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

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Most marine grainstones in carbonate ramps and platforms are commonly interpreted to form in high-energy, shallow-water settings where wave energy dissipates by friction on the sea floor. The locus of energy dissipation varies with platform type. On rimmed shelves, skeletal-oolitic sands mainly accumulate near the wave-agitated shelf margin as a rim, which restricts wave action and a low-energy lagoon may form landwards. On ramps and open platforms, by contrast, grainstones commonly accumulate in the shallower zone near or attached to the shoreline, grading basinward into muddier carbonate successions. Within this conceptual scheme, most carbonate ramp subdivisions have been established according to the facies and sedimentary structures associated to the bathymetry-related hydraulic regime, in which the bases of the surface storm-waves and the fairweather waves are the boundary layers.

Since seagrasses encroached the oceans by the late Cretaceous, baffling the surface wave energy, and burrowing activity increased significantly, most Cenozoic ramp successions lack the bathymetry-related sedimentary structures and the record of wave and storm activity is commonly lost. This has induced ramp subdivision to become progressively based in light penetration, as inferred from the light dependence of the carbonate producers, particularly for the Cenozoic. This new scenario has permitted to recognize grainstone units detached from shoreline and shoals and produced at depths near the limit of light penetration, or even below, in basinal settings.

Here we document a 90-100-m thick Eocene example of crossbedded skeletal grainstones composed by echinoderm-, bryozoan-, red-algal fragments and orthophragminid larger benthic foraminifers. This facies belt occurs at 20-km from the paleo-coastline, downdip of Nummulites-Discocyclina facies, and passes basinward into finely comminuted skeletal debris and marls with planktonic foraminifers of the outer ramp. The skeletal composition of the cross-bedded belt indicates carbonate production to have occurred near the lower limit of the light penetration, and hydraulic turbulence to rework the coarser sediments and winnow-away de fines at the transition between middle- and outer ramp. Bedform migration indicates two main flow directions: oblique upslope traction currents (run-up) and downslope backwash return flow. This indicates turbulence to be detached from the surface storm waves and suggests internal waves breaking obliquely to the slopping ramp. This example documents the potential role of internal waves in shaping and redistributing sediments across ancient carbonate ramp systems, producing porous bodies close to basinal facies. These grainstone bodies may become good targets but acquire special relevance when prediction of good drains is needed in both exploration and production of unconventional.

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