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Contourite drifts as indicators of Cenozoic bottom water intensity in the eastern Agulhas Ridge area, South Atlantic

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ABSTRACT

High-resolution multichannel seismic reflection profiles acquired in the Agulhas Ridge area (eastern sub-polar South Atlantic) were used in conjunction with multibeam bathymetry and Ocean Drilling Program Leg 177 borehole data to characterise deep water contourite formation in the area of the northeastern Agulhas Ridge and the Cape Rise seamounts. The transverse ridge separates the Cape Basin from the Agulhas Basin and controls the exchange of water masses between these two basins. Small scale buried drifts, moats and sheet like deposits indicate that sedimentation was controlled by bottom currents since the late Eocene. After a pronounced early Oligocene erosional event resulting from the onset of Lower Circumpolar Deep Water (LCDW) flow, drift formation intensified. The type, position and formation history of the interpreted drifts suggest that the pathways of LCDW flow have undergone little change during the last ~33 Ma and followed roughly today's 4900 m depth contour. Northwest of the Cape Rise seamount we found a mounded drift with an oval shape, a height of ~400 m and a width of ~50–60 km indicating a clockwise circulating bottom water gyre in that area. Extensive drifts in the Cape Basin occur as features confined between the Agulhas Ridge and Cape Rise seamounts and as mounded and sheeted drifts further to the west. The confined drifts show erosional features on both flanks suggesting a west setting bottom water flow along the northern flank of the Agulhas Ridge and an opposing eastward directed flow along the southern rim of the Cape Rise seamount group. In contrast to the large drift deposits in the Cape Basin smaller, confined drifts showing more erosional features are found south of the Agulhas Ridge. Together these findings suggest that the deepest LCDW flowed anticlockwise around the Agulhas Ridge before taking a major clockwise loop in the Cape Basin. The returning bottom water then flowed around the Cape Rise seamounts before entering the Indian Ocean.

1. Introduction

Seismic investigations of contourite drift deposits have been extensively used to unravel the Cenozoic evolution of deep ocean circulation (Rebesco et al., 2014). The location, shape and internal structure of the sediment drifts can be used as indicators of changing pathways and intensities of bottom currents (Rebesco and Camerlenghi, 2008). This approach has been particularly successful on continental margins where deep western boundary currents created large contourite depositional systems (Hernández-Molina et al., 2008a; Muñoz et al., 2012; Nelson et al., 1999). However, far less is known about the history of bottom currents in the deep ocean basins and abyssal plains. In many cases, current controlled sedimentation in basinal systems is accompanied by the deposition of large sheeted drifts with a low-mounded geometry (Carter and McCave, 1994; Escutia et al., 2002; Maldonado et al., 2005; Masson et al., 2002). These drifts drape the pre-existing morphology of the oceanic basement and were formed by the current action of tabular water masses (Hernández-Molina et al., 2008b). In parallel, topographic features within or at the rim of ocean basins such as seamount ridges and plateaus can disrupt and accelerate the flow and also influence the current pathway (e.g. Merrifield et al., 2001). These changes are often leading to the formation of moats and mounded sediment drifts (Hernández-Molina et al., 2008b; Maldonado et al., 2005; Masson et al., 2003; Müller-Michaelis et al., 2013). A spectacular example of such topographic obstacles for deep ocean currents in the South Atlantic is the Agulhas Ridge, which forms an elongated part of the Agulhas–Falkland Fracture Zone (AFFZ) rising ~3000 m above the surrounding seafloor (Fig. 1). Constituting an important topographic barrier, the ridge has a strong influence on the exchange of water masses between high and lower latitudes (Fig. 1).

Geochemical proxies (such as $\delta^{13}C$ or ε_{Nd}) measured on samples from sediments drilled on the Agulhas Ridge (Hodell et al., 2002) have helped to decipher Cenozoic variations of water masses related to climate changes in the South Atlantic (Billups et al., 2002; Scher and Martin, 2008). Variations of neodymium isotope ratios on the Agulhas Ridge (ODP Site 1090) suggest an influx of shallow Pacific seawater to the South Atlantic sector of the Southern Ocean at approximately 41 Ma that may indicate an early opening of the Drake Passage (Scher

