AAPG HEDBERG CONFERENCE

"Variations in Fluvial-Deltaic and Coastal Reservoirs Deposited in Tropical Environments"

April 29 - May 2, 2009 — Jakarta, Indonesia

Variations in the Sedimentological Characteristics of Tertiary Coals in SE Asia; and Climatic Influences on Tertiary Coals and Modern Peats

Michael Friederich[1], Joan Esterle[2], Tim Moore[3], Chairul Nas[4]
[1]Coal Exploration Consultant, Sherwood, Queensland, Australia
[2]GeoGas
[3]Arrow Energy
[4]Trisakti University

Modern peat swamps in Indonesia and Malaysia have some characteristics that are consistent with those of Tertiary coals of Kalimantan. The study of modern equatorial peat environments, and the data that has been published on Tertiary coal deposits of Southeast Asia during the last 20 years of coal exploration, has added significantly to the understanding of how thick coal seams form, and to the relationship between coal seam characteristics and the depositional setting and palaeoclimates.

Modern Peats

Many modern peats seen today are not precursors to economic coal seams because they lack aerial extent, are too thin, or are in a setting above sea level where they will be destroyed by erosion or decomposition. The domed peat swamps in the Batang Hari River area of Sumatra, and in the delta / coastal plain of the Rajang River in Sarawak, Malaysia, (described by Esterle and Ferm, 1994 and Staub et al, 1991) have significant portions of their peat below river level, thus helping to ensure preservation. These peats are extensive, thick, and have exceptionally low ash (ie inorganics) and sulphur contents (Fig. 1). In the Rajang delta, peat accumulation rates in some cases outstrip clastic sediment accumulation, resulting in peat mires with a domed surface expression. This, along with sediment by-passing through the river-delta system keeps any clastic influx into the peat to a minimum, except during periods of extreme flooding.

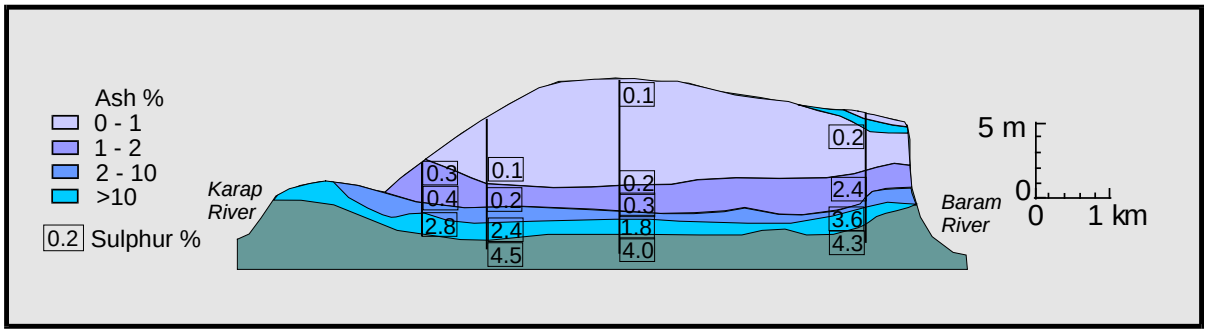

Figure 1. Cross section of a peat deposit at the Baram River, Sarawak (From Esterle and Ferm, 1994)

The influence of climate is clear. The development of domed peats, which grow above the regional water table, depends on sufficient rainfall, with continuity throughout the year. These climatic conditions occur in a band along the equator. Most known domed peats occur within these climatic constraints. Those peats formed in areas further from the equator with a long dry season will typically be more planar, with the top of the peat swamp limited by the position of the water table; although local exceptions may occur. These planar peats are subject to regular flooding which brings in clastic material; furthermore, the thickness of planar peats will be limited by the level of water table, and require basin subsidence to accumulate greater thicknesses. If preserved in the geological record, the resulting coal seams will tend to contain a more variable content of inorganics, and if thick seams have developed, they may contain more frequent mudstone partings. Sulphur contents will locally be high because of the influx of fresh (i.e. pH >4) to brackish water that allows and even encourages the growth of sulphur-fixing bacteria. This explains the contrast described in this paper between the lower ash low sulphur Miocene coals of equatorial Indonesia, and the locally thick but higher ash/sulphur Miocene coals of Thailand and Laos.

