Upslope migrating sand dunes in the upper slope of the Mozambican margin (SW Indian Ocean)

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ABSTRACT: The upper slopes of continental margins are very energetic areas where nepheloid layers are often observed. Multibeam bathymetry, sub-bottom profiler and multi-channel high-resolution seismic reflection data acquired during the PAMELA-MOZ04 survey in the Mozambique Channel revealed the presence of sand dunes on the upper slope at 120-250 m water depth. The dunes migrate upslope and their crests are oblique to the contours. They are medium to large dunes, with wavelengths between 20 and 150 m and heights between 0.15 and 1.50 m, and their size decreases upslope. Seismic reflection data of the water column show internal solitary waves travelling offshore in the depth range of the dune field. The formation of the dune field could be related to the interaction of the barotropic tide with the upper slope that results in the generation of internal tides.

1 INTRODUCTION

Sediment transfer from land to ocean basins is strongly controlled by sea-level fluctuations, especially in areas with extended continental shelves such as the Mozambican margin. During sea-level lowstands, the Zambezi river, one of the longest and largest river systems of eastern Africa (Fekete et al., 1999), supplied high amounts of fine-grained sediment to the continental slope (Schulz et al., 2011). However, at present, during the sea-level highstand, the sediment is redistributed by currents, and winnowed sand is accumulated along the upper slope (Schulz et al., 2011). Currents in the Mozambique Channel (SW Indian Ocean; Fig. 1) are very complex and intense. They comprise a southward-bound, western boundary current that forms sand dunes at the Mozambican outer continental shelf (Flemming & Kudrass, 2018), and large (≥300 km diameter), southward migrating, anticyclonic eddies affecting the entire water column (Halo et al., 2014).

The presence of nepheloid layers on continental slopes has often been related to the elevated bottom shear stresses generated by internal tides (Cacchione & Drake, 1986; Puig et al., 2004). We propose that, in addition to geostrophic currents, internal tides can also affect the sedimentation of continental slopes.

2 MATERIALS AND METHODS

The multibeam bathymetry and the related backscatter used for this study were acquired with a Kongsberg EM710 system in 2015 during the PAMELA-MOZ04 survey (Jouet and Deville, 2015). The horizontal resolution of the bathymetry is 3 m, and 5 m for the backscatter. The seismic data used in this study were acquired during the same survey with a sub-bottom profiler (1800-5300 Hz) and with a 72-channels high-resolution mini GI system (50-250 Hz), which also imaged the water column.

