Turbidite models revisited

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Several standard turbidite models have been proposed and acted as norms for the description and interpretation of deep-water stratigraphic successions and analyses of hydrodynamic processes of turbidity currents and their related sediment-gravity flows. Although flume experiments, numerical modeling, and some direct observations of turbidity currents have played important roles in elucidating the origin of component units of the models, formation processes of some component units have continued to rely on theoretical consideration and/or speculation based on their lithofacies features. The models have been established in terms mainly of the combination of grain sizes and sedimentary structures. Although sedimentary structures represent cross sectional views of bedforms, the origin of component units and their vertical successions in turbidites has not necessarily been investigated in terms of bedforms. Thus, incorporation of component elements of a bedform into a turbidite model is challenging for a better understanding of the origin of spatial and temporal variations in lithofacies organization of turbidites. Turbidites which formed in active margin basins are commonly coarser than those in continental margin basins, and are locally associated with conglomerates and pebbly sandstones. In addition, silty turbidites are also common in the uppermost part of classical (sandy/silty) turbidites formed in active margin basins and enable us to investigate the origin of laminated silts and siltstones in fine-grained turbidites.

Conglomerates and pebbly sandstones in turbidite successions have been interpreted to be formed by tractional processes of turbidity currents (*sensu lato*). Thus, their transportation and deposition are likely induced by migration and aggradation of coarse-grained bedforms. Using outcrop analogues of coarse-grained sediment waves, which have been observed in modern deep-water environments, inversely graded, ungraded or stratified, and normally graded conglomerates are interpreted to represent deposits formed in stoss side, central part, and lee side of a coarse-grained sediment wave deposit, respectively. In addition, planar stratified and/or spaced stratified pebbly sandstones, which have been assigned to be formed as traction carpets, show gently undulating waveforms, which gradationally overlie coarse-grained sediment wave deposits or constitute a distinctive bedform by themselves, and are overlain gradationally by ungraded or normally graded pebbly sandstones. Thus, component units of coarse-grained turbidites can best be interpreted to be formed by migration and aggradation of different parts of coarse-grained sediment waves.

The origin of laminated silts and siltstones in the uppermost part of classical turbidites still remain controversy, and has been supposed to be a result of shear shorting of silts and clay flocs. This process, however, was proposed to explain the formation of laminated muds and mudstones in the basal part of turbiditic muds and mudstones, and is not necessarily suitable for explaining the origin of laminated silts and siltstones. Detailed outcrop observations indicate that silt lamination commonly occurs as sinusoidal lamination over the underlying current-ripple cross-lamination, and distinct grain size breaks are obvious within the laminated siltstones in the stoss sides while gradational fining is common in the lee sides. Long axes of silt grains on the lamina planes is aligned nearly orthogonal to the paleocurrents in the lower part and gradationally changes to become nearly parallel to the paleocurents in the upper part of the laminated siltstones in response to fining and the increase in clay contents. Thus, laminated silts and siltstones are likely to have formed as a response to the development of low-amplitude sinusoidal bedforms over current ripples with an increased rate of suspended load deposition in turbidity currents.

Keywords: turbidite models, coarse-grained turbidites, coarse-grained sediment waves, fine-grained turbidites, laminated siltstones

