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Clastic Shelf Depositional Environment: Facies, Facies Sequences and Economic Values

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Abstract
Perhaps more than any other single environment, the continental shelf typifies the dynamic 'input/output' aspect of the earth surface processes. Clastic sediment introduced onto the shelf must bypass the various nearshore sediment 'traps', such as estuaries, bays, lagoons, tidal flats, etc. Once on the shelf, a complex mixture of tidal, wave, oceanic and density currents disperse the sediments, allowing some proportion to 'escape' over the shelf edge, into the deep ocean basins.

This paper offers examination of Facies and Facies Sequences of Shelf Depositional Environment, under the two classifications: Tide-Dominated and Stormwave-Dominated Shelf Deposits. Mention is also made of the economic importance of the environment, with special emphasis on its petroleum prospectivity. Some petroleum provinces producing from shelf depositional environments were equally touched.

INTRODUCTION

The continental shelf is that part of the sea floor between the shoreline and the shelf break, or upper edge of the continental slope (Fig.1).

The Clastic sediments introduced onto the shelf are always subjected to thorough and complex mixture by tidal, wave, oceanic and density currents; and could disperse the sediments, allowing some proportion to 'escape' over the shelf edge, into the deep ocean basins.

Several kinds of vertical successions may thus be generated in shelf sediments, depending upon whether deposition takes place during transgression or regression, and, of course, the dominant type of shelf processes operating during deposition.

The potential for economic oil and gas accumulation in sandstone facies of ancient shelf deposits is high. Indeed, the setting, whether it is of epicontinental or pericontinental, provides four main ingredients for petroleum accumulation:

i. Potential reservoirs
ii. Potential hydrocarbon source rocks
iii. Potential trapping mechanism
iv. Time and depth of burial required to generate petroleum

FACIES : TIDE-DOMINATED SHELF

- Physical structures tend to dominate sandy shelf with few bioturbation features.
- They are often characterized by the presence of sandbodies of various types and dimension (Fig.5).
- Individual sandbodies can range from about 8m to as high as 30-40m thick.
- Local subsidence and accommodation will have these sandbodies well developed. Hence, if properly followed, they could be seen to pinch out or die out.
- The distribution of grain sizes on a tide dominated shelf is complex. Sediments are deposited along transport paths as pebble sheet, sandwaves, sandy mud, sheet muddy and as extensive sandridges, up to 20m (Fig.5).
- There is always a general trend towards decreasing grain size along the transport path, perhaps from coarse sand to mud. This trend is due to decreasing net current strength (Leeder, 1982).
- The distal ends of transport paths are often areas of isolated sand patches and small sandwaves with numerous ripple bedforms and bioturbation features (Leeder, 1982), as seen in Figure 8.
- Reactivation surfaces are abundant (Fig.4)

