Alluvial - Fluvial Architecture of Synrift Deposits: An Observation from the Outcrops of Brani Fm., Ombilin Basin, West Sumatra

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ABSTRACT

Synrift sediments are currently a major focus of both academic research and industrial interest related to petroleum exploration, particularly with regard to their reservoir potential. Reservoirs are alluvial - fluvial deposits with a variety of sedimentary architectures. Their complexity requires good knowledge of basic sedimentology and use of outcrop analogies. The Brani Fm. of the Ombilin Basin has good outcrops that can be used as surface geology model. This paper uses measured outcrop data from the synrift, alluvial - fluvial sediments to characterize reservoirs, revealing that reservoir properties, such as porosities & permeabilities have wide ranges. Thicker sand body geometries in channel assemblages have good connectivity. Utilizing outcrop data is a useful analogue for the surrounding subsurface to tie into the geophysical data.

Keywords: *Alluvial, fluvial, synrift, Brani Fm., Ombilin Basin.*

INTRODUCTION

Neogene sediments in western Indonesia basins have long been recognized for their good reservoirs. Below, the Paleogene rift systems are becoming the future exploration target (Noeradi, et al., 2005). The Brani Fm. is a good example of a Paleogene synrift good outcrop data. Earlier geological studies {Koesoemadinata and Matasak (1981), Noeradi et al. (2005) and Zaim et al. (2012)} discussed the Ombilin Basin as a whole and part of Brani Fm. These papers generally described Brani Fm. as an alluvial-fluvial product that is widely distributed along the rim of the Ombilin basin. Reconstruction of its architecture, in particular the sand body connectivity is a key control of reservoir performance and is aided here by the outcrop analogy approach in order to clarify the alluvial-fluvial system of the Brani Fm.

REGIONAL GEOLOGY

Ombilin Basin stratigraphy comprises pre-, syn- and post-rift units. The latter is the pre- Tertiary basement and is followed upwards by the synrift phase, which is the manifestation of tectonic extension during Eo-Oligocene time, with two distinct sedimentary cycles distinguished: the early synrift and late synrift. The early synrift comprises two rock units: the Brani Fm., the basin marginal facies and the Sangkarewang Fm., the coexisting deeper basin facies. The late synrift cycle Sawahlunto Fm. reflects the basin geometry during the time of its deposition. The post-rift phase is a manifestation of regional sagging or thermal subsidence, and represented by the Sawahtambang and Ombilin Fms. The Brani Fm. comprises coarse clastic sediments consisting of fanglomerates and conglomerates deposited both at the basin margin border fault and the flexural margins. No palynomorphs or age determinant ichnofossils have been recovered from the Brani Fm. but it has been supposed to be late Paleogene due to its interfingering relationship with lateral and overlying stratigraphic units, which do have fossil dating (Noeradi et al., 2005) (Figure 1).

SIGNIFICANCE OF ALLUVIAL-FLUVIAL DEPOSITS

Alluvial fans are a form of fluvial depositional system distinguished on the basis of geomorphology as low, outspread, shaped like an open fan or a segment of a cone, and stream-deposited. Sedimentation on an alluvial fan is by the activity of fluvial, braided streams. The term alluvial fan used for any entirely non-marine and non-lacustrine fluvial system whose channel network is distributary rather than **con**tributory (Miall, 2006). Rift settings provide high-slope topography with valleys, with deposits comprising basin-margin, alluvial fans and alluvial plain deposits. Grain size distribution can predict the lateral and vertical progression of alluvial to fluvial stages, namely proximal, medial and distal stage.

