

## Sedimentology and Petrography of Selected North Sumatra Pre-Tertiary Formations: Anticipating New Petroleum Systems in Western Indonesia

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**Abstract.** This research is focused on studying the depositional system and petrographic characteristics of petroleum system that form in North Sumatera, Indonesia to reveal the diagenesis, metamorphism, alteration indicators related to reservoir and source rock potential. Field work was integrated with paleontology analysis and comprehensive petrographic study of selected thin sections. Paleozoic and Mesozoic Stratigraphy of North Sumatra can be divided into Tapanuli Group (Alas Fm, Kluet Fm, Bohorok Fm) and Peusangan Group (Pangururan Bryozoa Bed, Batumilmil Fm, Kaloï Fm, Kualu Fm). Pre-Tertiary Rocks were variously deposited in deep marine (ie: Sibaganding Limestone) with Radiolarian Limestone; shallow marine (ie: Batumilmil Fm, Kaloï Fm) with Limestone and dolomitic limestone; moraine glacier and till (ie: Bohorok Pebbly Mudstone); and shallow water (ie: Kualu Mudstone, Pangururan Bryozoa Bed). Batumilmil Fm can be divided into Dolomitic red limestone, Light-grey Limestone, Dark-grey Limestone, and Carbonaceous Claystone. Reservoir potential was formed by fractures, disslutions and dolomitization (ie: Kaloï and Batumilmil Dolomitic Limestone). Further more, source rock potential was found in Batumilmil and Kualu Mudstone.

**Keywords:** Petroleum system, Nothr Sumatera, diagenesis.

### 1. Introduction (Stratigraphy and Sedimentology of Pre-Tertiary Outcrop of North Sumatra)

The targets of study of Tapanuli Group outcrops are Alas Formation Outcrop in Dairi, Kluet Formation in Boho, and Bohorok Formation in Bohorok and Parapat. Alas Formation and Bohorok Formation are constituent of East Sumatra Terrane (Sibumasu) (Figure 1). Kluet Formations is a part of the West Sumatra Terrane (Indochina) (Figure 1). Peusangan Group under studies are from part of East Sumatra Terrane (Sibumasu) which consists of Pangururan Bryozoans Bed outcrop in the village of Boho, Batumilmil Formation outcrops in Marikeh and Berkail River, Kualu Formation outcrop in Parapat, Sibaganding Members Outcrop in Cave Sibaganding - Parapat, and Outcrop of Kaloï Formation in Kaloï village. The location distribution of the outcrop study is plotted on GRDC geological map [1]-[3] (Figure 2).

#### 1.1. Tapanuli Group

Tapanuli Group of this area consist of Alas formation, Kluet formation, Bahorok formation, and Bryozoa mudstone. Alas Formation is found in Dairi Area. According to previous studies this formation has Early Carbonaceous age (Cameron et al, 1980) [1] (Figure 2). The dimension of this outcrop is 50 meters width and 12 meters high dimensions. In the GRDC geological maps, this outcrop is located in the Sumatra Fault Zone with very intense weathering stage condition. This outcrop is composed by dolomitic limestone, with

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reddish brown color, highly weathered, crystalline, visible appearance of layered on top of outcrop and locally the limestone is brecciated. This limestone composed by Calcite and Dolomite mineral. Kluet Formation is located in Boho Village and Tampur River (Figure 2). Kluet formation is consist of Slate outcrop that produced by a low level Permo-Carbon metamorphism (Barber & Crow, 2005) [4]. The outcrop is located on a hillside, with outcrop dimensions 40 meters width and 12 meters high. Lithology is slate with dark gray to black color, medium weathered, very hard, very tight, and poor porosity (Figure 3). Kluet Formation also founded In Tampur / Tamiang River (outcrop TR-3) (Figure 2). There is an unconformity with Tampur formation above this formation. The Outcrop Dimension is 12 m wide and 7 m high, with medium weathered rock condition. The outcrop consist of bedded polimix breccia with quartz arenite and slate fragment. Bahorok Formation composed by pebbly mudstone that deposited by gravity flow system that may occur in alluvial fan environments, sub-marine fan, as moraine glacier and till that could be creeping 10-12 cm/year and has local provenance. According to previous studies this formation has Carboniferous – Early Permian age (Cameroon et al, 1980) [1] (Figure 2). Bryozoa Mudstone is found in Boho Village (Figure 2). This formation is included in the unit Pangururan Bryozoa Bed that has Early Permian age (Cameroon et al, 1980) [1] (Figure 2). The Outcrop has dimension 10 meters wide and 8 meters wide with Litology Characteristics are limestone, gray-brown, moderate to high weathered, easily crushed by hand (friable), many have bryozoa fossil (Figure 4). According to Barber & Crow (2005) [4] depositional environment of Bryozoa is shallow water environment.