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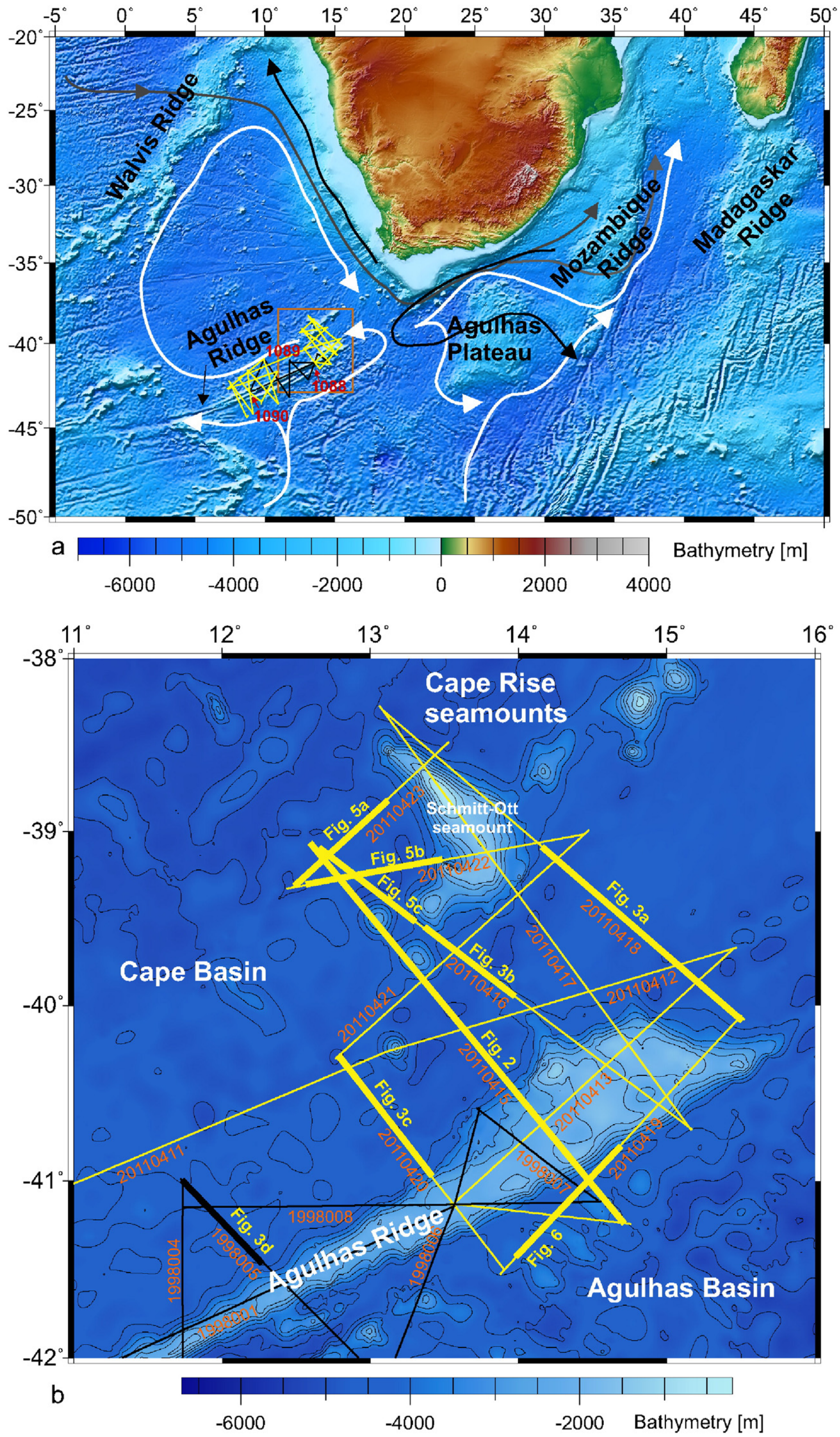

Fig. 1. (a) Bathymetric map with the general circulation scheme of deep-water masses south of Africa (Tucholke and Embley, 1984; Uenzelmann-Neben et al., 2007). (LCDW = Lower Circumpolar Deep Water; AAIW = Antarctic Intermediate Water; and NADW = North Atlantic Deep Water) and locations of reflection seismic profiles shot in 1998 (black lines) and 2011 (yellow lines). Stars indicate the positions of ODP Leg 177 drill sites. Orange box indicates working area shown in Figs. 1b and 8. (b) Detailed location of seismic profiles over the eastern Agulhas Ridge. Intervals shown in figures are marked by thicker lines. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

and Martin, 2006). Information on how these changes in transport influenced the intensity and position of current systems is currently sparse. They can, however, be gained by seismic investigations of contourites (Wildeboer Schut et al., 2002).

Here we present new multichannel seismic profiles recorded in the hitherto unexplored area of the Northeast Agulhas Ridge (Fig. 1b) that complement earlier data. A reconnaissance survey in the area of the western Agulhas Ridge provided evidence for sediment drift formation on both sides of the ridge due to a bottom current flow that intensified at the Eocene/Oligocene boundary (Uenzelmann-Neben et al., 2007; Wildeboer Schut and Uenzelmann-Neben, 2005; Wildeboer Schut et al., 2002). We combine our seismic interpretation with new bathymetric data from a multibeam survey and geological information from Leg 177 of the Ocean Drilling Program (ODP) which recovered high-quality sedimentary sequences at seven sites between 41° and 53°S for studying the Cenozoic history of the high-latitude South Atlantic

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