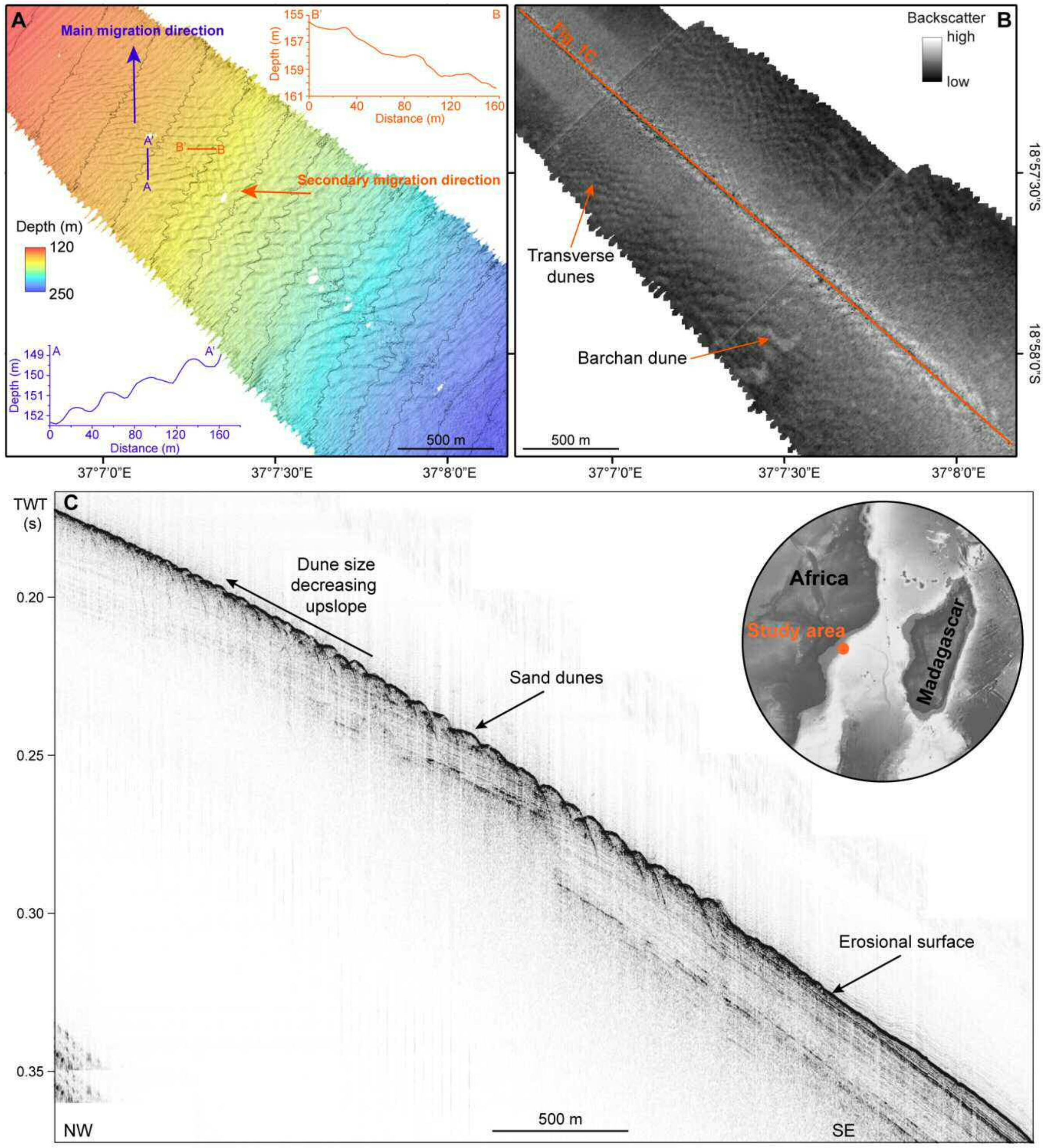

Figure 1. (A) Multibeam bathymetry and topographic profiles of the dune field. Depth contours are shown every 10 m; (B) Backscatter of the dune field; (C) Sub-bottom profiler image MOZ04-SDS-0102a showing an erosional surface in the deep part of the dune field and an upslope decrease in dune size.

3 RESULTS

A sand dune field was observed on the upper slope of the Mozambican margin (western Mozambique Channel) at water depths ranging between 120 and 250 m (Fig. 1A). The dunes are medium to large dunes, with wavelengths between 20 and 150 m and heights between 0.15 and 1.50 m. The dune crests are mainly oriented E-W (oblique to the contours), although some of them show a N-S orientation (Fig. 1A). Both orientations are superimposed, but the E-W orientation is dominant (Fig. 1A). The dune field is composed mainly of transverse dunes and only two barchan dunes were observed in the SW part of the dune field (Fig. 1B). The dunes migrate upslope, and their size decreases upslope (Figs. 1A, C). The deepest limit of the dune field is characterised by an erosional surface, indicating the presence of more energetic conditions in this area. The progressive change from erosion to large dunes and finally to medium dunes, suggests an upslope decrease of energy.

A multi-channel high-resolution seismic reflection profile acquired in the study area shows that the dune field is located above a plastered drift, which has a convex morphology (Fig. 2). The lower part of the plastered drift is characterised by low amplitude continuous reflections. In contrast, the area of the dune field (above the plastered drift) is characterised by high amplitude discontinuous and chaotic reflections (Fig. 2). These differences suggest a change in sedimentary facies, the upper part of the plastered drift being probably composed of coarser sediment.

