ABSTRACT

Contrasting Parameters of Deposition and Erosion of High Vs. Low-Latitude Muddy Shelf Seas – an Experimental Perspective

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Muds are common sediments on modern shelves and in deep sea environments from the equator to high latitudes. Given that mudstones are the most common sedimentary rock in the rock record, we can assume that these as well were deposited across a wide spread of latitude. Traditional clues to recognize depositional latitude in mudstones have come from faunal components and in the case of glacial activity, input of ice rafted sediment grains can also be diagnostic of high latitude mudstones.

Flume experiments with muddy suspensions show that low-energy settings are not a prerequisite for the accumulation of muds and shales. Flocculation produces deposition-prone aggregates that form bedload ripples at flow velocities that would also produce ripples in sandy sediments (Schieber et al., 2007). These floccule ripples are internally cross-laminated, but due their high water content (80-90 % by volume) are subject to substantial compaction. Because of this, original cross-laminae become severely flattened and are difficult to recognize. The rock record equivalent of this type of sediment are finely laminated shales with sharply defined laminae. Experiments also show that currents of comparable strength can re-erode water-rich muds and produce mm-size fragments that can be transported for large distances. When re-deposited these transported "soft" clasts give rise to what is known as lenticular fabric in the rock record (Schieber et al., 2010).

Extension of above experimental work to sediments where an approximation of marine snow (partially degraded finely ground kelp) is added to a moving clay suspension show that such flows produce clay-organic floccules that are deposited at the same flow velocities/shear stresses as the clay flocccules of earlier experiments. In room temperature experiments, the same features as observed in pure clay suspensions were observed, such as ripple formation and generation of laminated muds, once the critical velocity of sedimentation was reached. When flow temperature was lowered to approximately 5^0 C no sediment accumulation occurred at this velocity. This in itself was not unexpected, because viscosity of water increases as temperature drops, and thus one expects that shear stress will increase as well.

For a fluid to transport sediment across a bed surface, the boundary shear stress exerted by the fluid must exceed the critical shear stress for the initiation motion of grains at the bed. In an incompressible and isotropic fluid, the shear stress can be expressed as the product of dynamic viscosity and the derivative of the flow velocity relative to displacement in the perpendicular direction. Because the dynamic viscosity of water is temperature dependent and increases as temperature is lowered, in seawater the dynamic viscosity at approximate seafloor temperature (5^0 C) is 65 % higher than at room temperature (24^0 C). This implies that the ability of a fluid to move sediment grains increases as water temperature drops, or that in order to move a given grain lower flow velocities are needed at lower temperatures.

When the flow velocity in low temperature experiments with clay plus marine snow mixtures was lowered to compensate for the increase in viscosity (so as to keep the bed shear stress the same as in room temperature experiments) bedload floccules formed, gave rise to ripples, and a

laminated mud bed accumulated. For collecting the sediment a retractable piston, integrated into the flume base, was used. By slowly retracting the piston we were able to collect a “negative core” of laminated sediments that recorded the sedimentary history of the experiment. When experimental cores from room temperature and cooled experiments are compared, it is obvious that the former are liable to intermittent scouring when the piston fill reaches ~5 cm thickness, whereas the latter show less scouring. This difference between warm and cold experiments is even better developed when the oxygen content of the flow is lowered to dysoxic-suboxic levels.

Dispersed organic matter, microbial slime, and microbial coatings are a common aspect of modern marine muds, and the observed differences between warm and cold experiments suggests that the contained organic matter that contributes to the mud’s cohesion reacts to temperature and oxygen content of the depositional setting. TOC contents measured in these experiments are lower in the warm experiments, suggesting that microbial degradation of the binding slime matrix made these sediments more susceptible to erosion. Better lamina preservation in low oxygen cold settings suggests that a change from aerobic to anaerobic degradation caused a further slow-down of microbial degradation of the slime matrix.

The implications from these experiments for evaluating cold vs warm water mud deposition are as follows:

(1) Under otherwise equal conditions of flow velocity and sediment mix, bedload mud deposition via floccule ripples should be more common in warm water settings, whereas intermittent erosion of watery surface muds could be expected in cold water settings.

(2) In cold water settings, improved cohesiveness of surface muds should, in the case of an erosive regime, lead to mud rip ups that can be transported for substantial distances and redeposited elsewhere.

(3) A combination of cold water and oxygen restricted settings should enhance the potential for abundant mudstone intervals that consist of previously eroded soft mudclasts. Continued transport of these sand size particles could lead to large scale muddy bedforms at the decimeter, meter, and decameter scale (in height).

(4) Whereas in a shelf setting the duration of current events or current systems may be insufficient to generate muddy bedforms from soft rip-ups larger than a few dm’s in height, in deep ocean basins where temperatures are low as a rule, bottom currents should produce muddy bedforms at the meter and even decameter scale (in height). Muddy bedforms of that scale occur in modern ocean basins, and whether or not they are composed of recycled soft mud clasts is a testable hypothesis.