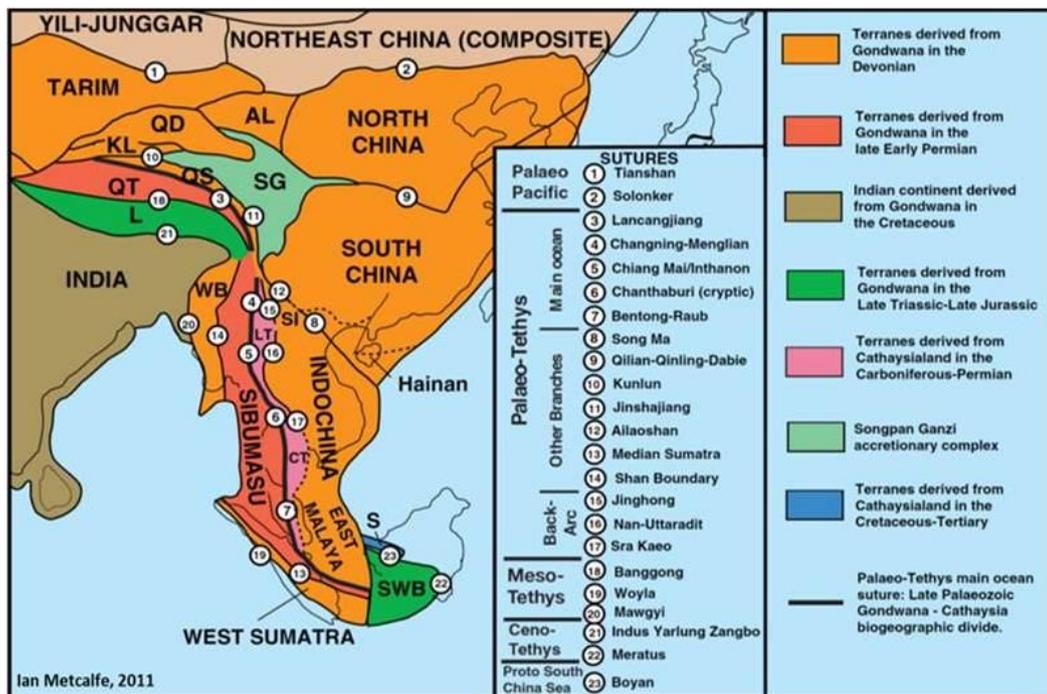


Fig. 1: Distribution of Continental Block, Arc Terranes, and Suture in Eastern Asia. (Metcalf, I, 2000) [5].

## 1.2. Peusangan Group

Peusangan group of this area consist of Batumilmil Formation, Limestone of Kalo formation, Kualu mudstone formation, and Limestone Sibaganding of Kualu formation. Batumilmil formations is founded in several places in Laukeutuken River (Sulkam/Marikeh area), Batukatak Cave – Berkail River, and Boho Village (Figure 2). In Laukeutuken River has dimension 4 meters high and 8 meters wide that consist of crinoidal floatstone with characteristics are dark gray limestones, fresh to moderate weathered, very hard, masive structure, reacts with HCL, the main mineral constituent is calcite, there are fractures filled by calcite veins and open fracture. Batumilmil Formation outcrops in Batukatak Cave - Berkail River consist of crinoidal floatstone with cave hole dimension 5 meters high and 15 meters deep (Figure 5). In the inside of cave there is stalactite with characteristic of the limestone are dark gray to reddish grey limestone, breccia limestone, and at the mouth of the cave is founded weathered reddish gray limestone. From above, characteristics can be concluded that cave is formed by ancient karstification (paleokarst), and recent karstification processes is occurring form stalactit and stalagmites. Paleo-karstification process may be can

formed in many times, namely when K / T Boundary (70 Million Years Ago), Middle Eocene (45 Million Years Ago) during early synrift, Middle Miocene (15 Million Years Ago) at the time of Bukit Barisan uplift, and Plio-Plietosten during subduction changes. Batumilmil Formation in Boho Village consist of blocks of crinoidal limestone with dimensions 21 meters wide and 3 meters high in hillside.

