GEOLOGY POSTER 4

TRANSGRESSIVE-REGRESSIVE CYCLES IN THE MALAY BASIN: THE INTERPLAY OF TECTONICS AND SEA LEVEL CHANGES IN A SILLED BASIN

Mazlan Madon

PETRONAS Research Sdn. Bhd., Kawasan Institusi Bangi, 43000 Kajang, Selangor, Malaysia

Understanding the interplay of tectonics versus sea level changes in sedimentary basins has important economic implications. In rift/extensional basins, stratigraphic onlaps and pinchouts can form important hydrocarbon traps. Onlap plays develop on the basin margins during transgressions, whereas reworked/re-deposited shallow water sands and turbidites deposited during regressive events may form basinal plays. Transgressive-regressive cycles in a deforming rift (extensional) basin are strongly influenced by both eustatic sea level changes and tectonic subsidence/uplift. To explore for such plays it is important to understand how these major factors control sedimentation.

The depositional environments in the Malay Basin during most parts of the Miocene (represented by the stratigraphic intervals I to E) have been interpreted as "brackish" or "lower coastal plain", implying a restricted marine setting of some sort. The absence of a fully marine faunal assemblage up to the uppermost Miocene does in fact indicate 'restricted' marine conditions. Thus, some authors have resorted to terms such as "lacustrine plain" or "lake plain" instead of "lower coastal plain" to denote a coastal plain fronting a lake, as opposed to that of an open sea. This is borne out of the uncertainty concerning the nature of the Malay Basin itself: was it (1) a lake, or (2) a marine embayment or gulf with periodic connection to the ocean?

Seismic data and biostratigraphic analyses carried out since the late 1980s have found evidences for periodic marine transgressions as early as group L time (late Oligocene). Although the Malay Basin did not become fully marine until Pliocene times, the data shows that at least partially marine ("brackish") conditions were well established by the middle Lower Miocene (J times) (Fig. 1).

Both models have major implications for the development of source rocks as well as reservoir distribution. The major reservoir sands in the basin have been interpreted as tidal or "tidally influenced" deposits, especially in groups E, I, and J, again based on the assumption that there had been a constant connection to the open sea to enable the tides to influence sedimentation. Whether the sands are deposited as fluvial-derived lacustrine deltaic sands or as tidally reworked offshore sands, would significantly impact our reservoir model, and would greatly influence field-wide sand correlation. On the other hand, the glauconitic J sands have been interpreted as storm/wave-generated offshore bars (e.g. Nik Ramli, 1986), possibly under open marine conditions when the basin was connected with the South China Sea. This would have increased the otherwise limited wave fetch in a shallow lake or restricted embayment to have generated large offshore sand bars.

In the Malay Basin, the cyclical pattern of alternating sand-shale units in the K, L, M groups, first reported in an early paper by Armitage and Viotti (1977), is generally attributed to sea level fluctuations. Tectonic controls on transgressive-regressive cycles, however, have not been given due attention. The interpreted sea-level fluctuations in the stratigraphic record bear little resemblance to the often-quoted global eustatic curve of Haq et al. (1987). This suggests that a local or regional, and most likely tectonic or structural, control has had a strong influence on relative sea level in this basin. Many workers have already established that tectonic processes and effects, e.g. lithospheric flexure and thermal subsidence, at evolving rift basin margins exert a strong influence on stratigraphic development (e.g. Watts et al., 1982). Any attempt at force-fitting a global eustatic curve onto the Malay Basin stratigraphy is, therefore, not recommended.

Evidence of tectonic deformation and its effects on the Malay Basin have been reported in many papers (e.g. Ngah et al., 1996, Tjia & Liew, 1996). The main inversion event in Middle-Late Miocene times must have had a big impact on the sedimentation patterns. Most significant is the semi-regional basement high at the southeastern end of the basin, bordering with the West Natuna Basin. The presence of a major structural high in the southeastern end of the basin is well established from seismic data, around the Belumut-Peta area. The basement uplift and inversion of SE Malay and West Natuna basins are also well documented (e.g. Madon, 1997). This basement high,

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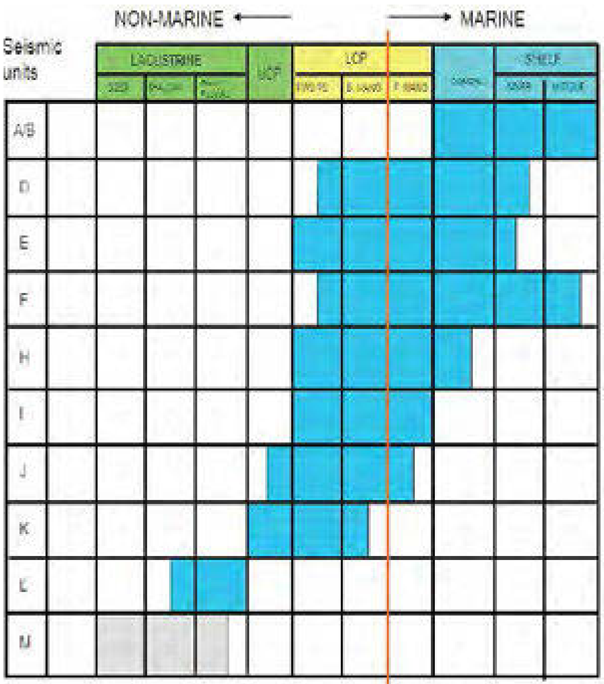

