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The Deep Western Boundary Current at the Bounty Trough, east of New Zealand: Indications for its activity already before the opening of the Tasmanian Gateway

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A B S T R A C T

The Eastern New Zealand Oceanic Sedimentary System is influenced by the main deep cold-water inflow to the Pacific Ocean, the Deep Western Boundary Current (DWBC). ODP Leg 181 targeted this region. The two northern sites ODP 1123 and 1124 are mainly used for interpretation of DWBC flow. Newly acquired high-resolution seismic reflection profiles directly cross ODP Site 1122 in the Outer Bounty Trough area. We can decipher the first appearance of a branch of the DWBC meandering into the Bounty Trough as early as 20 to 16.7 Ma. We identified four different drift deposits of the DWBC in the Outer Bounty Trough area. The deepest two drifts were formed before the opening of the Tasmanian Gateway and thus provide the first evidence of a pre-Oligocene deep circulation at the eastern New Zealand margin. Additionally, migration of the drift crests to the west and to the east is interpreted to indicate modifications in core flow pathway of the DWBC due to response to climate changes (Eocene cooling, cooling due to West Antarctic Ice shield build-up), tectonic influence (opening of Tasmanian Gateway) and enhanced sediment input (first turbiditic deposits of Bounty Channel).

1. Introduction

The Thermohaline Circulation (THC) is directly linked to global climate. Changes in global climate affect the THC and vice versa (e.g. Clark et al., 2002; Kuhlbrodt et al., 2007). Sedimentary archives recording circulation patterns at key locations of the THC are of great interest for interdisciplinary research. These archives contain valuable information about past changes in oceanic circulation and associated climate. One of these key regions is the Tasmanian Gateway between Antarctica and Australia (Fig. 1a, inset). The Western Boundary Current (DWBC), the main inflow of deep cold water, enters the Pacific Ocean at this location. The Antarctic Circumpolar Current (ACC) also passes through the Tasmanian Gateway directly affecting the cold water inflow of the DWBC (L. Carter et al., 2004; McCave et al., 2008). It is still under debate whether the opening of the Tasmanian Gateway and subsequent establishment of the ACC has been the major cause leading to thermal isolation and Antarctic Glaciation or whether changes in atmospheric carbon dioxide concentration triggered Antarctic Ice Sheet growth (e.g. Huber et al., 2004; Sijp et al., 2011; Zachos et al., 2001). No major tectonic processes such as opening of circum-Antarctic seaways occurred in the Southern Ocean during the Eocene (Cande and Stock, 2004), but at least a partial glaciation of East Antarctica hints towards cooling resulting from CO_2 drawdown (Zachos et al., 2001). Intensive cooling and sea ice enhance the deep water formation (Stocker, 2000; van Aken, 2007). Thus, cold climate conditions in an ice covered Antarctica caused intensified deep-water formation, which then formed specific sedimentary features in sedimentary archives. Such an archive is located directly downstream of the Tasmanian Gateway, where a vast amount of sediment is injected into the DWBC and ACC flow path. The sediments are supplied by the Eastern New Zealand Oceanic Sedimentary System (ENZOSS) (Fig. 1a), a sediment recycling system (L. Carter et al., 1996; R.M. Carter et al., 1996). Modern river discharge data suggest that ENZOSS has an estimated terrigenous material input of 109 million tonnes per year (Hicks and Shankar 2003). These sediments are transported to the deep sea via three deep sea channels, the Solander Channel, the Bounty Channel and the Hikurangi Channel (R.M. Carter et al., 1996) (Fig. 1a). Sediments are entrained, transported and deposited by the DWBC, regionally influenced by the ACC, and form depositional and erosional sequences at the seafloor visible in seismic reflection data.

Our knowledge of Eocene and older circulation in the ENZOSS region is still scarce. The only information, which help deciphering the oceanic circulation prior and during first Antarctic glaciation, is based on one deep-sea borehole. ODP Leg 181 Site 1124 suggests a flow of a warm deep water mass from a northern source but no record of cold circulation (R.M. Carter et al., 2004; Carter et al., 1999d). Additionally, most interpretations of the Oligocene and younger circulation originate from

