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Very large dune formation along the Ebro outer continental shelf (Western Mediterranean)

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Large and very large subaqueous dunes have been observed in a number of outer shelf regions around the world, tipically developing on fossil sand bodies and ridges. Dunes observed on outer shelves usually display large dimensions with maximum wavelength reaching up to 500 m and heights up to 20 m. Forcing mechanisms able to induce their formation have been described as strong bottom currents related to tidal variations and water masses flowing under geostrophic conditions, generally controlled and enhanced by local geomorphologic configurations. In this study, such bed features have been recognized, mapped and measured around the Columbretes Islands (Ebro continental shelf - Western Mediterranean) with the aim to reconstruct which are the potential forcing processes that could generate them in relation to the local settings of the area. Swath-bathymetry around the Columbretes Islands was collected using 30 kHz and 180 kHz Multi Beam echo-sounders for a 50-400 m water depth range. Bathymetric data revealed the presence of three main relict sand bodies along the outer shelf, for a 80-116 m depth range, above which asymmetrical, slightly asymmetrical and symmetrical large and very large 2D and 3D subaqueous dunes were observed. Dunes range from 150 to 760 m in wavelength and from tens of cm to 6 m in height. These bedforms are composed of sandy sediments, presumably coming from the degraded relict sand bodies on which they developed, mixed to the fine fractions coming from the recent draping holocenic sediments. The orientation of the dunes is SSW and progressively turns to W directions moving towards the southernmost sector of the area, following the trend of the shelf-edge. Observed dunes display a strong asymmetric profile for those occurring along the shelf-edge (Symmetry Index (SI): 2.6) and lose progressively their asymmetry towards the inner portion of the shelf (SI: 0.5), being 0.6 the minimum SI value to classify the dunes as asymmetric. The subaqueous dunes observed along the studied region are amongst the largest ever recognized on an outer shelf setting. Morphologic characters and the orientation towards SW and W directions suggest the Liguro-Provenzal-Catalan geostrophic current as the primary forcing factor in their formation. Contemporary hydrodynamic measurement at the Ebro continental shelf-edge show that near-bottom wave action is negligible in this area, whereas maximum shear stresses induced by currents are able to resuspend fine sand particles and prevent the relict transgressive deposits from being covered by mud. However, recorded nearbottom currents generate shear stresses below the critical value for transport the relict coarse sands found in the study area and form large bedforms. The comparison of successive bathymetric images and the relation wavelength/height suggest that the described very large dunes are inactive features over long periods, as observed in similar environments along several continental margins. Thus, the morphological configuration of the Columbretes outer shelf must have played a crucial role in enhancing the southward flowing bottom currents during energetic hydrodynamic events, giving them the potential to generate such bedforms.