Figure 1: General trend in depositional environments in the Malay Basin.
(Note: UCP: upper coastal plain, LCP: lower coastal plain, FWS/PS: freshwater and peat swamp)

or sill, separates the Malay Basin from the West Natuna and the ancestral South China Sea, and must have exerted a strong influence on the relative sea level in the Malay Basin. The diachronous nature of the late Miocene unconformity suggests prolonged compressional uplift since early Miocene times (group H) to late Miocene-Pliocene, with increasing intensity from north to south.

How do subsidence/uplift and sea-level changes in the South China Sea interact and influence sedimentation in the Malay Basin? The long-term uplift of the basement in the south would have been superimposed upon by the higher frequency fluctuations in sea level. There would have been times when the rate of sea level rise exceeded the uplift rate to cause marine flooding into the basins (Fig. 2).

A hypothetical model is envisaged (Fig. 3) in which the basement uplift in the south acts as a "gate" that opens and shuts in response to sea level cycles. At times of high sea level semi-open marine conditions will be established, while during low sea level, the basin behaves like an internally drained lake basin that may be subject to climatically controlled base level changes. It is therefore possible to identify changes in sedimentation patterns associated with these two environmental.

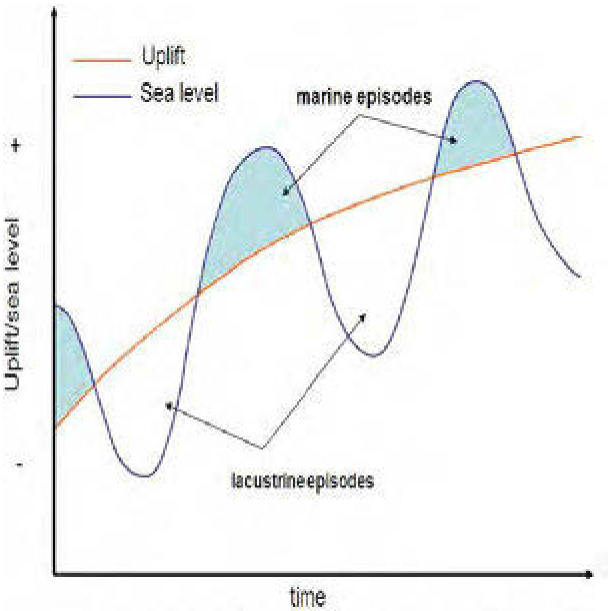

Fig. 2. Schematic diagram showing the interaction of uplift and sea-level fluctuations in creating episodic transgressions in a semi-restricted basin. Assuming a long-term uplift (red), there are times when the sea level will exceed uplift to cause marine influx.

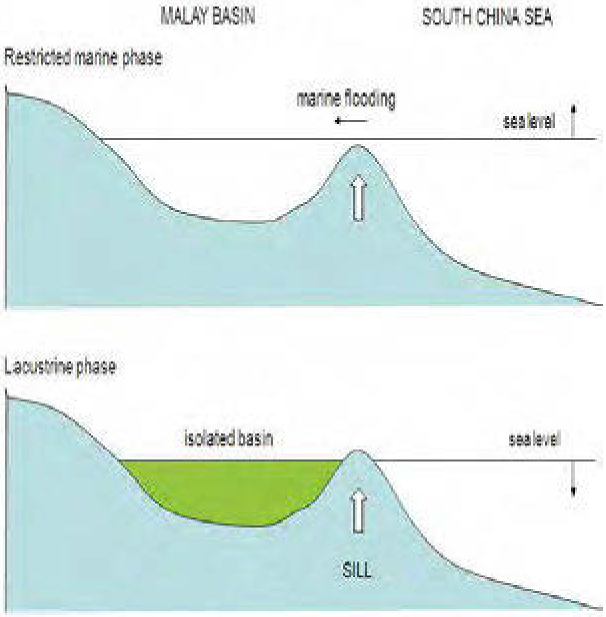

Fig. 3. Schematic of Malay Basin as a semi-restricted basin with a growing structural feature controlling the marine flooding episodes when the rate of sea-level rise exceeds that of the uplift.

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