A Field Trip to the Syn-Rift Petroleum System of Central Sumatera

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In September 2012, a field trip was run by the authors above into the Ombilin Basin of West Sumatra province to examine outcrop analogs of the syn-rift petroleum system of Central Sumatra (Figure 1). This was organized by SEAPEX and AAPG as part of the AAPG International Conference held in Singapore. The field trip started and finished in Padang but was conducted in the Barisan mountains amidst the stunning scenery of West Sumatra.

Rift basin evolution is a key component of the petroleum systems of many Southeast Asian basins (e.g. South Sumatra Basin, Sunda Basin). Syn-rift lacustrine mudstones are prolific oil prone source rocks and syn-rift and early post-rift clastics sediments can provide excellent reservoir intervals. Rift petroleum systems are, however, geologically complex and hydrocarbon exploration within them requires a greater knowledge of the structures and sedimentological evolution of the basin than is often the case elsewhere. Local factors such as provenance and rift related tectonic activity can have a significant impact on the quality, quantity and distribution of source, reservoir and seal.

The field trip was conducted over four days with each day concentrating on a separate aspect of the petroleum system as follows:

Day 1 Basement and Regional Geology (SYN-RIFT)
Day 2 Source Rock (SYN-RIFT)
Day 3 Reservoirs (EARLY POST-RIFT)
Day 4 Syn-rift Reservoirs (SYN-RIFT)

DAY 1 - BASEMENT AND REGIONAL GEOLOGY

The aim of the field trip stops on the first day was to study the basement geology and to set the regional setting for the remainder of the field trip. Complex structural aspects were addressed, with reference to the problems associated with deciphering Oligocene rift related structures subsequently modified by strike slip deformation and the Plio-Pleistocene Barisan mountain uplift.

Basement in the area is varied with metamorphic, igneous and sedimentary lithologies all exposed. Basement sediments are both clastic and carbonate in nature and range in age from Lower Carboniferous to Triassic. Sediments are widely metamorphosed. The igneous component to the basement is largely of an intrusive nature with granites dominant. Radiometric dating on a variety of exposures gives late Permian to early Miocene ages with most basement igneous activity occurring in the Mesozoic.

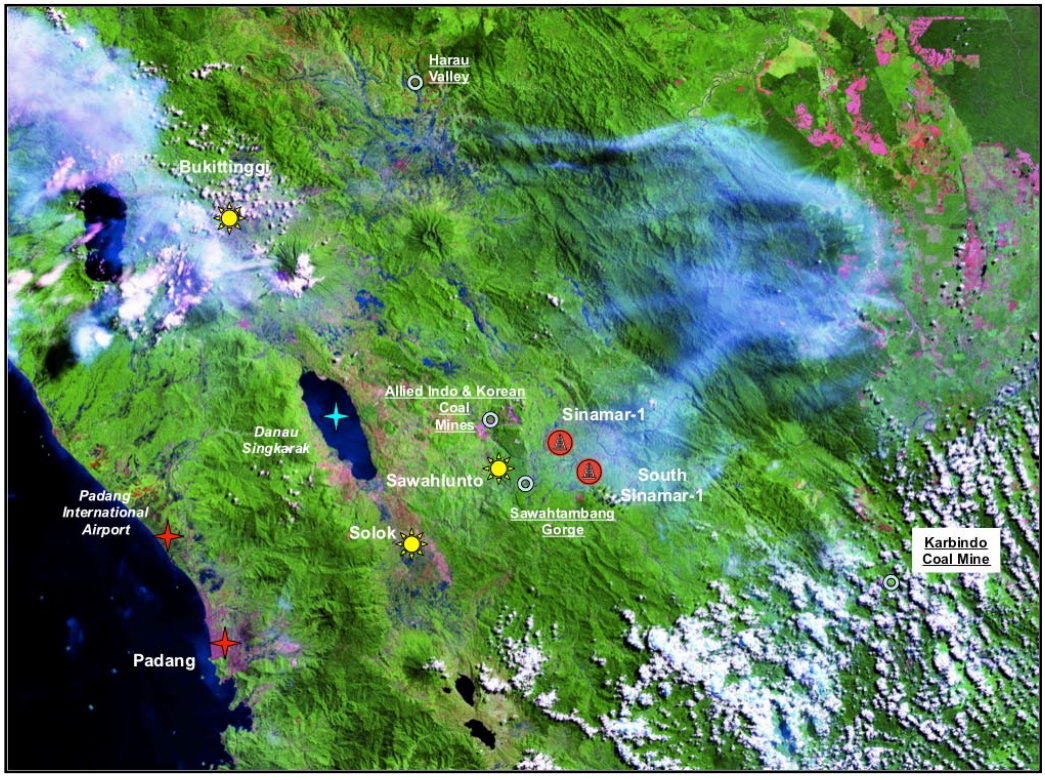


Figure 1. *West Sumatra, showing location of principle outcrops visited. The Karbindo mine is in the highly fragmented Kiliran Sub-basin to the east. The Harau Canyon is on the north eastern margin of the Payakumbuh Basin.*

