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Sedimentation adjacent to atolls and volcano-cored carbonate platforms in the Mozambique Channel (SW Indian Ocean)

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ABSTRACT

Recently acquired data from the Iles Eparses (southwestern Indian Ocean) reveal new information about the geomorphology, depositional processes, and sedimentary deposits on the slopes of atolls and atoll-like platforms. The deposits discussed here lie on the deepwater flanks of isolated, inactive volcanos that are capped by shallow, relatively flat carbonate platforms 45–210 km^2 in area. Much of the slope geomorphology is controlled by the underlying volcanic edifice. Steep (~25–35°) upper slopes consist of outcrops of volcanic basement, smooth banks, failure scarps, and channels. Sedimentary features seen in the lower slope and proximal basin (2000–3500 m deep) consist of channels, levees, lobes, and mass transport deposits (MTDs). In places, channels terminate 13–18 km from the platform margin, ending in lobes up to 3.5 km across, a feature not often seen in modern carbonates. In the subsurface, MTDs are present near all platforms. Within MTDs, seismic character is variable, often consists of chaotic reflections indicative of sediment gravity flow processes. Subsurface units with organized (retro- or progradational) reflections are interpreted as turbidite lobes or MTDs with compressional features. Core taken within lobes and near the base of slopes reveal decimeter-scale turbidites and debrites composed primarily of graded and massive bioclastic grainstones and packstones with abundant neritic skeletal components, interbedded with hemipelagic aragonitic and clay-rich foraminiferal ooze. Slope depositional processes are therefore primarily gravity-driven and occur at different scales; i.e., bed-scale turbidites and muds may be remobilized and redeposited through slope failure and deposition of large MTDs. Dominant wind direction may also play a role in slope sedimentation: leeward slopes are generally less rugose and show increased sedimentation at the toe of the slope. This study thus provides new insight into depositional systems surrounding atoll-like carbonate platforms, and provides a new analogue for similar deposits in the geologic record.

1. Introduction

Sediments on carbonate slopes are well-represented in the ancient geologic record (Blomeier and Reijmer, 2002, and references therein), and are an important component of carbonate depositional systems. However, a detailed, actualistic understanding of these environments in modern settings was hampered for many years by the inaccessibility of deepwater deposits in modern oceans (McIlreath and James, 1978), and much work remains to be done. Although many studies have documented the shallow-water portions of modern carbonate platforms and coral atolls (e.g., Reijmer et al., 2009; Gischler, 2011; Harris et al., 2011), most existing research on modern deepwater allochthonous carbonates (distinguished here as those predominantly transported into the deep sea from elsewhere, as opposed to cold-water carbonate muds and buildups precipitated in situ) has focused on a limited number of well-known settings (e.g., the Caribbean). Although more recent studies have expanded research into new areas (e.g., the Maldives, Papua New Guinea, NE Australia, and New Caledonia; Betzler et al., 2016; Tcherepanov et al., 2008; Dunbar and Dickens, 2003; Yamano et al., 2015, respectively), relatively few studies have been conducted in the southern Indian Ocean. More studies in new areas and in different geo-environmental settings are required in order to understand the full range of carbonate slope sedimentation around the world.

This study examines the submarine slopes of four isolated, volcano-cored atolls and atoll-like carbonate platforms in the southern Indian Ocean (Fig. 1) with the goal of improving our understanding of the depositional processes and products operating on their slopes and nearby basin floors. The deposits formed when carbonate sediments are

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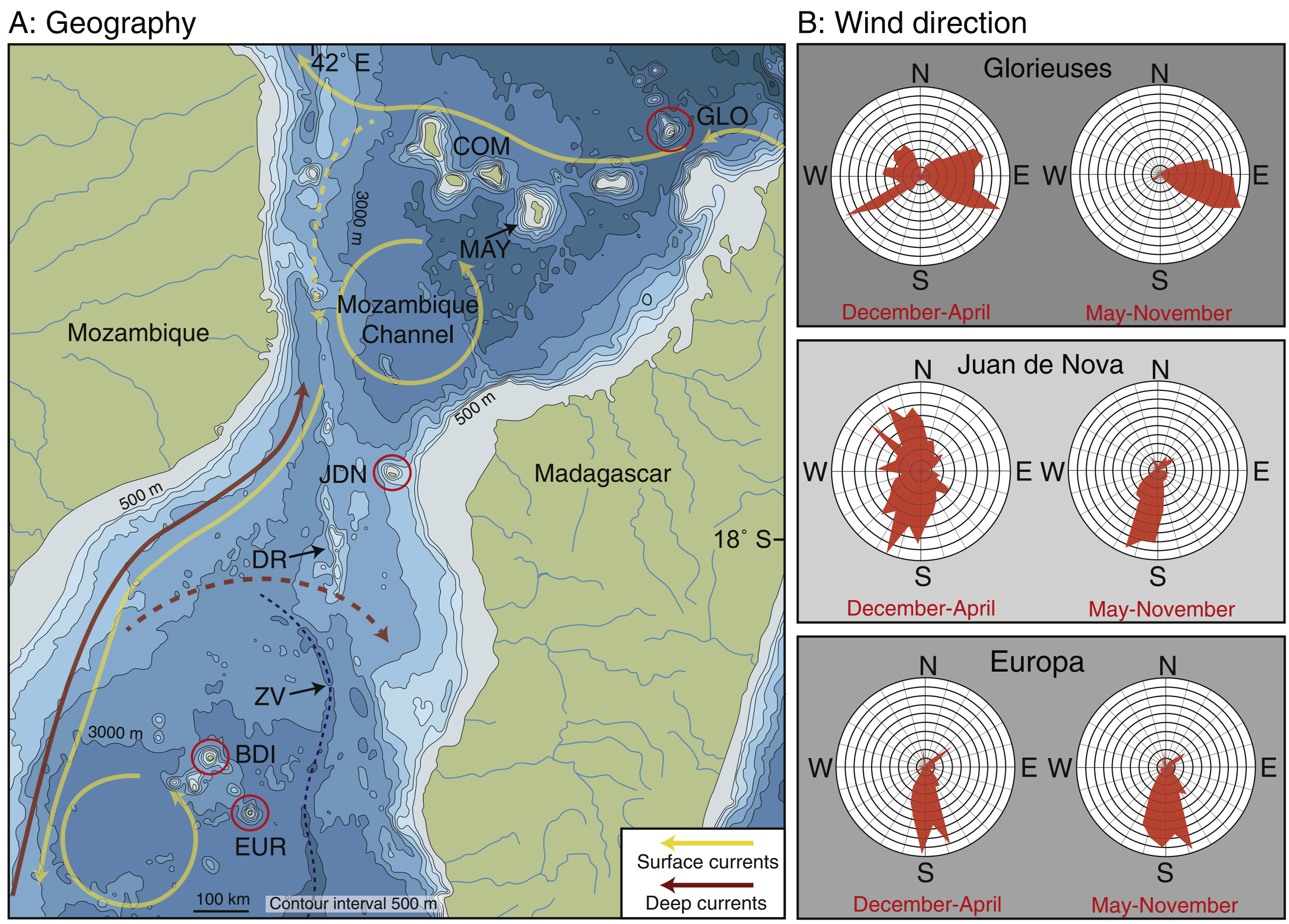

