Depositional History and Petroleum Potential of Ombilin Basin, West Sumatra - Indonesia, Based on Surface Geological Data*

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Abstract

The Ombilin Basin is situated in the Southwest Bukit Barisan Block, West Sumatera Province (Figure 1). The main objective of the study is to understand historical basin formation and sedimentation, including petroleum potential, based on detailed surface geological survey. The survey reveals that sedimentation in this basin was started soon after the rifting of the basin due to regional Paleogene tectonic event. Graben and half graben basin systems occurred in West Sumatra, including the Ombilin Basin, influenced sedimentation processes in the basin.

The initial stage of rift basin evolution marked by sedimentation of the Brani and Sangkarewang formations took place during Eocene to Middle Oligocene deposited in alluvial fan and in lacustrine environment in the lake basin. During syn-rift development in the Oligocene, the Ombilin Basin became shallower and changed from lake into fluvial basin such as meanders, flood plains and marshes of the river. Simultaneously, there was marine ingression into the basin and formed delta at the river mouth where sedimentation of the Sawahlunto Fm. took place. Further syn-rift development has uplifted the basin; it became shallower and changed into low land basin in form of braided river systems where Sawahtambang Fm. sedimentation took place in Late Oligocene. The Ombilin Formation was deposited during post-rift development in Early Miocene when the basin changed into a marine environment due to global sea level rise as well as tectonic activities at the end of Oligocene that caused the basin to be entirely covered by marine ingression to overlie unconformably above the Sawahtambang Formation.

Geochemical analyses on thirty shale samples from Tertiary sediments show that the source rock potential in the Ombilin Basin is mainly from the Sangkarewang, Sawahlunto and Ombilin formations.

Reservoir potential in the Ombilin Basin is from the Brani, Sawahlunto and Sawahtambang formations as well as the pre-Tertiary basement rocks. The Pre-Tertiary rocks are highly fractured due to Tertiary tectonic deformations, and can be a fractured reservoir. We suggest the Brani, Sawahlunto and Sawahtambang formations are the main priority for reservoir rocks. SEM examination on samples from these formations indicates the existence of microporosity, which is a very important property for a reservoir.

Evolution and Depositional history of the Ombilin Basin

Based on the field geological data, stratigraphic correlation (Figure 2), and interpretation of the evolution as well as depositional history of the Ombilin Basin could be established. The Ombilin Basin evolution is closely related to regional tectonics of Sumatra. Some authors believed that the Ombilin Basin is a pull-apart basin resulted from tensional or transtensional duplex system along a segment of a strike-slip fault oriented slightly oblique to the main trend of the fault zone (Koening, 1985; Situmorang et al., 1991). The main trend of the fault zone is NW-SE, which is known as Sumatra Fault Zone (SFZ).

Development of the Ombilin Basin was initiated by the end of Mesozoic time or Paleogene tectonic activities that formed the rifted graben depression, with a NW-SE trend, in a form of isolated lake that was surrounded by mountainous of the pre-Tertiary basement high.

The Ombilin Basin is bounded from the pre-Tertiary basement by the NW-SE faults: Sitangkai and Silungkang faults in the west and the Tigojangko-Takung fault in the east.

Sedimentation took place along the foothills scarp of the basin margin in the form of an alluvial fan consisting of very coarse sediments, while in the central basin sedimentation occurred in the deep (lake) basin as represented by finer-grained sediments. The alluvial fan deposits comprise fanglomerate, breccias and/or conglomerate and very coarse sandstones of the Brani Formation. The sediments deposited in the central basin consist of interbedded very fine sandstone and shale with papery structures and rich with fresh water fishes of the Sangkarewang Formation. These formations were deposited during Eocene to early Middle Oligocene time (Figure 3A; the section line is shown in Figure 1). The sedimentation processes in the Ombilin Basin were contemporaneous with

development of the rifted graben depression developed during the Paleogene tectonics, known as initial stage of rift basin sedimentation.

