Unbioturbated marine mudstones: environmental stress or rapid deposition? A worked example from the Ordovician Beach Formation, Newfoundland, Canada

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Recent research demonstrates that most mudstone successions contain a great deal of evidence of having been deposited by advective sediment transport processes. These processes are commonly difficult to investigate because original sediment fabrics are commonly disrupted by the activity of burrowing organisms. In order to investigate some of the mechanisms of mud dispersal, Lower Ordovician sediments of Bell Island have been studied. These sediments are ideal because the primary sedimentary textures in the mudstones are commonly still preserved. At Freshwater Cove, storm-dominated shoreface sediments are partially bioturbated by trace fossils of a proximal *Cruziana* ichnofacies. The purpose of this study was to examine all possible controls on deposition of intercalated, unbioturbated mudstones in the succession through integration of sedimentological and geochemical datasets at a range of different scales. Previous sedimentological studies interpreted unbioturbated mudstone intervals as being deposited in an anoxic, low-energy paleoenvironment. Our micro-fabric analysis and geochemical studies of these mudstones suggest that anoxia is not the only possible control on intensity of bioturbation. Within thick, unbioturbated siltstones and mudstones, bases are erosive, and rip-up clasts are common. Through microfabric studies (i.e., low-power microscopy), a wide range of previously unrecognized sedimentary structures has been described in the unbioturbated mudstones. Those structures include thin (<1 mm), stacked beds with erosional tops and bases and well-developed low-angle cross-stratification. Microscopic bioturbation in the form of very small (<1 mm) *Planolites* burrows is common in mudstone horizons. Mudstones contain 0.5% TOC in average, with peak values of up to 3.4% TOC. Pyrite framboid analyses of unbioturbated intervals reveal that the water column close to the sediment-water interface was fully oxygenated during deposition. Sedimentary provenance of mudstones within distinct facies associations (using Rare Earth Elements, REE) reveals that all examined mudstones are either from the same source, or have undergone the same mixing process before deposition. We have therefore determined that, (1) given the distal location of the exposure with respect to a potential fluvial source, (2) the fully oxygenated state of the water column, and (3) the evidence for bottom currents, that at least some of the unbioturbated muds were deposited as wave-enhanced fluid mud flows. This episodic form of sediment supply is widely recognized from recent, mud-rich coasts but has never been appreciated as a significant depositional process in the lower Palaeozoic. A careful, integrated, study of other ancient mudstone successions is needed in order to assess the importance of fluid mud deposits throughout the sedimentary record. In addition, uncritical interpretation of unbioturbated mudstones as resulting from bottom water anoxia is potentially flawed.

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