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Research Advances

An Upward Shallowing Succession of Gravity Flow Deposits in the Early Cretaceous Lingshandao Formation, Western Yellow Sea

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Objective

Several well-exposed gravity flow deposits in the Early Cretaceous Lingshandao Formation provide a rare opportunity to study deep-water processes. The main objective of this work is to establish the spatial and temporal relationships between the various gravity flow deposits, and thus to establish their sequence stratigraphic patterns and depositional conditions.

Methods

Field observations, large-scale measurements (1:20), sketches of field profiles and thin-section analysis were performed for the study.

Results and Interpretations

Five types of lithofacies including dark shales (DS), hyperpycinites (HP), turbidites (TB), debrites (DB), and slumps (SP) and five middle-term base-level cycles (MSC) were identified in a section on the Lingshan Island of 16.2 m thick. Horizontal lamination is well developed in dark shales and argillaceous siltstones (Figs. 1a and 1b). Sole marks are common at the bottom of sandstones and siltstones (Fig. 1c). Various soft-sediment deformation structures are well developed in sandstones and siltstones (Fig. 1). Both normal and inverse grading are common in the sandstones and siltstones. The Lingshandao Fm. consists mainly of dark shales, grey siltstones and light grey fine sandstones. The sandstones are poorly sorted, have a high matrix content (~20%), and consist of angular to sub-angular particles (Fig. 1d).

The identification of the short-term base-level cycles was based on the alternations of dark shales, siltstones and sandstones. The middle-term base-level cycles could subsequently be constructed on the basis of asymmetric short-term cycles and upward changes in thickness. Each of the middle-term cycles starts with a fairly short rising base-level, followed by a longer lowering base-level (Fig. 1). Couplets of beds with upward coarsening and upward fining are separated by micro-scale erosion surfaces; these couplets are interpreted as hyperpycnites originated from estuarine floods (Figs. 1a and 1b). Combined occurrences of sole marks, graded bedding in siltstones/sandstones and alternations with dark shales are interpreted as deep-sea turbidites (Fig.1e). Sharp basal and top boundaries of sandstones/siltstones with floating mudstone intraclasts most commonly typify deep-sea debris flow deposits (Figs. 1f and 1g). Large-scale convolutions and other sedimentary deformations, combined with mixing of various lithologic components, are interpreted as resulting from slumping over depositional slopes (Figs. 1h, 1i and 1j), mostly on delta fronts.

The lithofacies change from deep-sea dark shales at the base to hyperpycnites, turbidites, debrites and slumps at the top in each middle-term base level cycle. The turbidites, debrites and slumps tend to become ever thicker from MSC1 to MSC5. This indicates that the delta fronts prograded more extensively in successive middle-term base-level cycles. Dark shales developed after a short time when the sea level rose due to episodic tectonics or sea-level rise. Then the water shallowed ever more with ongoing sedimention in the basin.

The development of gravity flow deposits started with deep-sea dark shales and hyperpycnites, followed by turbidites, debrites and eventually slumps in each middle-term base-level cycle. This indicates that flood-generated hyperpycnal flows with high suspended-sediment concentrations reached distal basin floors and deposited fine-grained sediments when the sea level rose and maintained a high stand. Turbidity currents and debris flows reached to where the hyperpycnal flows were deposited when the delta fronts prograded farther and the sea level became ever shallower.

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Conclusion

The Early Cretaceous Lingshandao Fm. was deposited in a deep sea, and autochthonous sedimentation was interrupted by gravity flow events. Their deposits depended on the distance to the slope breaks in the belt of delta fronts and their progradation, and on the upward shallowing in each middle-term base-level cycle.