The upper Mozambican slope has been previously identified as a hot spot for the generation of internal tides and internal waves (Da Silva et al., 2009). A seismic image of the water column confirms the presence of Internal Solitary Waves (ISW) at the water depth of the dune field (Fig. 2). Their amplitude is bigger offshore, indicating that they were moving toward the ocean (eastwards) (Fig. 2). The interaction of the barotropic tide with the continental slope may result in the generation of internal tides, that can radiate horizontally in the form of ISW (as observed in Figure 2) or as rays into the stratified water column (Da Silva et al., 2009). Internal tides generate turbulence near the seafloor and currents flowing across the slope (Gayen & Sarkar 2010), that may be strong enough to erode the seafloor and generate upslope migrating sand dunes.

4 CONCLUSIONS

4.1 A dune field composed of medium to large sand dunes was identified in the upper continental slope of the Mozambican margin at 120-250 m water depth. The dune migrate upslope and their size also decreases upslope. High-resolution seismic reflection data showed the presence of internal solitary waves at the depth of the dune field. The formation of the observed dune field may be related to the currents near the seafloor created by the generation of internal tides on the slope.

5 ACKNOWLEDGEMENT

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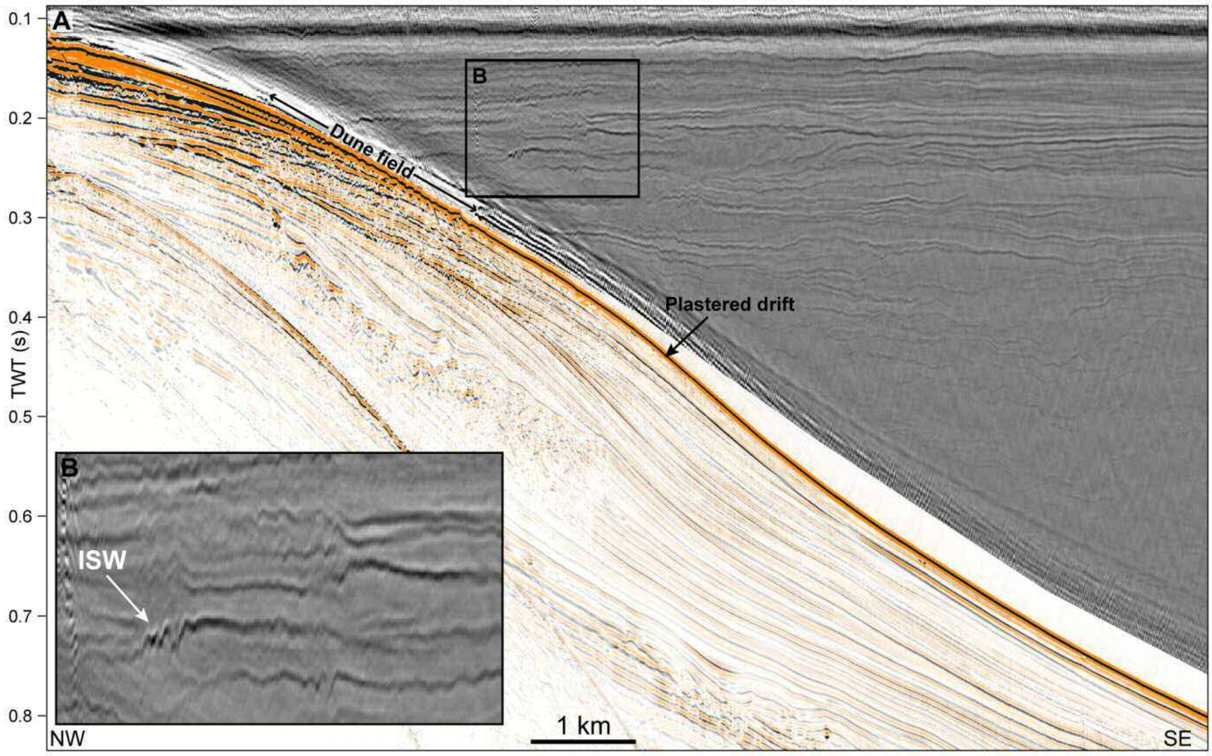

Figure 2. Multi-channel high-resolution mini GI gun seismic reflection profile MOZ04-HR-102 showing the dune field at the upper part of a plastered drift and Internal Solitary Waves (ISW) moving offshore at the water depth of the dune field.