutes its related backarc.

While the transcurrent structures in the eastern end of the boundary are approximately symmetrical, towards the west all the extensional structures are clearly asymmetrical. A major high angle normal fault constitutes generally the southern boundary of the South Shetland Block, while the Antarctic Peninsula side shows lower slopes, with basement tilting. The cross section of the central Bransfield Basin is typical of an asymmetric spreading related to a major low-angle normal fault dipping northwestwards, below the South Shetland block and that may have originated the initial thinning of the Bransfield Strait, prior to the oceanic spreading.

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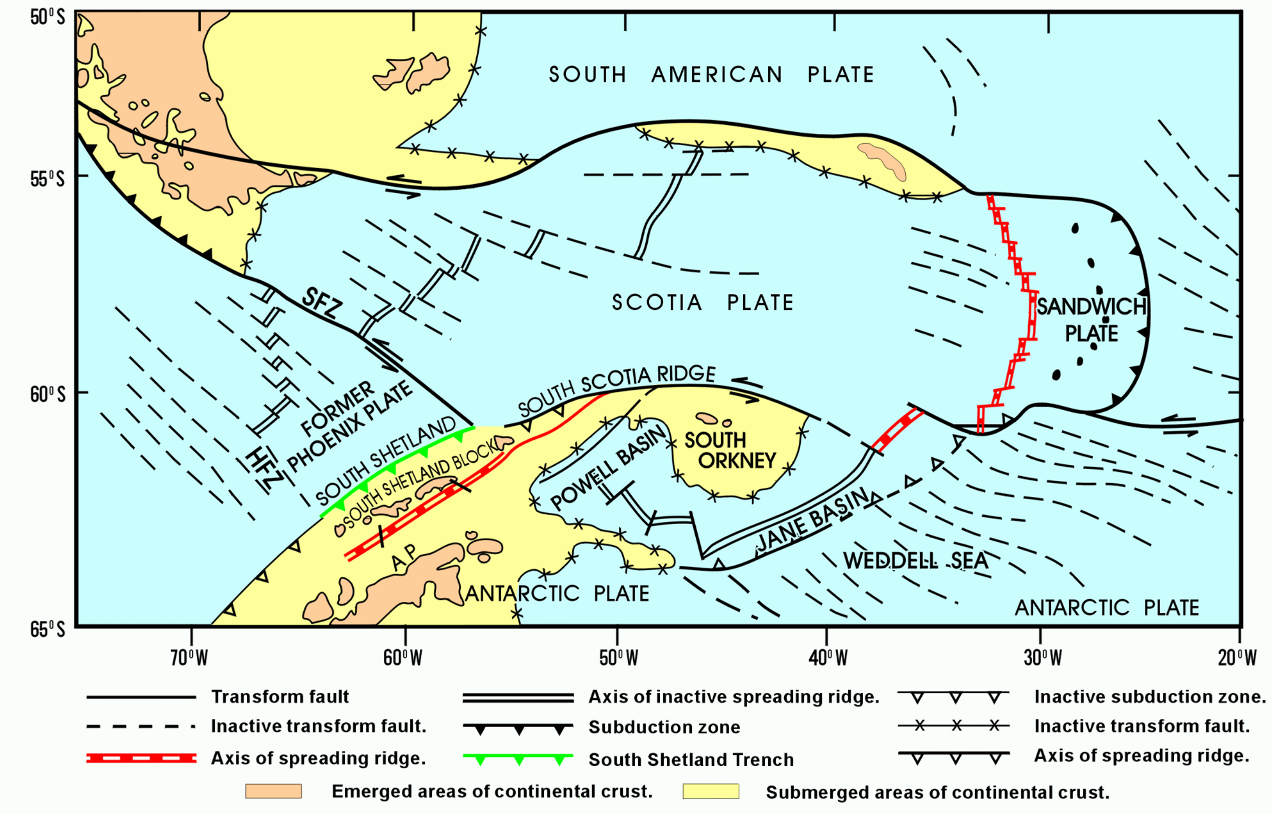

Figure 1 - Tectonic setting of the Antarctic Peninsula and Scotia Arc region (from Galindo - Zaldivar et al.,1996)