Fig. 1. A) Location map of platforms and other geographic and geologic features mentioned in this paper. Oceanic circulation from Breitzke et al. (2017). COM-Comoros Islands; MAY-Mayotte Island; GLO- Glorieuses Islands; JDN-Juan de Nova; DR-Davie Ridge; ZV-Zambezi Valley; BDI-Bassas da India; EUR-Europa. B) Present-day dominant wind directions from Metéo France, sourced from over 5000 individual measurements from weather stations on the islands. Bassas da India has no weather station, but is situated close enough to Ile Europa that wind directions are not appreciably different (see location in Fig. 1A).

transferred, deposited, and remobilized on the platform slopes are the focus of this paper, as well as the mechanisms responsible for such deposits. By using seismic, bathymetric, and core data, this study reveals new information about the geomorphology and sedimentology of these unique depositional settings. Because of their relatively small size (on a scale of tens of kilometers), the entire sedimentary system of each platform can be examined as a whole, forming a complete source-to-sink picture of sedimentation. This information is used to create a new, unique facies model for the type of atoll-like carbonate platforms discussed here, which are lacking in the geological literature, and provides a point of comparison to other, genetically different carbonate systems elsewhere.

2. Regional setting

The islands that are the focus of this study (Grande Glorieuse, Europa, Juan de Nova, and Bassas da India) lie within and around the modern Mozambique Channel (MC), an elongate basin in the Indian Ocean between the African continent and the island of Madagascar (Fig. 1). Together, these islands and the waters surrounding them are known as the Iles Eparses, and are part of the French Southern and Antarctic Lands. Islands are the subaerial portions of carbonate platforms that sit atop volcanic pinnacles originating from the basin floor. Platform tops are relatively flat and composed entirely of carbonate; there is no central volcanic peak. All are circular/equant in map view, except for Glorieuses, which has a roughly triangular shape.

The detailed origins and tectonic histories of each of these structures are not well-studied, but the emergence of all platforms is a result of the interplay between tectonic uplift and subsidence, extrusive volcanic growth, eustasy, and the rate of carbonate aggradation, all of which vary between platforms (Courgeon et al., 2016). Platforms are of different ages and genetic origins and may be related to localized hotspot chains or mantle plumes. The Glorieuses Archipelago (Fig. 2A, B) is at minimum Paleocene in age and is a part of a linear ridge of volcanoes that also encompasses the nearby Comoros (Courgeon et al., 2016). It shows no indication of any significant drowning events during its lifespan, and has been interpreted to now be tectonically stable (with a very slow uplift of ~0.012 mm/year since ~130 ka) owing to its position away from the Somalia-Nubian plate boundary (Guillaume et al., 2013). Juan de Nova (Fig. 2C, D) has been studied very little; however, it likely has a granite core (Förster, 1975) and is not currently undergoing any notable uplift or subsidence (Testut et al., 2016). Bassas da India (Fig. 3A, B) and Europa (Fig. 3C. 3D) have been hypothesized to be related to the Quathlamba hotspot, which formed the archipelago up to 60 Mya and is currently under Lesotho (Johnston and Thorkelson, 2000). Bassas da India specifically has also been shown to have originated in the late Oligocene/early Miocene, and has been volcanically active as late as the early Pleistocene (Courgeon et al., 2017). Large-scale faulting, structural deformation, and volcanism in Bassas da India and associated submarine banks have been tied to a southern extension of the East African Rift system (Courgeon et al., 2016).

Carbonate deposition in the Iles Eparses began between the Paleocene and Early Miocene, and continues until the present day (Courgeon et al., 2016, 2017). Sediment production was periodically