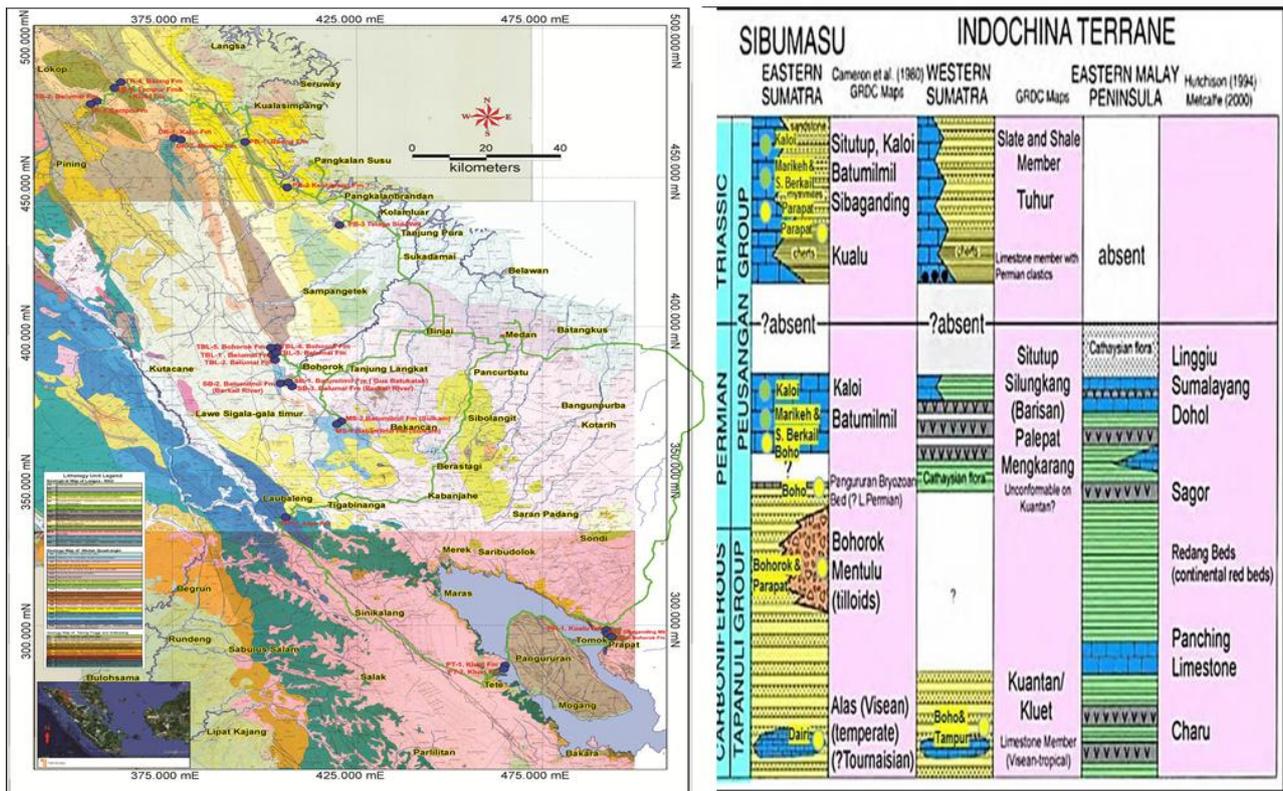


Fig. 2: (a) (left pic) Location Map of Survey Outcrop (GRDC map) [1]-[3]; (b) (right pic) Stratigraphy Position of Pre-Tertiary Outcrops in this Fieldwork Based on Lithostratigrafi Column of Carboniferous, Permian and Triassic Sequence of East Sumatra Terrane (Sibumasu), after Cameron et al, 1980 and GRDC Map, Indochina Terrene in West Sumatra (Map GRDC) and The East Malay Peninsula, after Hutchinson, 1994 and Metcalfe, 2000 (modified from Barber and Crow, 2005) [1] [5] [6].