The Paleogene tectonic activity continued in the Oligocene during the sedimentation of the Sawahlunto Formation. The Ombilin Basin became shallower and changed from a lake into a fluvial basin where sedimentation took place in meandering rivers, flood plain and swamps, and simultaneously, there was a marine ingression into the basin and formed a delta at the river mouth (Figure 3B). This marine ingression into the Ombilin Basin might be related with sea level rise that occurred during the Oligocene. Evidence for this condition was marked by the existence of coal seams found in fluvial sediments and the presence of shallow marine/tidal ichnofossils as well as the shallow marine mollusks/Gastropods *Skeneidae*, found in a siltstone layer of the Sawahlunto Formation.

The regional tectonic activities of West Sumatera during the sedimentation of the Sawahlunto Formation resulted in uplifting of the Ombilin Basin that became shallower. This uplifting changed the area into a low land basin with a braided river drainage systems, in which sedimentation of the Sawahtambang Formation took place in the Late Oligocene. The sedimentation during this period is well known as late syn-rift sedimentation (Figure 3C).

Transgression due to global sea level rise as well as tectonic activities occurred at the end of the Oligocene and had caused the Ombilin Basin to be entirely covered by marine ingression, and then became a marine environment where the Ombilin Formation was deposited in the Early Miocene. The sedimentation during this period is well known as post-rift sedimentation (Figure 3D). The Ombilin Formation unconformably overlies the Sawahtambang Formation.

Strong intensity of the tectonic activities in the Mid Miocene has caused the entire basin to be folded and thrusted, followed by strike-slip fault displacement.

The NW-SE and NE-SW strike-slip faults found in the fieldwork areas dissects all sediments and almost all fold and thrust fault, as well as N-S strike-slip fault structures in the Ombilin Basin. It is evident that these strike-slip faults were generated by the last tectonic event (probably Plio-Pleistocene) after the deposition of all formations as well as the fold and thrust fault structures.

Petroleum Potential of the Ombilin Basin

Geochemical analyses on thirty shale samples from Tertiary sediments show that the source rock potentials in the Ombilin Basin are mainly from the Sangkarewang Sawahlunto and Ombilin formations.

The Tmax data show the samples from Sangkarewang, Sawahlunto and Ombilin formations have mostly reached the oil window stage (Tmax: 435° – 447° C). The S2 vs. TOC shows that the Sangkarewang and Ombilin formations have good to excellent values, while the Hydrogen Index (HI) vs. Tmax indicates that samples from the Sawahtambang, Ombilin and some of the Sangkarewang and Sawahlunto formations are immature, with the kerogene Type III. However, other samples of the Sangkarewang and Ombilin formations are mostly down to mixed and oil zones, with the kerogene classified Type I and Type II.

The Oil Index (OI) vs. Hydrogen Index (HI) shows that samples from the Sangkarewang and Ombilin formations are classified as oil prone to highly oil prone with kerogene Type I and Type II. Samples from the Sawahlunto and some of the Sangkarewang Formations are down to gas prone with kerogene Type III. On the other hand, samples from the Sawahtambang Formation are classified as non-source with the kerogene Type IV.

Geochemical analyses show that the potential source rocks in the Ombilin Basin are mainly shales from the Sangkarewang and Ombilin formations, and probably from the Sawahlunto Formation. Potential reservoirs in the Ombilin Basin could be the coarse clastic rocks of the Brani, Sawahlunto and Sawahtambang formations as well as the pre-Tertiary basement rocks. The pre-Tertiary rocks consist of granite, crystalline limestones and metasediments (phyllite, slate and quartzite), and they are highly fractured due to Tertiary tectonic deformations. The basement rocks may have quality as fractured reservoir porosity.

Conclusions

We suggest the coarse sediments occurring in the Brani, Sawahlunto and Sawahtambang are the main priority as the reservoir rocks in the Ombilin Basin. These sediments are comprised of fanglomerate, breccias and or conglomerate as well as the coarse and conglomeratic quartz sandstones. SEM examination on the samples from these formations indicates the existence of microporosity, which are very important properties for the reservoir rocks.