Unfortunately it was not practical to visit all the basement lithologies present in the area, although a representative selection were examined. These studied outcrops give a good indication of how differing types of basement have a variable influence on topography, tectonism, sediment supply and water chemistry.

DAY 2 – SOURCE ROCK

The second day of the field trip was spent at the Karbindo Coal Mine, an open cast coal mine in which the Eocene Brown Shale is very well exposed (Figure 2). This is a remarkable exposure since it is one of the few places around the world where by walking up through the mine it is possible to walk up through the evolution of a syn-rift lacustrine system.

The lowest exposures in the mine are a dark grey palaeosol in terrigenous mudstone (Figure 2). This palaeosol is at least 25m thick (the base is not exposed) and represents slow sediment accumulation and subsidence. Any introduced sediment was fully reworked by pedogenetic processes so that no primary sedimentary structures remain. The palaeosol is overlain by a coal seam that varies in thickness from 5m to 18m along strike. At its base the coal is black hard and vitreous and represents peat accumulation in a slowly subsiding swamp. Towards the top of the coal are interbeds of dark brown algal rich coal that were deposited in standing water. Laterally these brown coals pass into agal-rich limestones which represent lacustrine margin carbonate accumulation. This upper part of the coal seam reflects continuing subsidence but at a rate where ephemeral lakes were able to develop. Coals show TOC and HI values of 36.71% - 71.77% and 237 - 350 respectively and are generally mostly gas prone source rocks containing higher-plant material.

The coal seam is capped by a dark brown, highly organic rich (TOC 16.3% and HI 582), undercompacted shale of irregular thickness which is an excellent quality oil prone source rock with algal organic matter predominant. This is interpreted to be the deposit of a shallow, algal rich lake and probably represents the very first development of continuous lacustrine conditions.

Overlying the carbonaceous shale are ~100m of Brown Shale facies. In the Karbindo Coal mine the Brown Shale is broadly divisible into three intervals, namely: a lower (approximately 40m thick) highly fissile paper-laminated shale, a middle (approximately 15m thick) gastropod-rich red weathering shale and an upper (approximately 50m thick) weakly laminated highly bioturbated shale. At its base the brown shale is dark brown, finely laminated and fissile. The lowermost portion is strongly calcite replaced. Thin sharp–based flood-related sandstones are locally developed and become more frequent and thicker upwards. High TOC (3.16%-8.91%) and HI (442-717) indicate an excellent quality oil prone source rock dominated by algal organic matter. Palynology reveals a *Botrycoccus* spp. rich assemblage. Deposition of the lower Brown Shale interval was in a shallow lake with a strongly stratified water column.

The middle of the studied succession comprises beds of *Goniobasis*-like and *Viviparus*-like reworked gastropods. This interval weathers red and shows a slight reduction in organic content (TOC 2.58% - 5.94%) and source quality (HI 424-547). Palynological data indicate a change in algal forms present with abundant *Pediastrum* spp recorded. This middle section of the Brown Shale is interpreted to represent an overall shallowing to a lacustrine margin setting where gastropod accumulations mark concentration by wave action.



Figure 2. *The Karbindo Coal Mine. Palaeosols in the foreground are overlain by coal, which in turn is overlain by a very thick section of lacustrine Brown Shale. Note the light coloured limestone*

The upper interval comprises dark brown, faintly laminated, organic-rich brown shale, which in thin section is seen to be strongly bioturbated. TOC (3.75%-8.44%) and HI (624-743) values are exceptionally high and confirm the presence of oil prone algal organic matter. Palynofacies analysis reveals a *Botrycoccus* spp dominated assemblage. This interval represents a return to deeper lacustrine conditions.

The water column was strongly stratified but sufficiently oxygenated to allow bioturbation to occur. Overall deposition of the Brown Shale sediments at Karbindo is interpreted to have taken place in relatively shallow water where subtle variations in the hydrological regime have resulted in great differences in the rock record.



