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Coarse cross-bedded grainstones in the Bartonian mid-outer ramp of the Urbasa-Andia plateau (W Pyrenees, N Spain)

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Coarse grainstones in carbonate platform successions are commonly interpreted as shallow-water deposits resulting from the dissipation of surface wave energy on the sea floor. On rimmed shelves, skeletal-oolitic sands form a rim near the shelf margin, which hinders the wave action and favors the occurrence of a back-rim lagoon. In contrast, on ramps and open shelves, grainstone facies mainly occur close to the shoreline, grading basinward into muddier carbonate successions, with two main boundary layers for ramp subdivision: the surface fair-weather and the storm wave bases. Nevertheless, most Cenozoic ramp successions lack sedimentary structures recording these hydraulic reference boundaries due to the seagrass baffling and/or intense burrowing, and ramp subdivision must be based in light penetration, as inferred from the photic dependence of the carbonate-producing organisms. This new criterion has permitted recognizing grainstone bodies occurring near the limit of light penetration, detached entirely from the shallow-water shoreline- and shoal related units.

In this case study, a 90-100-m thick Eocene example of crossbedded skeletal grainstones composed by echinoderm-, bryozoan-, red-algal fragments and orthophragminid larger benthic foraminifers is analyzed. This facies belt occurs at ca. 20-km from the paleo-coastline, downdip of *Nummulites-Discocyclina* facies, and grades basinward, at the outer ramp, into finely comminuted skeletal debris and marls with planktonic foraminifers. The skeletal composition of the cross-bedded belt is consistent with oligophotic carbonate production near the lower limit of the light penetration, and hydraulic turbulence to rework the coarser sediments and winnow-away the fines at the transition between middle- and outer ramp. Bedform migration reflects two main flow directions: oblique upslope traction currents (run-up) and downslope backwash return flow. These flow directions and the position within the ramp profile indicate turbulence to be detached from the surface storm waves and suggests internal waves breaking obliquely to the ramp slope. The present example documents the potential role of internal waves in redistributing sediments and shaping sand bedforms across carbonate-ramp systems, producing porous bodies close to basinal facies. These grainstone bodies may become excellent targets for hydrocarbon exploration but acquire particular relevance when a prediction of drains is needed in both exploration and production of unconventional reservoirs.

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