The subsurface fold structures, particularly the anticlines could be considered as the structural traps in this basin. The youngest formation affected by the folds is the Ombilin Formation which comprises of dominantly thick shale intercalated by thin layers of sandstones. Since the shale of the Ombilin Formation is impermeable material, then it has high possibility as the seal. Therefore, we suggest the petroleum exploration in this basin concentrate in these subsurface anticlines (Figure 4).

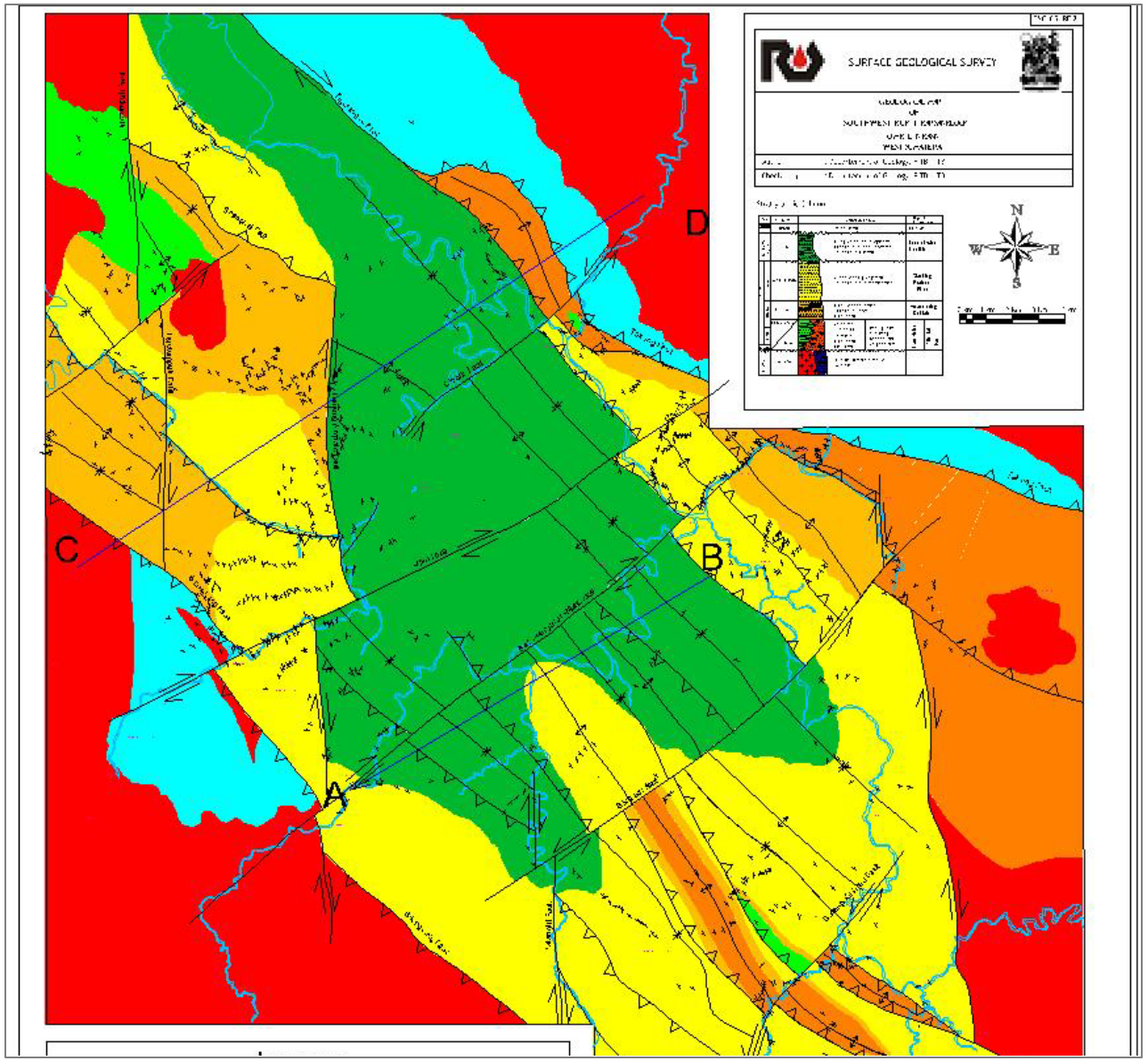

Figure 1. Geological map of the Ombilin Basin.