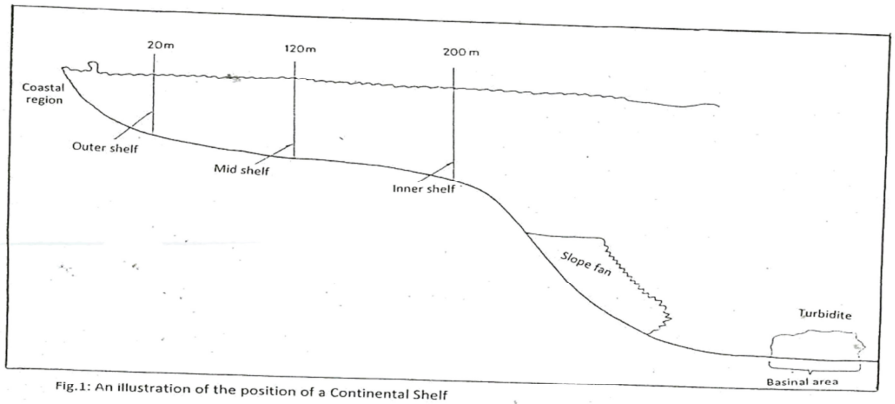

Fig.1: An illustration of the position of a Continental Shelf

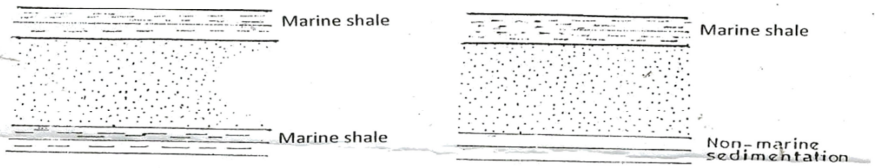

Fig.2: An illustration of sandy shelf characterized by marine sedimentation in the Greensand Series of South/South East England (Lower Aptian – Lower Albian). (*Adapted from Dike, 2004*).

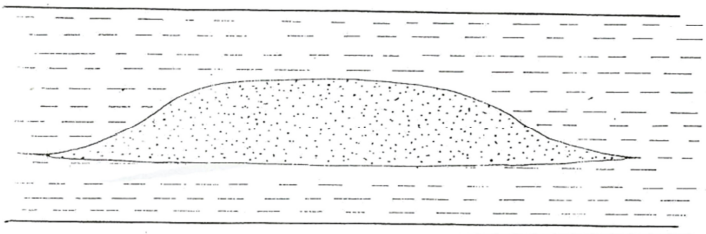

Fig.3: An illustration of sheet geometry of sandy shelf, elongated parallel to subparallel to shoreline. (*Adapted from Dike, 2004*).

- Sandy shelves are usually associated with marine sedimentation (Dike, 2004). It could be overlain and underlain by marine shale. Yet, in some places, it could be overlain by marine shale and underlain by continental non-marine sedimentation (Fig.2).
- They tend to form sheet geometry with the direction of elongation parallel to sub-parallel to the shoreline (Fig.3).
- Abundant cross-bedding and ripple cross lamination.
- Ubiquitous presence of glauconite and marine fauna like ammonites, pelecypods, brachiopods, etc.
- Sandy shelves have good preservation potential.
- They can be seen as basal deposits of major transgression.
- Paleocurrents are mainly unimodal, although bipolar cross-stratification could be present locally.
- Tidal current velocities could range from about 50cm/sec to more than 150cm/sec.

FACIES: STORMWAVE-DOMINATED SHELF

- Commonly highly bioturbated with few physical structures, except possibly planar lamination.
- Little coarse sediments occur here except during intense storm conditions.
- Muds are typically thoroughly bioturbated.
- Linear sand ridge, 2-3km wide and few tens of kilometers long could be present.
- Storm layers and hummocky cross-stratification are especially characteristic of stormwave-dominated shelf sediments.

- The sediments have low preservation potential; the reason for the seeming difficulty in recognizing them in ancient record.
- They contain greater proportion of mud than do tide-dominated deposits.
- Cross-bedding in sands tends to be hummocky cross stratification type.
- They are often characterized by low tidal current velocities; commonly less than 25cm/sec, and fair weather wave base is normally shallow (below 10m).
- They often exhibit coarsening upward sequence that commense with shelf mud, passing upward gradationally into bioturbated muddy sand, interbedded sand and mud, and topped by well sorted orthoquartzite bar sandstone.

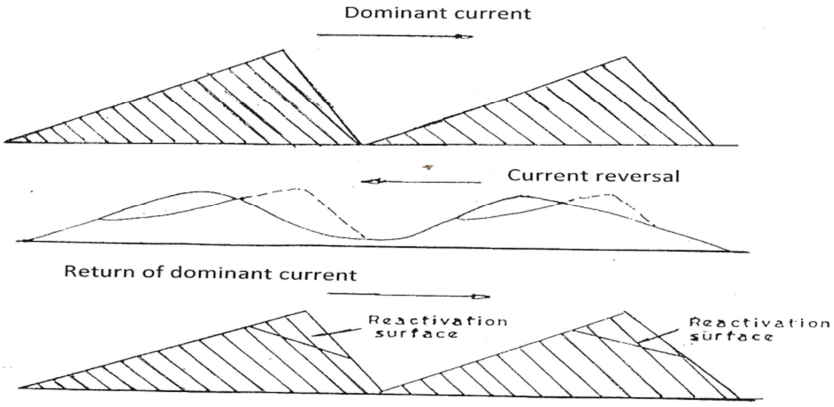

Fig.4: An illustration of reactivation surface.