Figure 3. *Allied Indo Coal Mine (Parambahan-Rasau Members, Sawahlunto Formation). Fluviatile sands are laterally discontinuous and separated by thick well developed palaeosols.*

DAYS 3 AND 4 – RESERVOIRS

The third and fourth days of the field trip concentrated on sandstone reservoirs in the syn- and post-rift sequence and how their reservoir architecture is affected by local tectonic and provenance factors. In the Central Sumatra area, as with other syn-rift sections from Southeast Asia, there is considerable variation in sandstone thickness, lateral development and quality. Such sandstones are exposed in the Ombilin Basin and its environs where, unusually for Southeast Asia, there are numerous excellent quality exposures in river beds, cliffs, road cuts and coal mines (Figures 3 and 4). It is in the last mentioned that much of the third day is spent since in these mines exposures are extensive and allow for:

- an appreciation of fluvial sandstone reservoir architecture, from isolated sand bodies surrounded by mudstones, to vertically and laterally stacked sandstone showing good three dimensional interconnection,
- Allow for an interpretation of the evolution of fluvial systems such that conditions may become suitable for sandstone aggradation in vertical and lateral sense within the same overall sequence.

Although the greater part of the outcrops are fluviatile in nature and can be regarded as analogous to producing reservoirs elsewhere in Indonesia, turbidite and alluvial fan sediments were also examined. In the magnificent Harau canyon it is possible to cross over from basement to alluvial fan sediments and to walk up the alluvial fan observing how the sediments evolve with time.

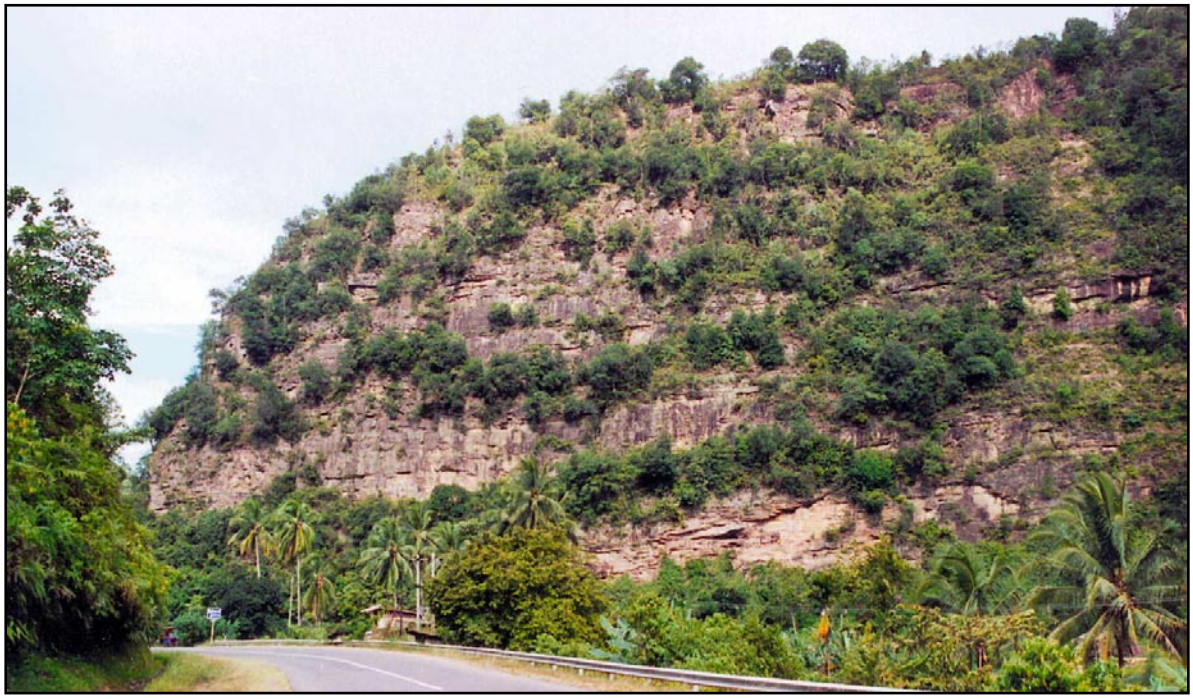


Figure 4. *Sawahtambang Gorge (Sugar Member, Sawahtambang Formation). Sands are very well developed and show excellent lateral and vertical continuity.*