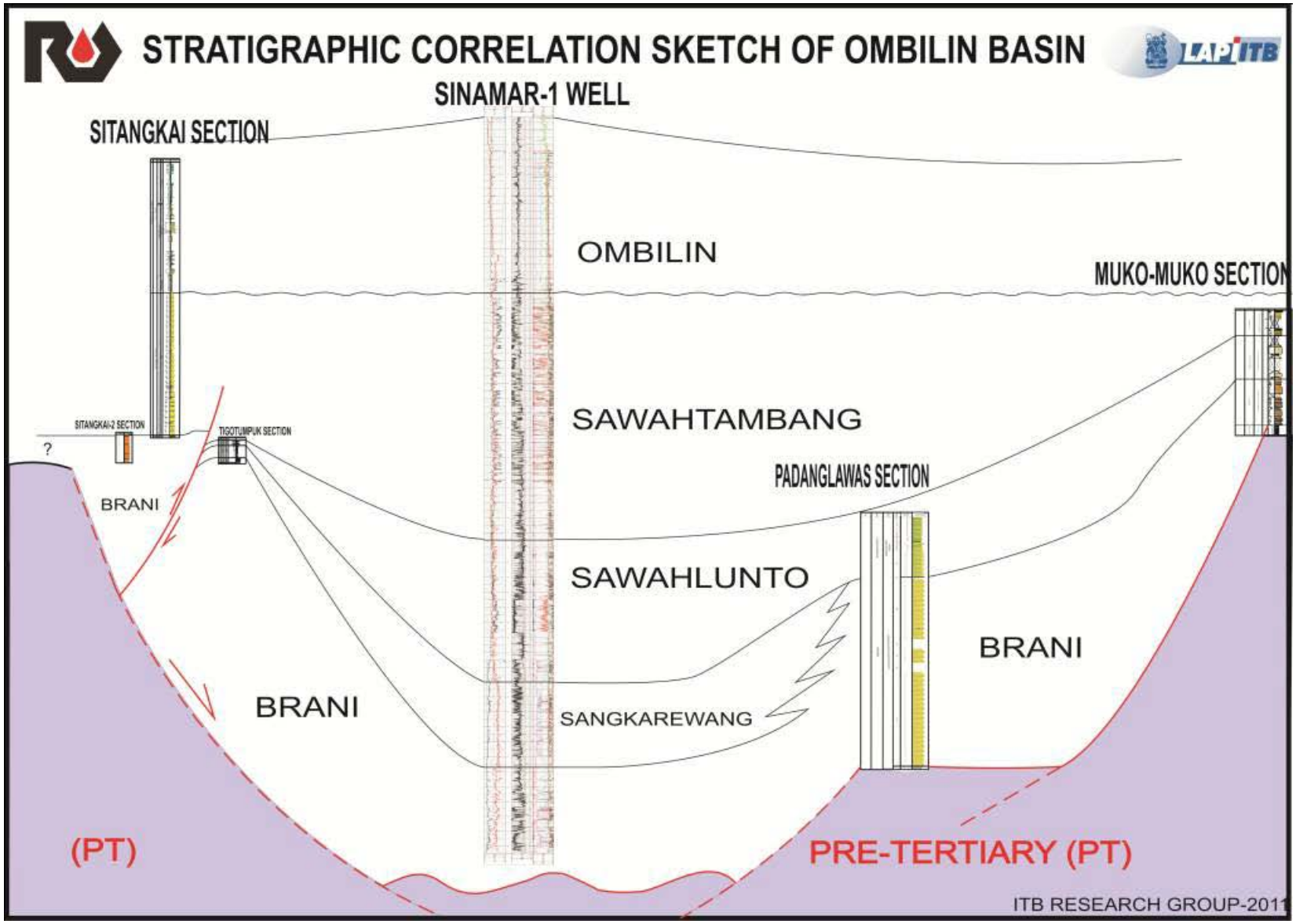

Figure 2. Stratigraphic correlation of Ombilin Basin.