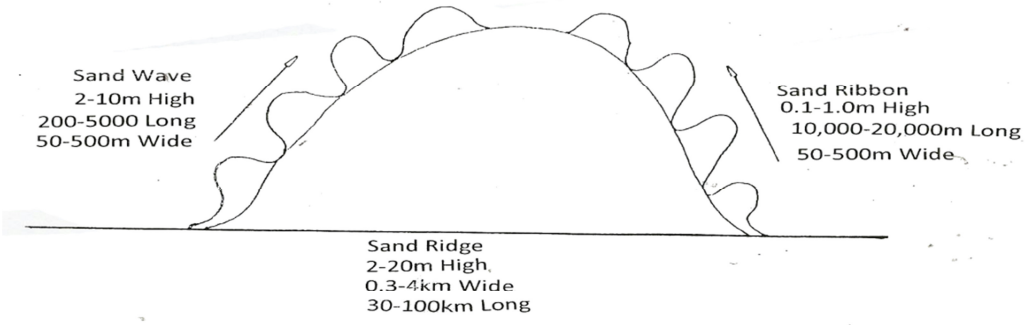

Fig.5: An illustration of sediments in a tide-dominated shelf. (*Adapted from Dike, 2004*).

ECONOMIC IMPORTANCE OF CLASTIC SHELF DEPOSITS

The potential for economic oil and gas accumulation in sandstone facies of ancient shelf deposits is high. Some of the favourable elements include:

- Marine sorting mechanism, which produces relatively clean and well sorted sands for reservoir.
- Adequate supply of organic rich mud for source rock and seal lithology.
- Abundant intrabasinal tectonism which enhances trap potential by creating additional trapping situation and migration pathways.
- Also, burial, which comes with time and continued deposition, may be enhanced by tectonism, and provides the heat required to release petroleum from organic-rich source rocks.

PETROLEUM PROVINCES FROM ANCIENT SHELF DEPOSITS

There are quite a number of petroleum provinces where petroleum exploration and production have been successfully undertaken from ancient shelf deposits. They include:

- Petroleum reservoirs of Simpson Sandstone (Ordovician), in Oklahoma, USA.
- The tide-dominated Southern North Sea is a world class province, noted for its substantial gas potential.
- The Sussex and Shannon Sandstone Members (Cretaceous) of the Powder River Basin, Wyoming, USA. As at 1 March, 1976, both have generated well over 10 x 10^6 bbls of oil and about 4.8mmcf

of gas (Crews *et al,* 1976).

- The Greensand Series of South and South-East England (Lower Aptian – Lower Albian), in the Isle of Weight.

FACIES SEQUENCES

Several kinds of vertical successions may thus be generated in shelf sediments, depending upon whether deposition takes place during transgression or regression, and, of course, the dominant type of shelf processes operating during deposition. It is difficult to generalize about these successions, except to say that transgression tends to produce fining upward succession that may begin with coarse lag deposits, and regression produces coarsening upward successions. However, these successions can only be considered as working models. Actual transgressive and regressive successions may differ markedly in detail from these idealized profiles.

According to Dike (personal communication, 2004), tide-dominated shelves have no distinct sequence; they are independent of each other (Fig.7). They depend on the strength of the current in operation at a particular moment. On the other hand, the stormwave-dominated

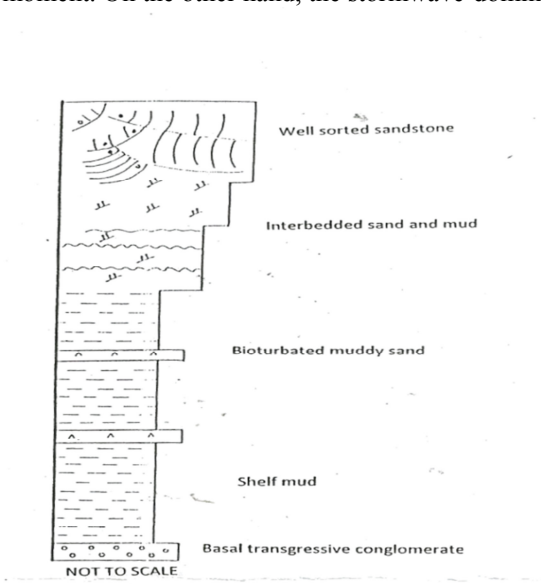

Fig.6: An illustration of a coarsening upward sequence of a stormwave-dominated shelf. (*Adapted from Dike, 2004*).

