Pseudo-shallow marine features in deep marine gravity-flow successions: lessons from the Menilite Beds at Skrzydlna (Oligocene; Western Outer Carpathians)

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Quite common in publications devoted to the marine and lacustrine environments are differences of opinion on bathymetry of the basin receiving detrital sediment, especially when sedimentary structures are interpreted as indicators of specific depth-defined environments (following classic textbooks). However modern studies of deep-water environments, experimental work, modelling and numerous outcrop studies of ancient successions mitigate against such an approach. In this respect, the flysch succession of the Menilite Beds strata at Skrzydlna, which contains a variety of features that can confuse a cursory observer seems to serve as a universally applicable example.

The succession at Skrzydlna records deposition in the western part of the synorogenic Dukla Basin during the Oligocene. The Menilite Beds are considered by most authors as deep marine deposits (the bathyal zone). The exposed section, almost 200-metre thick, is divided into three lithological intervals, each of which represents a radically different type of sedimentation. These are: i) a fine-grained association of terrigeonous and hemipelagic sediments; ii) infill of a canyon incised by about 40–50 m into the underlying strata, wider than outcrop and dominated by an olistostromal succession of debris flows with pebbles, boulders, slide and slump sheets; iii) succession of turbidites forming three fining-upwards sequences and ranging from thick, massive, amalgamated sandstones deposited by high-density flows in laterally migrating outcrop-scale channels, through 'normal' turbidites forming complete Bouma sequences (Ta-e), containing dunes and fining to Tce in the uppermost associations of thin-bedded sandstones and shales. These features suggest rapid uplift of the source area resulting in canyon incision and sudden onset of the olistostrome deposition that evolved upwards into proximal turbidite-fan sequence, which subsequently retrograded due to decreasing intensity of supply.

The oldest interval (i) consists of predominantly fine-grained facies, most characteristic of the Menilite Beds at their regional development. These are dark mudstones deposited in anoxic to dysoxic conditions and containing thin layers of fine-grained sandstones — turbidites with Bouma Tab; Tbc; Tabc; Tabe intervals, a 2–3 m thick intercalation of massive amalgamated sandstone, dark cherts, and locally silicified marls and limestones. The latter contain isolated lenses of medium-grained sandstone current ripple marks indicating three palaeocurrent directions. Two sets represent bipolar distribution of palaeocurrents, typical of shallow sea/shelf sediments reworked by tidal currents. However, these are interpreted here as the products of tidal currents reworking bottom sediments of the bathyal zone, the case known from contemporary environments. In this context, the third direction, perpendicular to the bipolar flows does not represent reworking by littoral current on shelf but deep marine contour current.

The main channel, or canyon (ii) incised into the slope sediments fed the depositional system with olistostrome deposits supplied from the rapidly uplifted source zone. Above there is a thinning upwards, turbidite sequence of four sub-complexes (A-D): A – conglomerate and sandstone fill three laterally migrating narrow, outcrop-scale erosional channels with a maximum depth of 15 m; B – two shallow (up to 2 m deep) distributary channels filled with very thick, massive or normally graded sandstones; C – turbidites Tb, Tc, Tbc with single occurrences of hummocky-like cross stratification and sandstone beds forming dunes at the mouth of distributary channels; D – less ordered interval of thick-, medium- and thin-bedded sandstones interbedded with mudstones, forming various incomplete sequences of Bouma intervals.

Interbeds of hummocky-like cross stratification, commonly found on the shelf, are interpreted in the deep-sea environment as the effect of Kelvin-Helmholtz instability or other complex flow processes, e.g. reflections of turbidity currents. A few occurrences of ripplemarks symmetrical in outer shape show unidirectional cross-lamination in cross section. These were modified by erosion that could have resulted from occasional extremely violent storms or flow reflections off channel margins. In spite of the external shape reminiscent of symmetrical ripplemarks these features do not possess the internal structure of composite cross laminae characteristic for oscillatory reworking of sand by prolonged, rhythmic action of waves. Solitary current ripplemarks showing flow directions opposite to the main transport

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direction are antidunes or deposits of currents reflected/deflected by channel sides.

In summary, in spite of geometrical and structural similarity to the features traditionally considered as formed on shelf, the structures described here, assessed in association with facies and evidence referred to in the introductory paragraphs, fall into the category of deposits known also from below the 'normal' wave base and below the shelf edge, i.e. in the slope region. Hence from deep-sea environment for which the occurrence of bipolar currents, dunes, hummocky cross-stratification and symmetrical ripplemarks are neither typical nor diagnostic, but do exist.