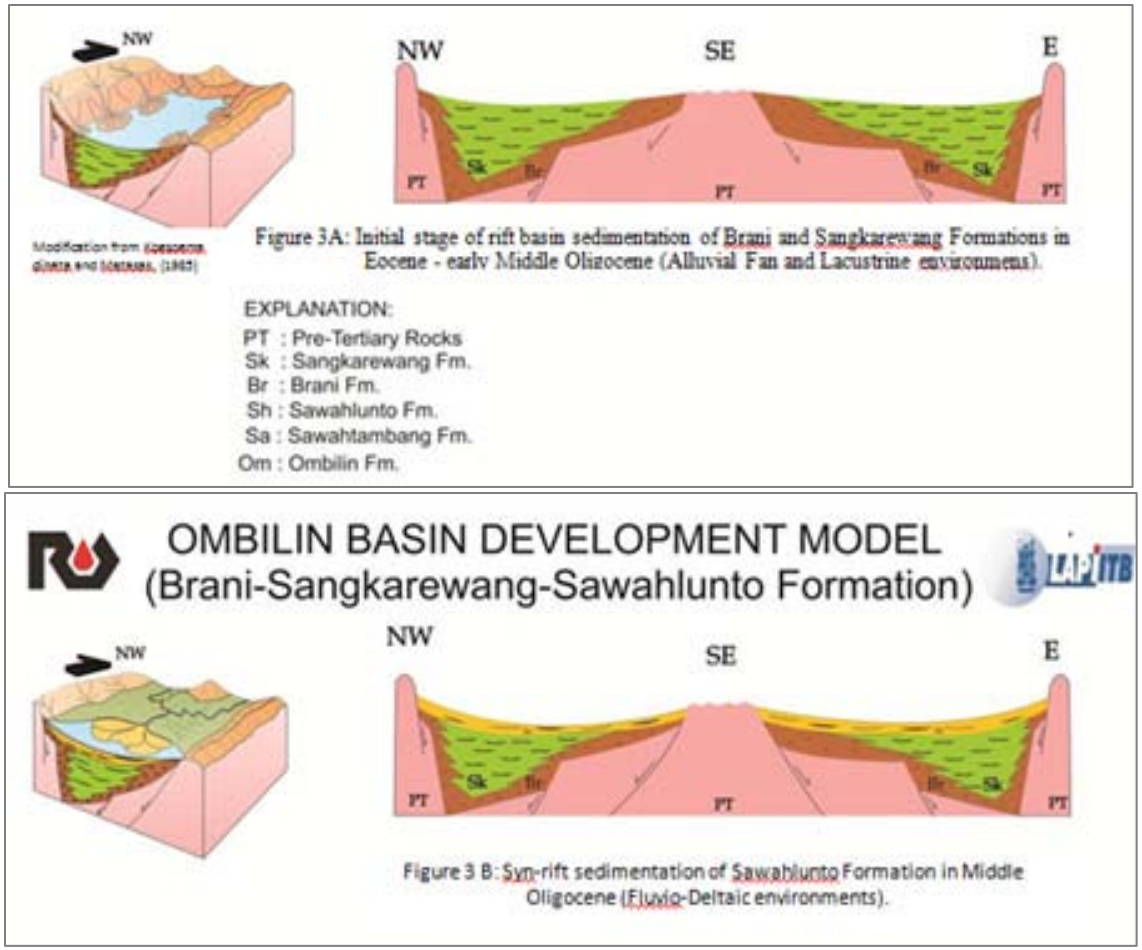

Figure 3. A) Initial state of rift basin sedimentation of Brani and Sangkarewang Formations in Eocene - Early Oligocene (alluvial fan and lacustrine environments). B) Syn-rift sedimentation of Sawahlunto Formation in Middle Oligocene (fluvio-deltaic environments).

