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Structure and development of the Powell Basin (NE Antarctic Peninsula)

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ABSTRACT

Powell Basin is one of the few present-day examples of a small ocean basin largely surrounded by blocks of continental crust. The western and eastern margins are conjugate passive margins having a transitional crust in the continent-ocean boundary. The distinct characteristics of these two margins suggest a degree of asymmetry in their development. A possible origin of asymmetrical extension during the initial rifting stage may be the occurrence of a shear zone with an eastwards dipping component. A spreading ridge, located in the central part of the basin, split into two crests that may be interpreted as two segments of an overlapping spreading centre (OSC). The rifting episode could have begun about 35-40 Ma. A maximum age of Early Oligocene (29 Ma latest Early Oligocene) is proposed for the ocean basin spreading, that appears to have ceased during the Early Miocene (23 Ma). The eastward motion of the South Orkney Microcontinent relative to the Antarctic Peninsula created this basin. A pull-apart origin, related to a dextral fault system, has been proposed for the basin development. However, a possible alternative is to consider that the transcurrent fault bounding the basin has opposite kinematics (sinistral the northern one and dextral the southern one). In this model, the continental crust at the north of the Powell Basin remains fixed in relation to the Antarctic Peninsula.

INTRODUCTION

Powell Basin is a small ocean basin (approximately $5x10^4$ km^2), located within the Antarctic Plate. The chronology of the major events in its development and the relationships with the surrounding lithospheric blocks are relatively well known (Larter and Barker, 1991; Livermore and Woollett, 1993; Lawver et al., 1994; Barker, 1995). It is surrounded by continental crust with the exception of the SE corner where it connects with the Weddell Sea.

During the HESANT92/93 and the SCAN97 cruises with the B/O Hespérides, a grid of multichannel seismic profiles (MCS), multinarrow beam and magnetometric data were collected. These new data allow to discuss the origin and evolution of the basin.

MARGINS STRUCTURE

The western and eastern margins are conjugate and appear to coincide well in the geological reconstruction using the continent-ocean boundary, to the time of initiation of oceanic spreading. There is, however, an overlap in the northern part of the South Orkney Microcontinent with the South Scotia Ridge (King and Barker, 1988). The western margin is a nourished passive margin with well-developed progradational and aggradational depositional sequences, the upper part almost undisrupted by faults, and an extensive lower slope region, where the acoustic basement is buried by a thick depositional sequence. The eastern margin is characterised, in contrast, by features typical of a starved passive margin, where the faulted acoustic basement may crop out locally or only be buried just below the break-up unconformity by thin depositional sequences. This margin is deformed by normal faults affecting the basement with an activity more recent than in the western margin. In addition, the continental slope is narrower and steeper than in the western margin, and the intermediate crust does not seem to be as wide.

The northern and southern margins are rectilinear, with steep slopes and a sharp continent-ocean boundary. They behave as transcurrent during the eastwards drifting of the South Orkney Microcontinent from the northeastern Antarctic Peninsula along deep-seated faults (Rodríguez-Fernández et al., 1997).

The northern margin is steep-sloped, rectilinear, and separates the South Scotia Ridge from the basin plain. The continental slope trends N60º-70ºE and is almost sediment-depleted, except near the base where a thin depositional sequence onlaps the scarp. The slope is steeper in the southwestern sector (almost 20º) while in the northeastern area it is more irregular and less steep (17.5º). This fault zone separates the South Scotia Ridge continental crust from the Powell Basin oceanic crust. This fault zone is currently inactive and shows no associated seismicity (B.A.S., 1985; Pelayo and Wiens, 1989). Northeastwards the continent-ocean boundary is more diffuse, while the slope becomes less steep, as the result of the occurrence of a transition zone between the continental and oceanic crusts (King et al., 1997).

The lower slope has a thick depositional apron formed by the two depositional sequences of the basin plain. The sin-drift sequence is thicker towards the margin and is disrupted by normal faults, while the post-drift sequence shows only minor thickness variations. The acoustic facies of these deposits are also equivalent to these of the basin plain deposit, with the post-drift sequence having more continuous and higher-amplitude reflectors. This sequence also shows cut-and-fill channel features in the lower slope.

The southern margin corresponds with the northern flank of the structural ridge between Powell Basin and the Weddell Sea, elongated east-west. This ridge plunges eastwards, from a narrow elongation of the Antarctic Peninsula shelf, which is 500 m deep in the western sector. The narrow crest of the ridge is 1500 m deep in the west while toward the east it seems to be represented only by the elongated seamount emerging from the basin plain. The northern continental slope is rectilinear and steep, with segments of up to 20º, has a sharp contact with the basin plain, and no lower slope province. In contrast to the northern margin, the slope is characterised by a series of downthrow blocks bounded by east-west normal faults, which delimit perched basins. The oceanwards limit of the continental crust is controlled by a N80ºE trending fault dipping towards the north. Most of these faults are inactive at present, since recent sediments seal some of them and there is no seismic activity in the area.

Deposits do generally not cover the steeply inclined slopes. The upper part of the basement is constituted by deformed deposits, which may represent the Mesozoic paleomargin. In addition, the deposits within the perched basins are wedge-shaped. The ridge crest reveal an erosional flat surface (500 m water depth) probably caused by grounded ice sheets.