SE Asian Coals

Economically important coals occur within a variety of structural settings in SE Asia. The main Tertiary coal-forming periods are the Eocene and the Miocene to Pliocene. Eocene coal formed in extensional tectonic settings from Sulawesi through Kalimantan to Java and Sumatra. This extension was the first phase of basin development of the large back-arc basins of Sumatra.

Younger Tertiary coal formed in continental SE Asia, in separate rift basins, which occur in Thailand; eastern Myanmar; Laos; and through to Yunnan Province in China. There are also isolated Tertiary rift basins in northern Vietnam. The basins in Thailand are well known from the geological literature. It is believed that the basins in the NW of Thailand are the oldest (Late Oligocene to early Miocene) and formed in a warm temperate palaeoclimate (Songtham, 2000). In appearance these coals are typically composed of small to large twigs and tree trunks. Microscopically the coal is composed of vitrain with well bedded clarain and durain. Basins in the middle and eastern part of northern Thailand (such as the well known Mae Moh Basin) are younger, and the coal appears to have formed under a palaeoclimate similar to that prevailing now. For example, the thick (but high sulphur) coals of the Mae Moh Basin are believed to be of Middle Miocene age (Ginsburg and Tassy, 1985). The coals formed from peat swamps of reed and grass swamp, with associated fresh water algae. A forest swamp has also been interpreted by a coal petrographic study (Ratanasthien et al., 1997). The Hong Xa deposit nearby in NW Laos is also characterised by a very thick accumulation of coal, but with many partings, and a moderate sulphur content (Vilaihongs and Areesiri, 1997)

In the Miocene of the Barito and Asam Asam Basins of Kalimantan (which were then as now in a near-equatorial position), some coal deposits are also characterised by exceptional seam thickness; (over 35m in the Asam Asam Basin, see Figure 2, and even thicker in some areas of the Barito Basin) with very low levels of inorganics and sulphur; we believe these formed as domed peats, under conditions of year-round regular rainfall, which allowed the peat swamps to grow upwards above the water table and above the levels of seasonal flooding. These are likely to be stacked peat mire sequences as evidenced by thin partings and/or organics that indicate flooding (Shearer et al., 1994). The climate as well as the depositional setting may have allowed

this stacking to occur. The coal has a very low content of inorganics (1% to 3% in some deposits) and very low sulphur (as low as 0.1%). Palynological studies show that the Miocene coal in the Asam Asam basin was dominated by angiosperm flora, nearly identical to that of the modern peat swamps of Indonesia (Demchuk and Moore, 1993).

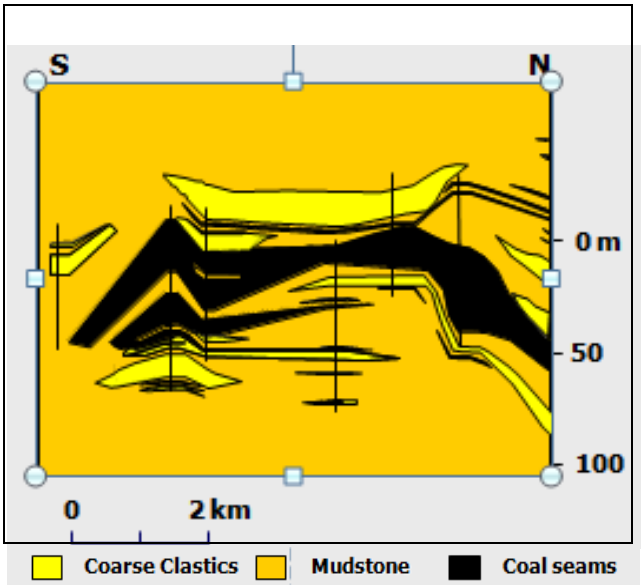

Figure 2. Schematic cross section, Sarongga deposit – Miocene, Asam Asam Basin (Friederich et al, 1995)