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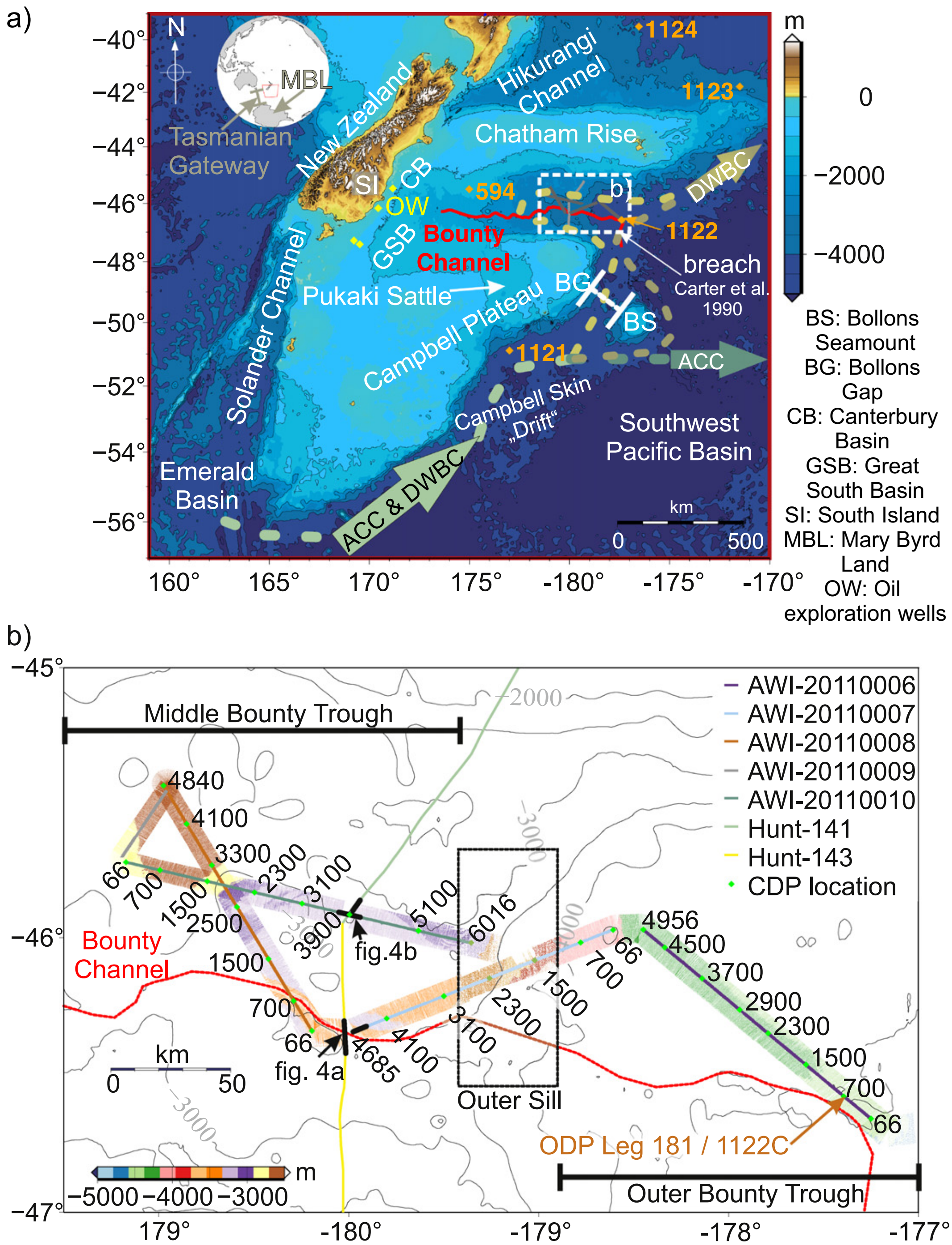

Fig. 1. a) Bathymetry (GEBCO_08 grid; Smith and Sandwell, 1997) of the area of interest. Dashed lines and arrows indicate the present deep circulation pattern around the New Zealand Microcontinent. Also shown are deep sea boreholes of ODP Leg 181, DSDP Site 594 and oil exploration wells used to characterise the sediment deposits; b) detailed view of the working area showing profile locations, coloured area shows swath bathymetry acquired during So 213/2 cruise (Tiedemann et al., 2012) with GEBCO_08 contours (Smith and Sandwell, 1997) in black. Numbers and green diamonds indicate positions of CDPs of the corresponding figures. Orange diamonds and numbers indicate ODP Sites in the area. Abbreviations: ACC = Antarctic Circumpolar Current, DWBC = Deep Western Boundary Current.

north of Chatham Rise (ODP Sites 1123 and 1124, Fig. 1; e.g. Hall et al., 2002; Hall et al., 2003; Joseph et al., 2004). Here the DWBC has been modified due to its journey around the Chatham Rise and has potentially taken up sediments from the Bounty Trough (erosion on the Outer Sill is evident from seismic data (Carter and McCave, 1997) implying an intrusion of DWBC into the Bounty Trough taking up sediments). To see the direct influence of the ACC on the DWBC since the opening of the Tasmanian Gateway a location directly downstream of the uncoupling point of the DWBC from the ACC is desirable. Without the strong erosive activity of ACC and DWBC which occurs south of ~50°S, the Bounty Trough represents an ideal location to study the signal of the DWBC. Sediments deposited here are mainly transported by the DWBC and by sporadic isolated turbidities possibly from influxes from the Bounty Trough (Carter et al., 1999b). Since the Bounty Trough is estimated to have formed during late Cretaceous (e.g. Davy, 1993; Grobys et al., 2007), its sediment archive may record footprints of a cold current from the south that has passed by the eastern continental margin of New Zealand.