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A submarine canyon as a climate archive — Interaction of the Antarctic Intermediate Water with the Mar del Plata Canyon (Southwest Atlantic)

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ABSTRACT

The Mar del Plata Canyon is located at the continental margin off northern Argentina in a key intermediate and deep-water oceanographic setting. In this region, strong contour currents shape the continental margin by eroding, transporting and depositing sediments. These currents generate various depositional and erosive features which together are described as a Contourite Depositional System (CDS). The Mar del Plata Canyon intersects the CDS, and does not have any obvious connection to the shelf or to an onshore sediment source. Here we present the sedimentary processes that act in the canyon and show that continuous Holocene sedimentation is related to intermediate-water current activity. The Holocene deposits in the canyon are strongly bioturbated and consist mainly of the terrigenous "sortable silt" fraction (10–63 μm) without primary structures, similarly to drift deposits. We propose that the Mar del Plata Canyon interacts with an intermediate-depth nepheloid layer generated by the northward-flowing Antarctic Intermediate Water (AAIW). This interaction results in rapid and continuous deposition of coarse silt sediments inside the canyon with an average sedimentation rate of 160 cm/kyr during the Holocene. We conclude that the presence of the Mar del Plata Canyon decreases the transport capacity of AAIW, in particular of its deepest portion that is associated with the nepheloid layer, which in turn generates a change in the contourite deposition pattern around the canyon. Since sedimentation processes in the Mar del Plata Canyon indicate a response to changes of AAIW contour-current strength related to Late Glacial/Holocene variability, the sediments deposited within the canyon are a great climate archive for paleoceanographic reconstructions. Moreover, an additional involvement of (hemi) pelagic sediments indicates episodic productivity events in response to changes in upper ocean circulation possibly associated with Holocene changes in intensity of El Niño/Southern Oscillation.

1. Introduction

Submarine canyons are common morphological features at continental margins worldwide (Harris and Whiteway, 2011). They are important natural conduits for the transfer of terrigenous sediments to the deep sea, but also represent considerable (temporary) sinks for enhanced accumulation of modern sediments (Carson et al., 1986). The traditional approach of submarine canyons implies that sediment discharged by a nearby river system and/or by sediment movement across the continental shelf is carried down the canyon by gravitational processes and is deposited as turbidites. However, as most of the world's canyons (Harris and Whiteway, 2011), the Mar del Plata Canyon at the continental margin off northern Argentina does not have any obvious connection to the shelf or an onshore river system (e.g., La Plata River) (Krastel et al., 2011), and is therefore isolated from shelf-originated down-slope processes. The canyon is incorporated into a significant Contourite Depositional System (CDS) extensively present at the continental margin off northern Argentina, whose sedimentation processes are primarily controlled by northward-flowing Antarctic water masses, in particular by the Antarctic Intermediate Water (AAIW) (Hernández-Molina et al.,

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2009; Preu et al., 2013) (Fig. 1). Drift deposits (typical deposits formed within CDSs) have been comprehensively described from (sub)-recent deposits throughout the world's deep ocean environments (Stow and Lovell, 1979; Stow et al., 2002; Rebesco et al., 2008), whereas submarine canyons incorporated into CDSs have not long been perceived (Marchès et al., 2007; Lastras et al., 2011). Although recent studies propose that submarine canyons significantly alter the hydrodynamics of contour currents, thereby leading to significant changes in contourite drift construction (Marchès et al., 2007); the sedimentary processes in these submarine canyons remain poorly understood.

Here we investigate the Holocene sedimentary records from the Mar del Plata Canyon, and consider the sedimentary processes and sediment characteristics of a submarine canyon that intersects a CDS. The deposits in the Mar del Plata Canyon yield insights into the interaction of the submarine canyon with an intermediate nepheloid layer (INL) generated by the AAIW, as well as into the role of the Mar del Plata Canyon as a considerable (temporary) sink for Late Glacial/Holocene sediments.