Eocene age coal deposits in SE Kalimantan occur in the Barito, Asam Asam and Pasir Basins. Stratigraphically the main coal is within the lower part of the Tanjung Formation, as part of an overall transgressive unit which unconformably overlies Mesozoic basement. Data on Eocene coal seams were derived from exploration and research activities, in the areas evaluated by PT Arutmin Indonesia and PT Utah Indonesia, within the Barito and Asam Asam Basins. The basal Eocene coal, the main economic target, is up to 9 metres thick, but is more typically 4 to 6 metres. It is remarkably laterally continuous, with good continuity of quality. A correlation has been established between the main coal seam at Senakin and Petangis, 70 km to the north.

Facies analysis of the Tanjung Formation sediments from drill core and outcrop studies, recorded by Pangabbean (1991), has shown that the sediments were derived from the north and west of the basin. An unpublished palynological study of an Eocene coal done for PT Arutmin (Friederich et al., 1995) describes a spore/pollen assemblage derived almost entirely from palms and ferns. In the modern environment of coastal southeast Kalimantan there is locally a thin zone of palm/fern dominated vegetation as a landward fringe behind the brackish *Nipa* swamps.

The main coal occurs at the boundary between underlying fluvial sediments and overlying shallow marine units. The peat swamps appear to have formed in a low energy coastal plain environment, at a time of sea level transgression over the coastal plain. The coal-bearing interval overlies fluvial sandstones and siltstones, which were the initial sediments above the basement. Overlying marine sediments consist of brackish to marine fine grained siltstones, thin siderite bands, mudstones and tidal-channel sandstones (Friederich et al., 1999) (Fig. 3), which probably formed in large sheltered shallow coastal bays, similar to the bays now seen on the present day

coast of SE Kalimantan (Fig. 4). In one location in the north of the area, shelly marine sandstones directly overlie the coal.

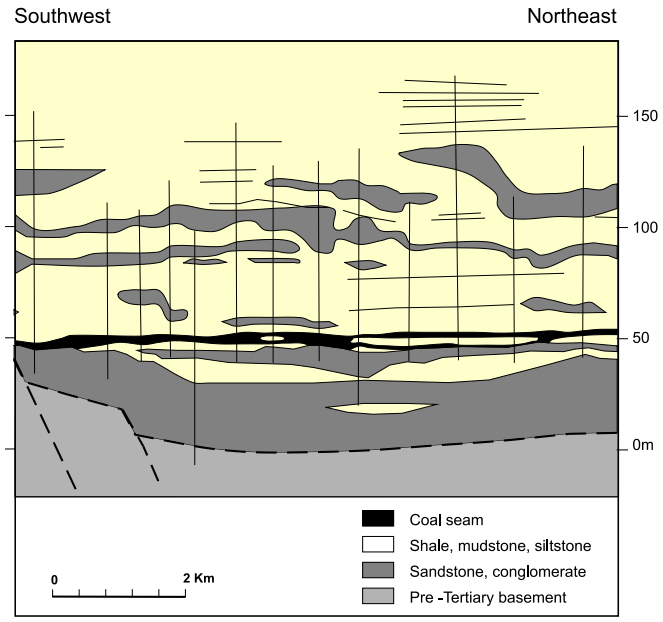

Figure 3. Schematic Eocene stratigraphy, Senakin Peninsula, SE Kalimantan. (Friederich et al, 1999)

Some reports in the geological literature state that the Eocene age coals formed within separate rifts, however, they are actually continuous over very large distances. In contrast to the thick Miocene coal seams known from parts of the Barito and Asam Asam Basins, the Eocene coal seams are thinner with higher ash contents and locally higher sulphur. The main control on these Eocene peats were probably external, the most important of which may have been their position on the coastal plain relative to the rising sea level. The peats may also have been seasonally flooded, as shown by their higher content of inorganics, in contrast to the very low levels of the Miocene coal. This frequent flooding would also account for the relatively degraded nature of the organic constituents within the coal (Moore and Ferm, 1992; Moore and Hilbert, 1992). Termination of the mires would occur when peat accumulation did not keep pace with a rising water table. Once the seams were flooded, the depositional environment may have inhibited stacking, and thus not allowing thick coal deposits to develop such as is seen in the Miocene sediments.