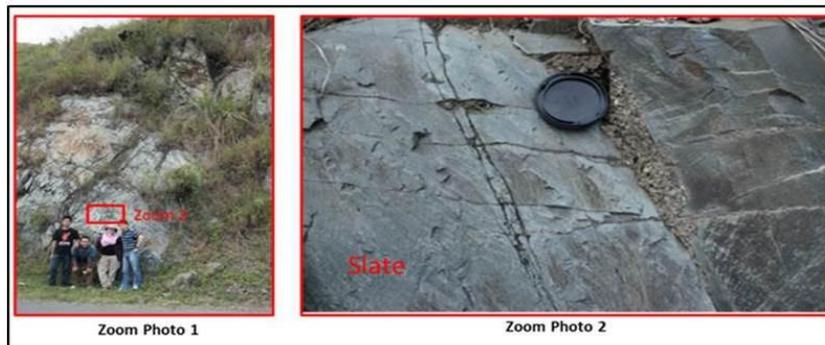


Fig. 3: Slate Outcrop of Kluet Formation (PT-2) in Boho Village.



Fig. 4: Outcrop PT-1 *Bryozoa* Claystone in Boho.

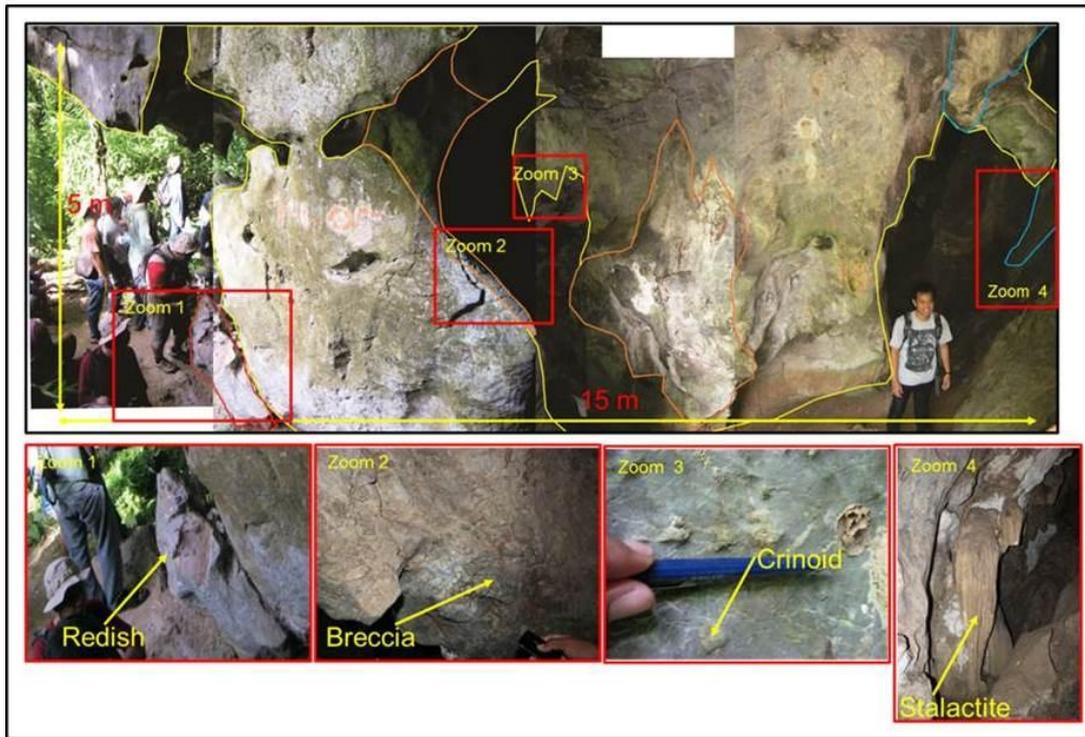


Fig 5: Outcrops SB-1 of Batumilmil Formation in Batukatak Cave is Composed by Grey Limestone that was Forming Shallow Cave.

Kaloi Formation is founded in the Kaloi village or Simpang Kiri River (Figure 2) with characteristics as follows; gray color, very hard, fresh to less weathered, crystalline, calcite, dolomite, intensive fractured, many veins of calcite, limestone outcrop thickness is about 2.5 m. Petrography of this formation outcrop shows the rock is dominated by calcite cement 43%, 23% dolomite mineral, 23% opaque mineral, and pore 3%. Kualu mudstone formation found in Parapat (Outcrops PR-1) (Figure 2) with dimension is 10 meters high and 24 meters wide, and lithology characterization are gray to dark mudstone, hard to friable, moderate weathered, non calcareous, there are Halobia fossils, Halobia species of this sample is *Halobia charlyana* Mojsisovics is included in Posidoniaceae superfamilia and has Lower-Middle Norian age (Upper Triassic). Limestone Sibaganding of Kualu Formation found at Sibaganding Cave and Hill in Parapat Area. The limestone have characteristics are black color, very hard, fresh to moderate weathered, blocky. Limestone is interpreted as a platform carbonate rock in the tidal area (tidal carbonate platform).