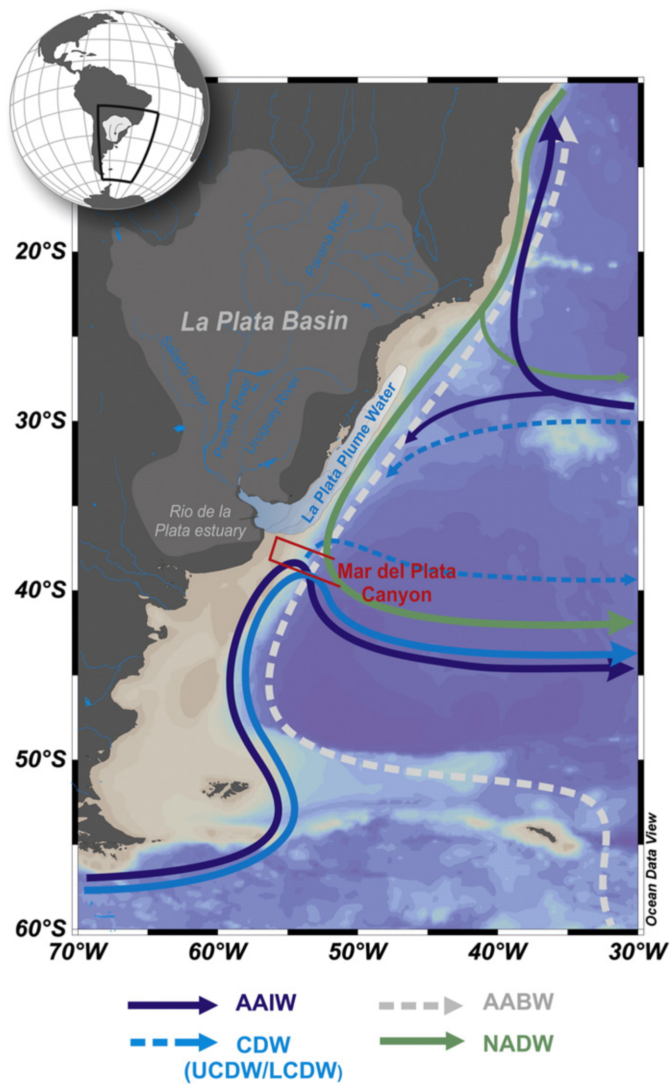

Fig. 1. Schematic intermediate and deep-water circulation in the Southwest Atlantic after Stramma and England (1999). Different water masses formed in remote areas of the world extend into that area and generate a highly complex vertical stratification structure. In the deep ocean, this structure is dominated by contributions from intermediate- and deep water masses, including (from top to bottom) the Antarctic Intermediate Water (AAIW), the Upper Circumpolar Deep Water (UCDW), the North Atlantic Deep Water (NADW), the Lower Circumpolar Deep Water (LCDW) and the Antarctic Bottom Water (AABW). The La Plata River discharges into the ocean waters from La Plata basin covering a large area of South America.

In highly energetic regions such as the Southwest Atlantic the sedimentary records found in submarine canyons may thus provide high temporal-resolution climate archives which can be used for paleoclimate and/or paleoceanographic reconstructions.

2. Regional setting

The Southwest Atlantic is a key location in the global intermediate and deep-water circulation (Fig. 1). Different water masses formed in remote areas of the world extend into that area and generate a highly complex vertical stratification structure. In the upper ocean, this structure is dominated by the encounter of southward flowing Brazil Current and northward-flowing Malvinas- (Falkland) Current generating one of the most energetic regions of the world ocean; the Brazil–Malvinas Confluence (BMC) (Chelton et al., 1990; Peterson and Stramma, 1991; Piola and Matano, 2001). In the deep ocean, the vertical stratification structure is dominated by contributions from intermediate- and deep water masses including (from top to bottom) the Antarctic Intermediate Water (AAIW, ~500–1000 m), the Circumpolar Deep Water (CDW, ~1000–4000 m) and the Antarctic Bottom Water (AABW, >4000 m) (Reid and Patzert, 1977; Stramma and England, 1999) (Figs. 1 & 2B). By penetrating into the CDW, the North Atlantic Deep Water (NADW, 2000–3000 m) vertically divides this water mass into two layers: the upper CDW (UCDW) and the lower CDW (LCDW). These contour-following bottom currents are able to significantly shape the continental margin by eroding, transporting and depositing sediments at the sea floor (Stow et al., 2002, 2008; Rebesco et al., 2008). Along the Argentine margin they generate various depositional (drifts) and erosional features (terraces) which together form a Contourite Depositional System (CDS) (Hernández-Molina et al., 2009).

The Mar del Plata Canyon, a relatively straight, deeply incised bathymetric feature, is incorporated into this CDS at around 38°S (Krastel et al., 2011) (Figs. 1 & 2B). The whole canyon is confined to the continental slope forming a so-called “blind” canyon (Harris and Whiteway, 2011) that does not have any obvious connection to the shelf or to modern terrestrial fluvial systems (e.g., La Plata River) (Krastel et al., 2011). The Mar del Plata Canyon head is situated on the upper continental slope at a water depth of ~1000 m and extends for ~110 km downslope to a water depth of ~3900 m. Mapping between the shelf break and the canyon by hydroacoustic and seismic methods shows neither any incision at the modern seafloor nor a refilled or sediment buried upslope continuation of the Mar del Plata Canyon (Krastel et al., 2011). The upper part of the Mar del Plata Canyon incises the Ewing contourite terrace, a pronounced bathymetric feature along the northern Argentine continental slope (Krastel et al., 2011).

Contourite terraces at the depth of ~1000 m are observed along the entire continental margin off Argentina, and have been developed in depositional and erosive phases over time caused by the interaction of northward-flowing AAIW and UCDW (Hernández-Molina et al., 2009, 2010; Lastras et al., 2011). At present, turbulent processes at the lower boundary of the AAIW inhibit sediment deposition over large areas on the Ewing terrace (Preu et al., 2013) (Fig. 2B). The hypothesis of strong AAIW in the study area is also supported by the OCCAM Global Ocean Model (Gwilliam, 1996) indicating flow velocities of ~15–20 cm/s at 1000 m water depth.

Measurements of high turbidity which are part of the world ocean nepheloid layer composition data base assembled by the Lamont–Doherty Earth Observatory (Fig. 2A) indicate a very pronounced intermediate nepheloid layer (INL) testifying to strong current activity in the depth range of AAIW. Nepheloid layers contain significant amounts of suspended sediment, and therefore have been inferred to play an important role in the formation of drift deposits (Rebesco et al., 2008). The amount of suspended sediments decreases drastically toward the UCDW, and indicates the lower transport capacity of the UCDW. Accordingly, directly beneath the high velocity core of the AAIW, toward