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Depositional processes and growth patterns of isolated oceanic basins: the Protector and Pirie basins of the Southern Scotia Sea (Antarctica)

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ABSTRACT

Sedimentary processes in small, isolated oceanic basins that form adjacent to continental margins but detached from continents remain poorly understood. This work describes two such basins located in the southern Scotia Sea, the Protector and Pirie basins. We analysed multichannel seismic profiles to interpret morphostructural features and stratigraphy of these basins. Sedimentary stacking patterns and depocentre distribution illustrate basin development patterns. Basal units infill basement depressions formed by the submerged banks of thinned continental crust that abut the basin plains. These lower and middle deposits of the sedimentary record are interpreted as *pre-* and *syn-rift* deposits. The laterally extensive upper deposits are interpreted as *post-rift* deposits. These include five discrete units evident in seismic profiles. A prominent regional reflection referred to as *Reflector-c*, separates in these upper deposits two sets of seismic units that have recorded major shifts in the dominant sedimentary processes, stacking patterns and paleo-environmental conditions. The most important processes controlling deposition of the older units (those beneath Reflector-c), include down-slope gravity processes that infill depressions created by crustal thinning and seafloor spreading. These occurred under the coeval influence of Circumpolar Deep Water circulation. The major processes influencing younger units (those above Reflector-c) include bottom water circulation of the Circumpolar Deep Water and Weddell Sea Deep Water water masses, which coursed along bathymetric contours of the seafloor. The Reflector-c discontinuity developed concurrently with middle Miocene tectonic changes, which led to the opening and deepening of deep gateways in the South Scotia Ridge. These facilitated overflow of Weddell Sea Deep Water from the Weddell Gyre into the Scotia Sea. This overflow in turn forced the Circumpolar Deep Water northwards. Analysis of the Protector and Pirie basins shows that their tectonic evolution influenced regional deep water circulation patterns in an area that makes a significant cold water contribution to the global conveyor belt system. As a long-term factor controlling basin evolution and sedimentary processes, tectonics events in this region therefore influenced the present day climate system. These results further clarify our understanding of deep, isolated oceanic basins in terms their sedimentologic, climatologic and oceanographic significance.

1. Introduction

In terms of sedimentary input, oceanic basins experience three types of sedimentary infilling processes. These include gravitational across-slope processes of terrigenous sediments from adjacent continents, pelagic and hemipelagic processes that supply autochthonous sediment and water-column organic matter, and bottom current processes (contourite), which contribute sediments transported over greater distances (Hüneke and Mulder, 2011; Rebesco et al., 2014). In addition, basins located in high latitudes also receive terrigenous sedimentary input from ice sheets and sea ice (Lee et al., 2012). The relative contributions of these processes to a given basin vary with geographic, geologic and oceanographic setting. In oceanic basins located close to emergent continents, large volumes of sediment contribute to the growth of the margin. The average thickness of continental margins ranges from 4 to 7 km, but may reach thicknesses of > 15 km, as in case of the southern Caspian Sea or western Gulf of Mexico (Laske and Masters, 1997; Divins, 2003; Whittaker et al., 2013). Rapid subsidence during early stages of basin evolution and/or insufficient sediment supply from terrigenous sources, can create isolated, sediment-starved basins,

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wherein the rate of subsidence exceeds that of sedimentation (Allen and Allen, 2005). Certain back-arc basins can, for example, experience high sedimentation rates (~100–200 m/Ma) during initial rifting with down-slope mass transport processes contributing to elevated rates of sedimentation (Kobayashi, 1984; Allen and Allen, 2005). As oceanic spreading wanes, sediment accumulation rates may drop to ~5–15 m/Ma. These rates primarily reflect pelagic and hemipelagic processes in deep ocean settings (Allen and Allen, 2005). Some authors suggested that local sedimentary input represents the most significant contribution to isolated basins (e.g., Graciansky and Poag, 1985), but these interpretations have not been empirically validated with observations of actual sedimentary sources and transport processes that occur in isolated basins.

The primary objective of this study is to determine the evolution and growth patterns of two small isolated oceanic basins that lie adjacent to continental margins but detached from nearby emergent continents. We analyse the major morphostructural features and sedimentary stacking patterns of the Protector and Pirie basins. These basins lie between 58° and 60° S latitude at 44°–52° W longitude in the southern Scotia Sea, close to the Scotia–Antarctica plate boundary (Fig. 1A). The Protector Basin was first described in the Tectonic Map of the Scotia Sea (British Antarctic Survey, 1985), whereas the Pirie Basin is described for the first time in this work. The growth patterns of these unusual basins help to assess the role of bottom current transport and deposition as critical sedimentary processes in the evolution of deep oceanic basins.

2. Tectonic and oceanographic setting

The Scotia Sea is a back-arc basin that developed during the Cenozoic separation of South America and Antarctica. Ocean crust of the Atlantic Ocean and Weddell Sea subsequently subducted beneath the Scotia Sea since the onset of the formation of this basin through the western Scotia Sea and West Scotia Ridge (WSR) oceanic spreading. Several additional spreading centres have also generated new oceanic crust that migrated eastwards behind the arc (e.g., Eagles et al., 2005; Dalziel et al., 2013; Eagles and Jokat, 2014; Maldonado et al., 2014).