THE BASIN PLAIN

The oceanic nature of the crust of the basin plain has been identified on the basis of high heat flow (Lawver et al., 1994), by the seismic refraction velocities (King et al., 1997), the acoustic features in MCS profiles and its bathymetry. In the central sector of the basin, the satellite-derived free-air gravity anomaly map reveals a symmetry axis with a northwest-southeast trend. In seismic profiles the axis appears split into two ridges, which are separated by a central depression ponded with sediments. The shape of the two ridges is strongly asymmetrical. Outside the central depression, basement is gently tilted by faults while near the depression the faults are more closely spaced and develop an irregular relief. The depression is bounded by two normal faults with a significant downthrow. The oceanic crust in the two ridges show faults with symmetrical tiltings with respect to the central depression. The central depression is 17 km wide and 1 sec (TWT) deeper than the ridge crests. The overlying reflectors onlap these ridges. These relationships suggest that the basement of the oceanic crust in the central depression has approximately the same age as the deepest basement of the external ridge flanks and is older than the ridge crests. The northeastern ridge seems to become inactive before the southwestern one.

Two depositional sequences are recognised in the basin plain. The lower one (syn-drift sequence) have a wedge-shaped, with basal onlap on the flanks of the ridges. This sequence reaches its maximum thickness (0.8 sec TWT) in the central depression and near the eastern and western margins, where it is gently folded and faulted. The reflector above the ridge crest marks the top of this sequence. The upper sequence (post-drift sequence) is characterised by higher-amplitude and more continuous reflectors, which may largely represent hemipelagic deposits and distal turbidites in the basin plain. This sequence is expansive on the margins and reaches their lower slopes, where it may be largely attributed to turbiditic deposits that develop submarine fans. Post-drift sequence reaches 2 sec (TWT) in thickness and developed during the period of thermal subsidence of the basin.

DISCUSSION AND CONCLUSIONS

The western and eastern margins are conjugate passive margins having a transitional crust in the continent-ocean boundary (Maldonado et al., 1993; King et al., 1997; Rodríguez-Fernández et al., 1997). The distinct characteristics of these two margins suggest a degree of asymmetry in their development, although additional data are required to corroborate the precise mechanisms of opening. A possible process that originate asymmetrical extension during the initial rifting stage, may be the occurrence of a shear zone similar to that proposed in the models by Wernicke (1985) and Lister et al. (1991), dipping with an eastwards component. The northern margin seems to be transcurrent while the southern margin is transtensional and reveals the development of perched basins in the slope. Both of these margins are rectilinear and steep with a sharp continent-ocean boundary and no transitional crust. The continental crust of the southern margin separates the Cenozoic oceanic crust of Powell Basin and the Mesozoic margin and basin plain of the northwestern Weddell Sea. Eastwards of the structural relief, the basin plain of Powell and Jane basins are connected, and separated from the Weddell Sea by the easternmost remnants of the relict arc-trench system of Jane Bank (Maldonado et al., 1998; Balanyá et al., 1999).

The Geosat gravimetric anomalies of the basin plain indicate an axial northwest-southeast trending ridge. The seismic profiles show this spreading ridge to be split into two crests, with a central depression filled with deposits older than those above the crests of the ridge. This structure is interpreted as two overlapping segments of the ridge, similar to the overlapping spreading centres (OSC) described for fast-spreading ridges in very young oceanic crust by MacDonald et al. (1984, 1988). The trend of the spreading zone and the northern transcurrent fault of the basin plain suggests ENE-WSW oriented spreading. Based on the depth of oceanic Layer 2, King and Barker (1988) propose a maximum age of Early Oligocene (29 Ma latest Early Oligocene) for the ocean basin and suggest that spreading appears to have ceased during the Early Miocene (23 Ma). The rifting episode that preceded the onset of seafloor spreading could have begun at about 35-40 Ma. Heat-flow measurements, however, yield slightly older ages for the oceanic crust, comprised between Late Eocene-Earliest Oligocene (Lawver et al., 1994). Compatible ages are obtained on the basis of wells drilled in the southern margin of the South Orkney Microcontinent (Site 966; Barker et al., 1988).

This spreading is related to the eastwards drifting of the South Orkney microcontinent from the northeastern Antarctic Peninsula (King and Barker, 1988; King et al., 1997). The opening of this small independent ocean basin was part of a much larger process of continental fragmentation of the northern Antarctic Peninsula, which occurred along the boundary between the South America and Antarctic plates (Barker et al., 1991). At the end of the drifting episode all the crustal elements located in the study area, southwards of the South Scotia Ridge, became part of the Antarctic plate. The post-drift tectonic evolution of the region was largely controlled by thermal subsidence (King and Barker, 1988; Lawver et al., 1994). A younger episode of alkali vulcanism is, however, observed in some locations of the continental margins (Barber et al., 1991).

According to King and Barker (1988), Powell and Jane basins are back-arc basins resulting from the subduction of the South Atlantic plate below the South Orkney microcontinent. However, the obliquity between the spreading zone of Powell Basin and the subduction zone related to Jane Basin, together with the suggested difference in age of about 10 Ma between Powell Basin and the youngest Jane Basin (Lawver et al., 1994), could indicate that these basins originated from independent tectonic processes. Other possible origin has been suggested by King et al. (1997), who interpreted the Powell Basin as a pull-apart basin formed by a dextral strike-slip faults system. In this model the northern and southern boundaries are considered dextral faults extending respectively westwards and eastwards. However, there is not evidence that the northern fault continue out of the basin up to the Brandsfield Strait. A possible alternative is to consider that the northern fault bounding the Powell Basin continue eastwards, trough the South Scotia Ridge and the northern boundary of the South Orkney Microcontinent and should have been sinistral, like the recent faults in the South Scotia Ridge. In this model, the eastward drifting of the South Orkney Microcontinent was responsible of the development of the Powell Basin and the northern boundary fault became inactive progressively from the west toward the east. In order to test the different model it is necessary to have additional data of the region.

Finaly the current tectonic setting of the Powelll Basin corresponds to a special kind of Dormant Ocean Basin (Ingersoll and Busby, 1995), where the activity probably ceased as a result of the Scotia-Antarctic plate boundary rearrangement.

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