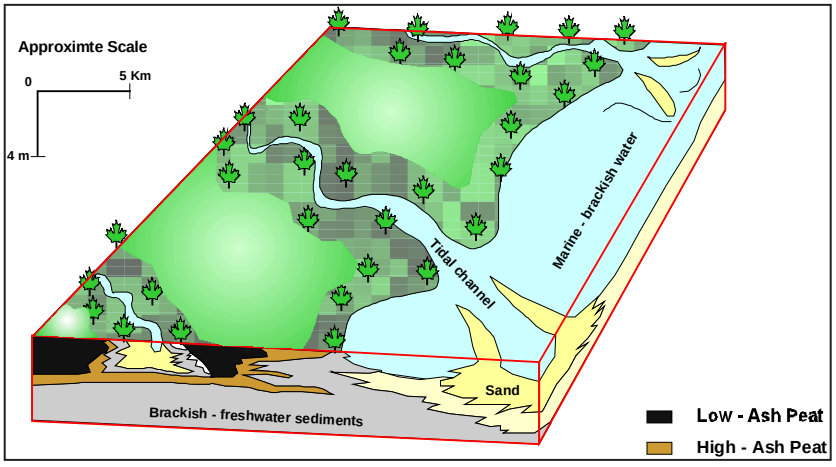

Figure 4. Eocene coal depositional model (From Friederich et al., 1995)

There are also macro- and microscopic differences between the Eocene and Miocene coals. The Eocene coals are finely banded (ie vitrain bands are thinner than 1mm), while the vitrain bands are thicker in the Miocene coal, averaging 4 cm. (Demchuk and Moore, 1993). The Miocene coal had a component of decay-resistant woody vegetation, where the Eocene coal formed from a palm/fern vegetation, which is more susceptible to chemical and physical decay (Moore and Ferm, 1992; Moore and Hilbert, 1992).

The influence of Palaeoclimates

The widespread Eocene coals clearly developed under a wet palaeoclimate. Morley (2000) describes palynological evidence for major climate cooling in SE Asia at the end of the Eocene. In the northern part of the region the climate became drier and warm temperate, rather than tropical and humid. The range of tropical rainforests became more restricted. During the Oligocene and earliest Miocene, lowland rainforests in SE Asia were mainly replaced by monsoonal vegetation types, indicative of a climate change from abundant year-round rainfall to a monsoonal climate with an extended dry season. The Oligocene and the earliest Miocene is then believed to have been a cooler drier period; consistent with the few known coal deposits of Oligocene age in SE Asia. From the later part of the Early Miocene, tropical rainforests expanded across SE Asia as wet equatorial climates re-established. (Fig. 5).

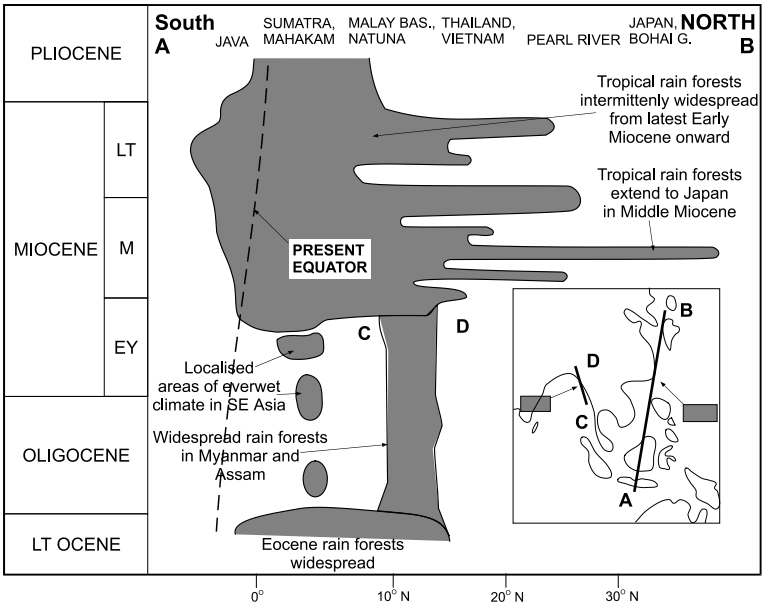

Figure 5. Schematic and simplified distribution of tropical rainforest climates in SE Asia during the Tertiary (from Morley, 2000).

