Poster 15

Sedimentology and reservoir properties of shoreface sandstones in the Sandakan Formation, Sabah

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Shoreface sandstones are recognized worldwide as excellent and important petroleum reservoirs as well as in Brunei and Malaysia. However, few studies relate sedimentological data and stratigraphic successions to porosity, sand body geometry and permeability trends. This is especially true for low latitude settings on semi-enclosed seas where depositional environments, and hence stratigraphic successions, are markedly different from the temperate, open ocean coasts where most of the commonly-used facies models were derived. Wave energy generally is low in semi-enclosed seas and shoreface sands often form sand bodies that are thinner, narrower, finer-grained and muddier than their open-ocean counterparts. The shoreface reservoir sands of Brunei and adjacent Malaysia that were deposited under the low wave energy regime of the South China Sea are an excellent example (Sandal, 1996; Petronas, 1999). However, the rate at which those sedimentary parameters vary with changing wave energy remains poorly understood, especially for low energy systems.

The middle Miocene Sandakan Formation of Sabah is comprised of sandstones and mudstones from several shallow marine depositional environments, including shoreface sandstones (Noad, 1998). Facies associations within the Sandakan Formation are much different than those on the northwest Borneo margin and suggest a significantly higher energy depositional environment. The sandstones are well-exposed in several prominent ridges that allow estimation of lateral continuity as well as detailed facies and stratigraphic analysis.

Four facies are represented in the major sandstone outcrops. Upper shoreface sandstones have excellent reservoir properties. They are fine to medium grained, moderate to well sorted and occur as 10–30 m thick units that coarsen upward and are laterally continuous for at least 1 km. The units consist of amalgamated 0.3–1.0 m thick beds with erosional bases that are locally separated by thin (< 0.01 m), laterally discontinuous mud layers. Generally, the sands appear massive with little bioturbation but trough cross-bedding, low-angle cross-bedding and parallel lamination are relatively common and most of the bed surfaces are wave-rippled. The sandstone units have a net to gross of 90 and porosities that range from 20 to 32% and average 27%.

Beds of very fine to fine grained lower shoreface sandstones separated by very thin, highly carbonaceous mudstones are stacked into 8–10 m thick units. The moderately bioturbated sands are parallel laminated and wave-rippled with mud rip-up clasts; hummocky cross-stratification and trough cross-bedding indicative of storm events occur locally. Porosity averages 18% but reservoir potential is only moderate because carbonaceous mud laminations and drapes form abundant permeability barriers. The medium grained, moderate to well sorted, clean sandstones within the offshore transition facies are storm beds that are 0.7–1.5 m thick with erosional bases and wave-rippled tops; hummocky cross-stratification, parallel lamination and planar and trough cross-bedding are common. Despite an average porosity of 20%, reservoir potential is moderate because the sands are separated by 0.3–0.5 m mudstones that constitute significant permeability barriers. The fourth facies is thick mudstones that Noad (1998) has interpreted as tidal flat and mangrove swamp deposits based on faunal evidence.

Outcrop successions consist of progradational parasequences. Offshore transition storm sands and interbedded mudstones pass upward into lower shoreface sandstones followed by upper shoreface sandstones in some outcrops and directly into upper shoreface sandstones in others. There is an abrupt, but transitional, boundary between the shoreface sands and the tidal mudstones that cap each parasequence. The facies associations suggest that the depositional environment was a relatively high energy, wave-dominant coastline immediately shoreward of an extensive mangrove swamp, whilst the stratigraphic succession indicates progradation in response to relatively small changes in sea level. The offshore mudstones that occur in nearby outcrops (Noad, 1998) probably record larger sea level falls.

An apparent modern analogue for the depositional environment of the Sandakan Formation is the north coastline of the Dent Peninsula in Sabah. There, large tracts of mangrove swamp lie shoreward of a ~100 m wide, vegetated barrier beach of fine sand that extends for approximately 50 km along the coast. The beach is broken at 4–6 km intervals by tidal estuaries that have spits growing to the northwest, suggesting longshore transport in that direction. Sediment plumes extend seaward from the estuaries during the ebbing tide and presumably transport fine sediment offshore. Progradation of the Dent Peninsula shoreline would deposit the same sedimentary structures, facies and stratigraphic succession, as in the Sandakan Formation outcrops, with mangrove swamp muds overlying shoreface sands that succeed offshore transition storm sands and interbedded muds. Sediment plumes associated with estuaries may supply a large amount of carbonaceous mud to the lower shoreface.

Hindcasting from wind records indicates that the coastline of the Dent Peninsula is not an exceptionally high energy environment. The strongest winds blow from the east-northeast approximately 10% of the time; the 500 km fetch suggests that wave heights rarely exceed 1.5–2.0 m waves, which is small compared to open ocean coasts but larger than in northwest Borneo where they rarely exceed 1 m (Sandal, 1996). However, the waves approaching the Dent Peninsula are large enough to overwhelm the effects of the small spring tidal range of 1.2 m, to develop the clearly wave-dominant shoreline and, by analogy, to have deposited the shoreface sands of the Sandakan Formation with their excellent reservoir properties.