Mud dispersal on continental shelves and predicting shale gas reservoir targets

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Successful shale gas exploration requires a subtle appreciation of the sedimentological and petrophysical properties of mudstones that are the reservoir targets. For decades, these rocks have largely been neglected because they are fine-grained and, at first sight, commonly appear laminated. Recent research, however, has demonstrated that mudstones, which are also economic shale gas reservoir plays, are typically enriched in organic carbon and susceptible to hydrofracturing. As a result, geologists seeking to determine a particular units' shale gas potential, have typically investigated:

(a) Their composition (ideally they should contain higher than average silica and carbonate concentrations) – to determine how likely they are to successfully fracture during completion.
(b) Their TOC contents (ideally >2%) – to ensure that economic volumes of gas will be present.
(c) Their maturity (ideally in the gas window) – to ensure that gas has been generated, and to ensure that adequate porosity for economic volumes of are likely to be present.

Once these data have been obtained, this information is typically incorporated into geological models that are designed to predict the stratigraphic location of "shale gas reservoir sweet spots". On the basis that "target shale gas facies" appear to preserve lamination, are commonly enriched in pyrite, as well as organic matter and predominantly composed of fine-grained detritus, these models typical assume that deposition mainly occurred in low-energy, deepwater anoxic basins, where sediment was being delivered to the basin floor by suspension settling as a continuous rain from buoyant plumes. In these models, facies variability is usually interpreted as being caused by variations in primary production within the water column coupled with rare influxes of sediment linked to turbidite emplacement. Recent research, however, clearly demonstrates that many of these sediments are bioturbated. These fabrics suggest that persistent anoxia cannot have been a prerequisite for organic matter preservation in these settings. The presence of bioturbation in these rocks, however, raises questions as to how unusually large amounts of organic matter were actually preserved, when the most efficient oxidant was present and in theory capable of dramatically downgrading their source potential. In the light of this problem the aim of this research is to investigate how sediment was delivered to the sea floor in these paleoenvironments to determine if there any clues as to how the organic matter was preferentially preserved.

In order to investigate this problem, unusually thin, polished thin sections were manufactured of a variety of mudstones collected from organic-carbon enriched successions, including the Kimmeridge Clay Formation, Jet Rock and Mowry Shale. Textural analyses of the fabrics present in these units combined with geochemical analyses reveal that they are highly heterogeneous, and where not bioturbated, are commonly organized into thin, normally-graded beds organized into "triplets", evidence of erosion, and abundant pellets composed of clay, amorphous organic matter and calcareous nanoplankon even where they contain up to 20% TOC. The presence of these fabrics indicates that sediment was delivered to the sea floor in these basins by a combination of advective currents and suspension settling. Moreover, the characteristic triplet structure of these beds suggests that at least some of the sediment was delivered by newly-recognized wave-en-

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hanced sediment gravity flows of fluid mud, whereas much of the rest was being delivered in the form of pellets. The existence of these fluid mud flows is important, as their presence indicates that much of the sediment was actually delivered in episodic pulses to the basin, rather than as a continuous rain. Additionally, the presence of pellets is also significant as they indicate that much of the sediment was likely packaged into larger organo-minerallic aggregates in the water column, prior to settling to the sea floor. The existence of these aggregates means that detritus in the water column likely settled rapidly to the sea floor following its formation, thereby minimizing the effects of oxidation in the water column and maximizing the chances of organic matter preservation.

The combination of episodic sedimentation coupled with rapid transit of sediment through the water column explains the preservation of organic matter in these settings, as local sediment accumulation rates were sufficiently rapid to ensure that at least some of the organic matter was preserved. These factors mean that it is simply not necessary to invoke bottom water anoxia as a pre-requisite for organic matter preservation. Additionally, the requirement for deep-water enclosed basins to preserve organic matter has likely been overstated; consequently mudstones that might have shale gas potential are likely to be much more widespread than most researchers assume.