## 2. Pre-Tertiary Source Rock and Reservoir Potential

Pre-Tertiary source rock potential consist of Claystone of Kualu formation and Black Claystone of Batumilmil formation. Through macroscopic observation of the rocks, there is possibility of Pre-Tertiary source rock potential in claystone of Kualu Formation. Kualu Formation outcrop has been visited is located in Parapat (PR-1 outcrop) ( Figure 2) with characteristics of claystone are grey to dark grey (in the lower part of outcrop), hard to friable, moderately weathered, non-calcareous, contain Halobia Fosils, carbon spec is occurred. Black Claystone of Batumilmil Formation is a potential source rock because contained of carbon material and freshwater mollusca shell, based on previous research information by GDA-ITM.

Pre-Tertiary reservoir rock potential consist of Limestone of Batumilmil formation, Limestone of Kaloi formation, and Limestone of Tampur formation. Limestone of Batumilmil formations that have potential as a reservoir rock is composed of several types are fracture of dark grey limestone in Sulkam area, Fractured light gray limestones and occurs paleokarstification make caves and limestone breccia, the outcrop is found in Batukatak Cave, and Red dolomitic limestone, the outcrop found in the Berkail River. Dolomitization process cause downsizing of the crystals so that pores become enlarge. Kaloi Formation can be a potential reservoir because the limestone have intensive fractures. Based on petrographic data in Limestone found secondary porosity of imperfect filled fracture is equal to 3%. Tampur Limestone Formation is one of the

pre- Tertiary rock which potentially to be reservoir, because of secondary porosity from the fracture and chalky zone are presence. Potential reservoir of Tampur Formation is shown in an outcrop that compose reefal limestone (reefal build-up) that make up the chalky zone in the upper part, and fractured mudstone in the lower part. Characteristics of the rocks in the top is a white limestone cliffs, rich in calcium carbonate (CaCO<sub>3</sub>) as chalky zone, there is a cave, estimated as a reefal build-up.

### 3. Conclusion and Recommendation

Pre-Tertiary rocks in northern Sumatra are not much altered into metamorphic rocks, so the components of the petroleum system of the Pre-Tertiary rocks not only as a reservoir rock but can be a source rock potential. Pre-Tertiary Reservoir rocks potential are limestone of Alas Formation, Limestone of Batumilmil Formation, Limestone of Kalo Formation, and Limestone of Tampur Formation. The rocks have Pre-Tertiary source rock potential are mudstone of Kualu Formations and black claystone of Batumilmil Formation.

Further research need to be conducted in detail sedimentology- stratigraphy, potential petroleum systems in Batumilmil Formation, reservoir quality and source rock geochemistry in potential Pre-Tertiary sediments.

### 4. References

- [1] Cameroon, N.R., Clarke, M.C.G., Aldiss, D.T., Aspden, J.A. & Djunudin, A. 1980. *The Geological Evolution of Northern Sumatra*. In: Indonesian Petroleum Association, Proceedings of The 9th Annual Convention: Jakarta. 1980, 9, 149-187.
- [2] Cameroon N.R, Aspend J.A, Bridge D. McC., Djaenuddin A., Ghazali S.A., Harahap H., Hariwidjaja, Johari S., Kartawa W., Keats W., Ngabito H., Rock N.M.S., Whandoyo R.. 1982. *The Geology of The Medan Quadrangle, Sumatra*. Geological Research and Development Centre: Bandung.
- [3] D.T. Aldiss, R. Whandoyo, Sjaefuddin A.G, Kusjono. 1983. *The Geology of the Sidikalang Quadrangle, Sumatra*, Geological Research and Development Centre, Bandung.
- [4] Barber, A.J., M.J. Crow & J.S. Milsom. 2005, *Sumatra: Geology, Resources and Tectonic Evolution*. Geol Soc., London, Mem. 31.
- [5] Metcalfe, I. 2000. *The Bentong-Raub Suture Zone*. Journal of Asian Earth Science, 18, 691-792.
- [6] Hutchjson, C.S. 1994. *Gondwana and Cathaysian Blocks, Palaeotethys Sutures And Cenozoic Tectonics in South-East Asia*. Geologische Rundschau, 82, 388-405.