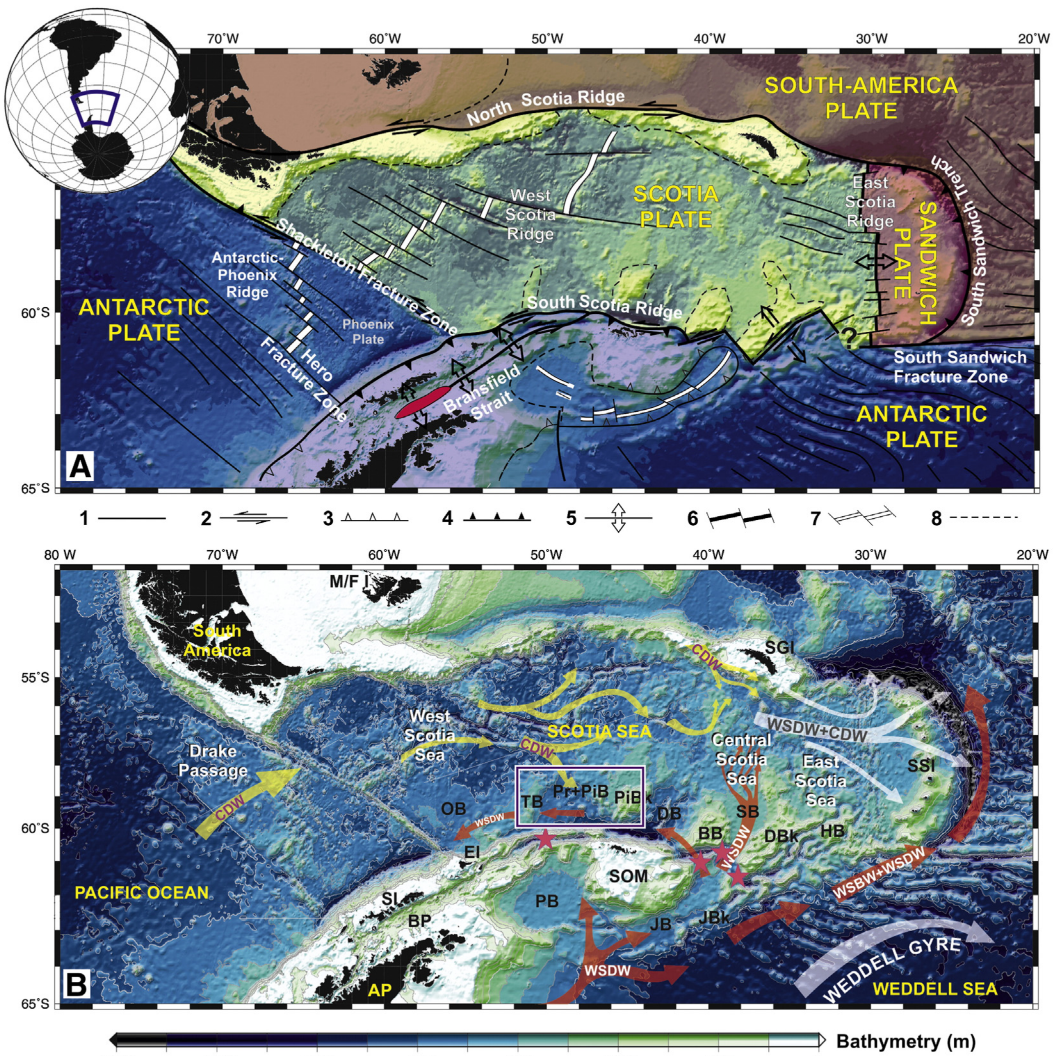

Fig. 1. Simplified bathymetric map of the Scotia Sea derived from the GEOSAT gravimetric anomaly map (Sandwell and Smith, 1997). A) Tectonic setting of the Scotia Sea (modified from Maldonado et al., 2000; Galindo-Zaldívar et al., 2006). Legend: 1, transform fault; 2, active transcurrent fault; 3, inactive subduction zone; 4, active subduction zone; 5, active extensional zone; 6, active spreading centre; 7, inactive spreading centre; 8, continental-oceanic crust boundary. B) Morphological and oceanographic features: AP, Antarctic Peninsula; BB, Bruce Bank; BP, Bransfield Passage; DBk, Discovery Bank; DB, Dove Basin; EI, Elephant Island; HB, Herdman Bank; JB, Jane Basin; JBk, Jane Bank; M/F I, Malvinas/Falkland Islands; OB, Ona Basin; PB, Powell Basin; PiB, Pirie Basin; PiBk, Pirie Bank; PrB, Protector Basin; SB, Scan Basin; SGI, South Georgia Island; SI, Shetland Islands; SOM, South Orkney Microcontinent; SSI, South Sandwich Islands; TB, Terror Bank. Water mass legend: CDW: Circumpolar Deep Water; WSBW, Weddell Sea Bottom Water; WSDW, Weddell Sea Deep Water. The pink stars indicate the principal gateways of the SSR from west to east: Phillip, Orkney, Bruce and Discovery. The purple rectangle outlines the study area depicted in Fig. 2.