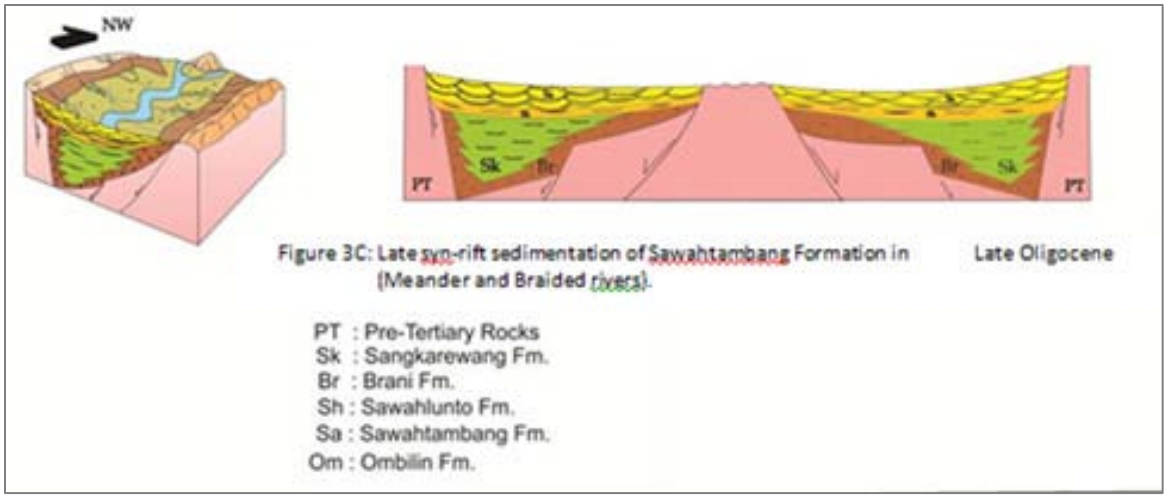

Figure 3C: Late syn-rift sedimentation of Sawahtambang Formation in Late Oligocene (Meander and Braided rivers).

PT : Pre-Tertiary Rocks
Sk : Sangkarewang Fm.
Br : Brani Fm.
Sh : Sawahlunto Fm.
Sa : Sawahtambang Fm.
Om : Ombilin Fm.

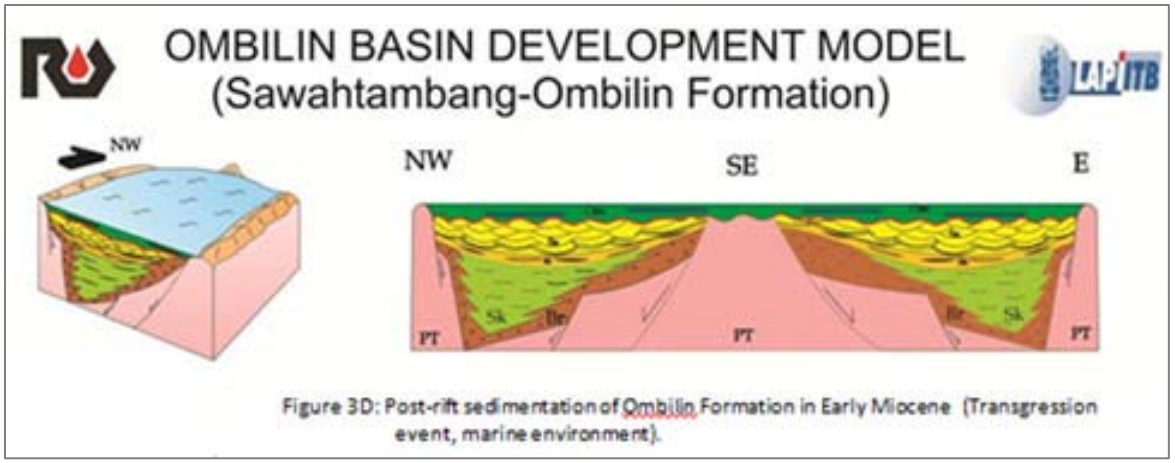

Figure 3D: Post-rift sedimentation of Ombilin Formation in Early Miocene (Transgression event, marine environment).

Figure 3. C) Late syn-rift sedimentation of Sawahtambang Formation in Late Oligocene (meander and braided rivers). D) Post-rift sedimentation of Ombilin Formation in Early Miocene (transgression event, marine environment).