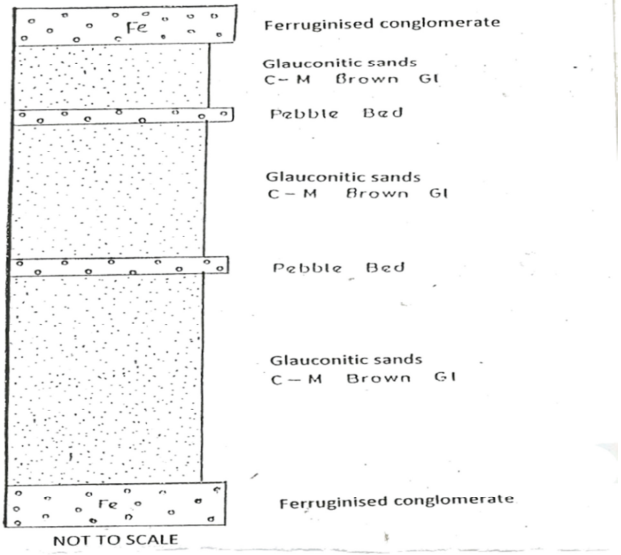

Fig.7: An illustration of a tide-dominated shelf sequence. (*Adapted from Dike, 2004*).

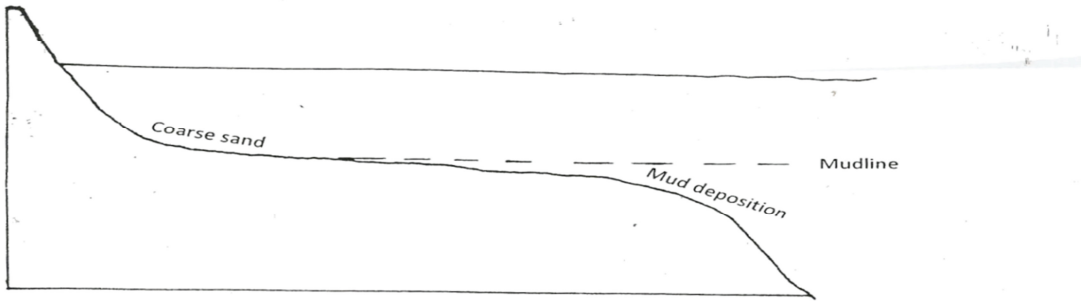

Fig.8: An illustration of tidal current transport path showing the distal ends of mud deposition. (*Adapted from Crews, 1976*).

shelf (Fig.6) exhibits a coarsening upward sequence that usually commences with shelf mud, passing upward gradationally into bioturbated muddy sands to interbedded sand and mud, then topped by well sorted orthoquartzite bar sandstones.

CONCLUSION

Clastic sediments on the shelf are moulded by tidal and wave currents. The final pattern of modern shelf facies depends not only on the magnitude and direction of these currents, but also upon the availability of sediments provided from the coast by the various escape mechanisms.

Tide-dominated shelves and winter wind systems assume an overriding dominance, causing net residual currents to arise from wind drift, set-up and surge.

Shelf sands are normally well sorted and free of clay. Hence, they have excellent porosity and

permeability. Sometimes, individual sand waves are enveloped in mud. But, commonly, continental shelf sands occur in laterally extensive blankets.

Indeed, the lateral permeability of such formations has often engendered excellent aquifers and petroleum reservoirs.

This paper is expected to add impetus to the search for liquid hydrocarbon,as more nations continue to record measurable success in hydrocarbon exploration and production.

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