Acknowledgments

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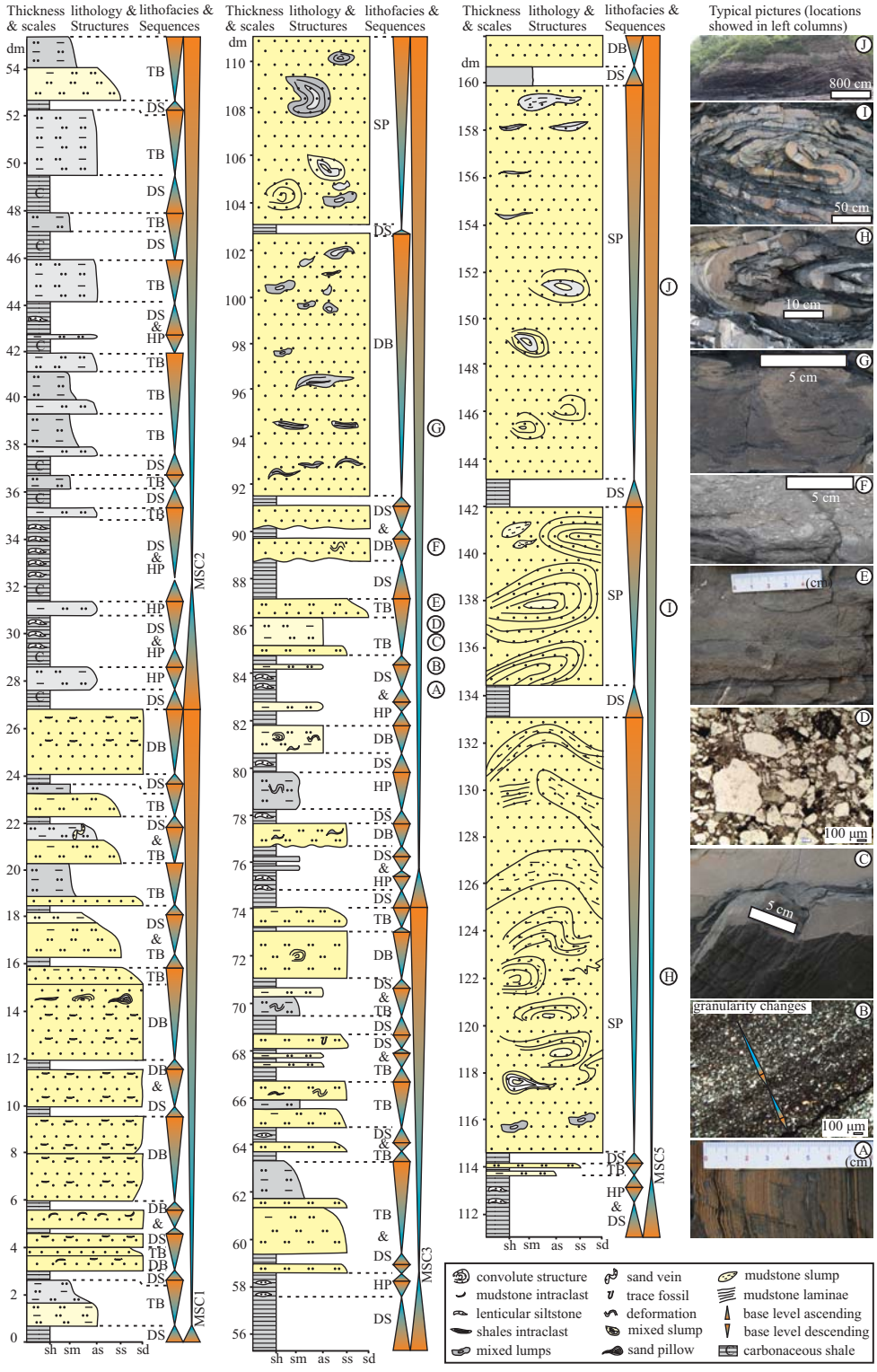

Fig. 1. Lithological log and base-level cycles of the Lingshandao Fm.
DS: deep sea; HP: hyperpycnites; TB: turbidites; DB: debrites; SP: slumps; sh: shales; sm: silty mudstones; as: argillaceous siltstones; ss:siltstones; sd: sandstones.