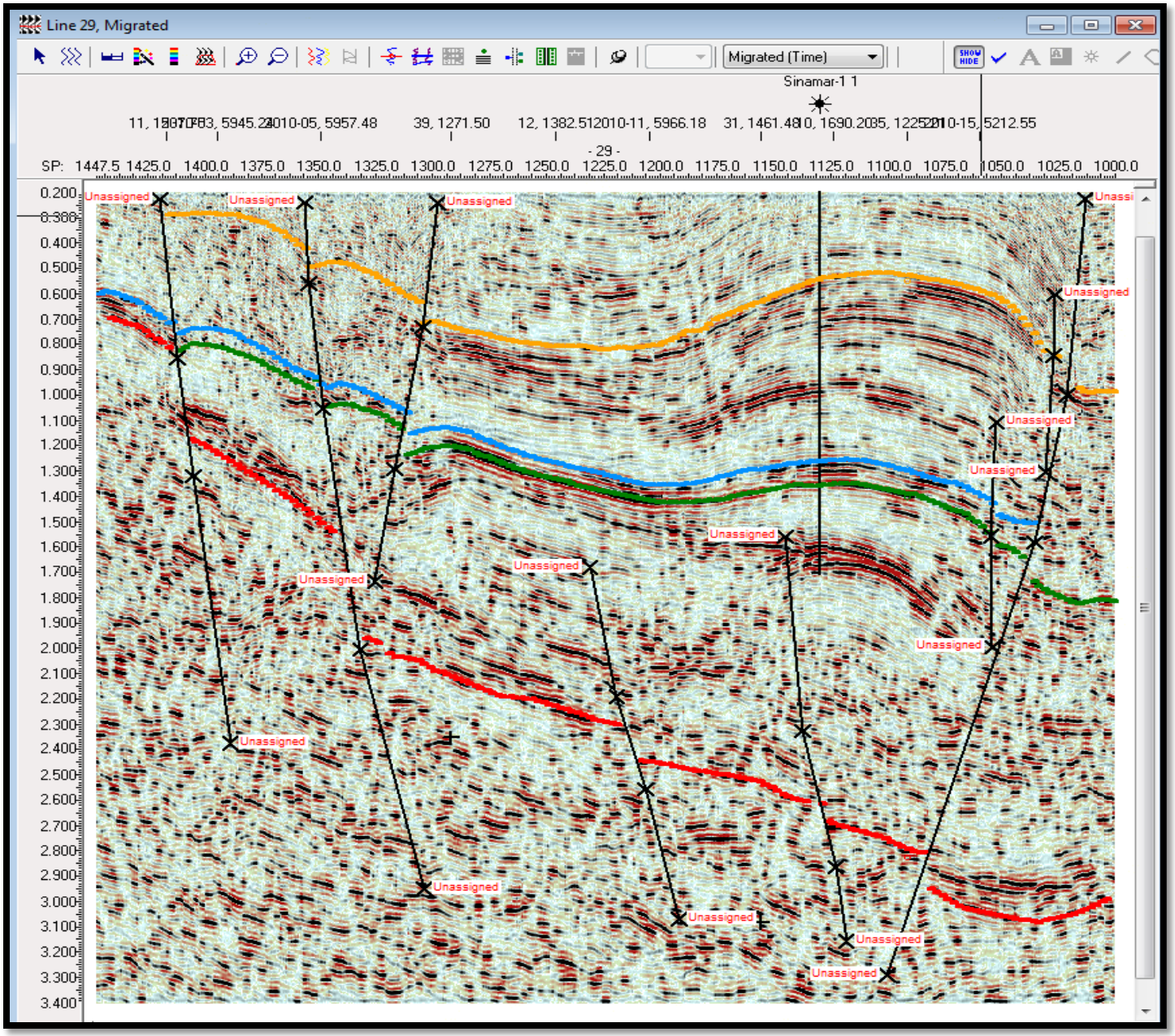

Figure 4: Seismic data shows subsurface fold structures in the Ombilin Basin (Habrianta, 2011).