There are important regional differences in the younger Tertiary coals. The Late Miocene to Pliocene coals of Indonesia include deposits with exceptionally low contents of inorganics. It is likely these formed under conditions of year-round rainfall, leading to thick seams formed from

raised peat bogs. However in the north of the region, Miocene coals typically contain much higher inorganics than the Miocene – Pliocene Indonesian coals to the south, and this may have been from rainfall which was more seasonal which is less conducive to the formation of raised peat swamps.

References:

Demchuk, T.D. and Moore, T.A., 1993. Palynofloral and organic characteristics of a Miocene Bog-Forest, Kalimantan, Indonesia. Organic Geochemistry, 20 (2), 119-134.

Esterle, J.S., Ferm, J.C, 1994. Spatial variability in modern tropical peat deposits from Sarawak, Malaysia and Sumatra, Indonesia. International Journal of Coal Geology 26, 1-41.

Friederich, M.C., Moore, T.A., Lim, M.S.W., and Langford, R.P., 1995: Constraints on coal formation in southeast Kalimantan, Indonesia. Proceedings 6th New Zealand Coal Conference, 137-149.

Friederich, M.C, Langford, R.P., Moore, T.A., 1999. The geological setting of Indonesian coal deposits. The AusIMM Proceedings 304, 23-29.

Ginsberg, L., and Tassy, P., 1985. The fossil mammals and the age of the lignite beds in the intramontane basins of northern Thailand. J. Geol. Soc. Thailand, 7, pp. 13-17.

Moore, T.A., and Ferm, J., 1992. Composition and grain size of an Eocene coal bed in southeastern Kalimantan, Indonesia. International Journal of Coal Geology, 21, pp. 1-30.

Moore, T.A. and Hilbert, R.E., 1992. Petrographic and anatomical characteristics of plant material from two deposits of Holocene and Miocene age, Kalimantan, Indonesia. Rev. Paleobot. Palynol., 72, 199-227.

Morley, R.J., 2000. Origin and Evolution of Tropical Rain Forests. John Wiley and Sons, West Sussex, England.

Shearer, J.C., Staub, J.C., Moore, T.A., 1994, The conundrum of coal bed thickness: a theory for stacked mire sequences, Journal of Geology, 102, 611-617.

Pangabbean, H., 1991. Tertiary source rocks, coal and reservoir potential in the Assem-Assem and Barito Basins, southeastern Kalimantan, Indonesia. PhD thesis, University of Wollongong, Wollongong, 224 pp. (unpublished).

Ratanasthien, B., Chomphusri, S., and Mahatthanachai, T., 1997. Depositional environment of Mae Moh Basin as indicated by coal petrography. In: Theeradilok (ed.-in chief), Proc. International Conference on Stratigraphy and Tectonic Evolution of Southeast Asia and the South Pacific, Bangkok, pp. 596-605.

Songtham, W., 2000. Palynology of Na Hong Basin Amphoe Mae Chaem Changwat Chiang Mai, M.S. Thesis, Graduate School, Chiang Mai University, 115 pp.

Staub, J.R., Esterle, J.S. and Raymond, A.L., 1991. Comparative geomorphic analysis of Central Appalachian coal beds and Malaysian peat deposits. Bulletin Geol. Soc. France, v. 162(2), 339-351.

Vilaihongs, M., and Areesiri, S., 1997. Geology of lignite deposit and tectonic evolutions in Hong Sa Tertiary basin, Khwaeng Sarabury, northern Lao PDR. Int. Conference on Stratigraphy and Tectonic Evolution of SE Asia and the South Pacific, Bangkok, Thailand, August 1997.