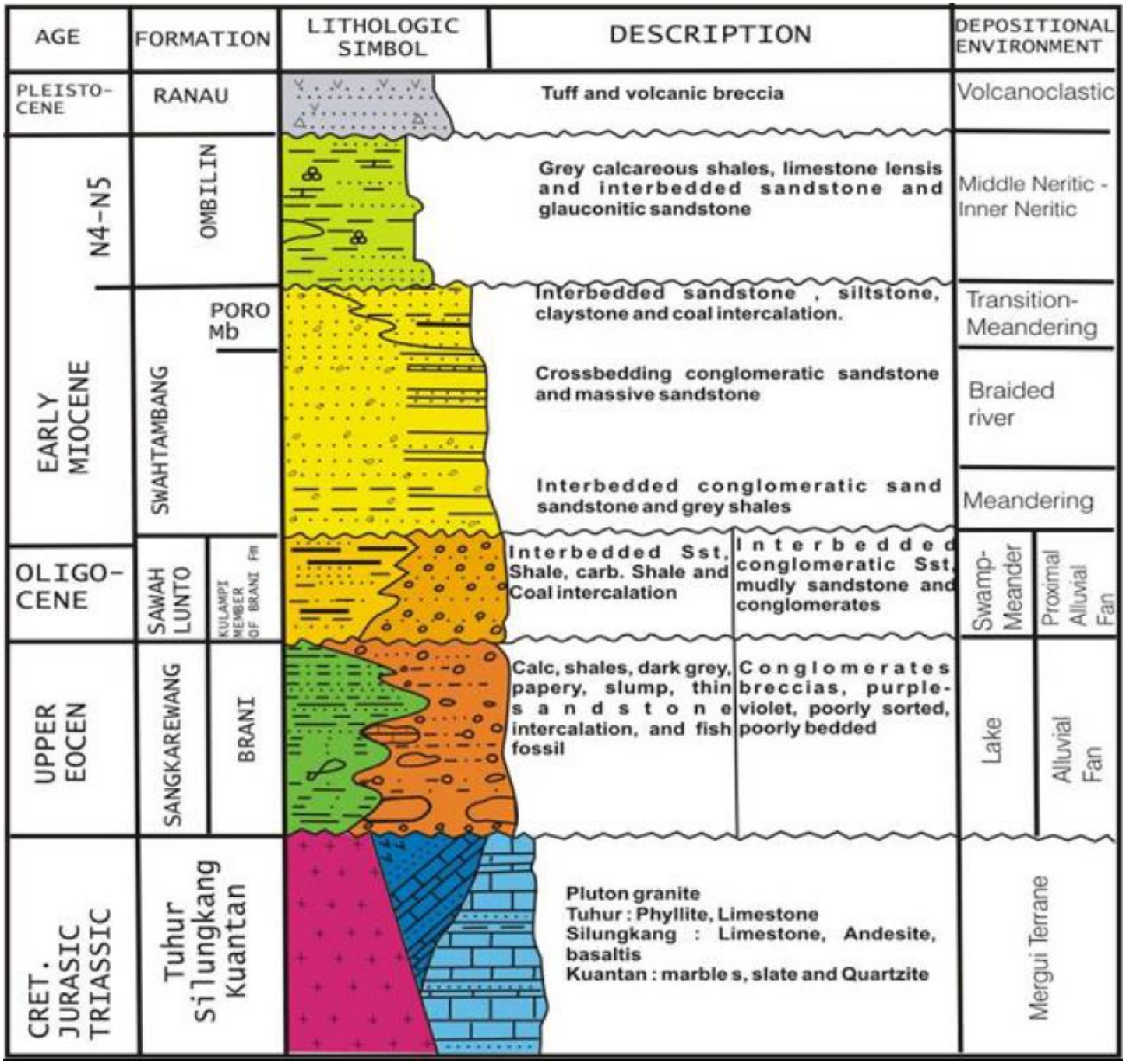


Figure 1. *General lithostratigraphic column of the Ombilin Basin (Noeradi et al., 2005).*

FIELD LOCATIONS

The outcrops are easily accessible and excellent in term of vertical extent of the sequences. Administratively, the outcrops belong to Payakumbuh Area, Limo Puluh Koto Regency, West Sumatra, Indonesia (Figure 2).

BRIEF RESULTS

Two large-scale outcrops (width & height up to 60m and 25m, respectively) represent the development of the Brani Fm. The initial phase of the development is an alluvial fan characterized by debris-flow conglomeratic bed. The last phase of the development is the deposition of a 12m-thick braided stream deposit. Facies analysis was conducted to define the alluvial-fluvial architecture.

1. Alluvial Fan Outcrop

The outcrop shows immature textures, which is characterized by dominantly boulder-size grains, very poor sorting, matrix-supported, highly-consolidated, and fewer sedimentary structures. Quartzite oxidized fragments form red beds (Figure 3). Probably Volcanic Andesite fragments are observed in the upper part. No imbricated fragments were observed. There are two groups of facies association: Debris deposit, consisting of massive conglomerate facies (Cm) and channel-fill sandstones consisted of both trough cross-stratified facies (Stc) and parallel stratified facies (Sps). The basal fining-up sequences are followed upwards by coarsening-up sequences towards the top.

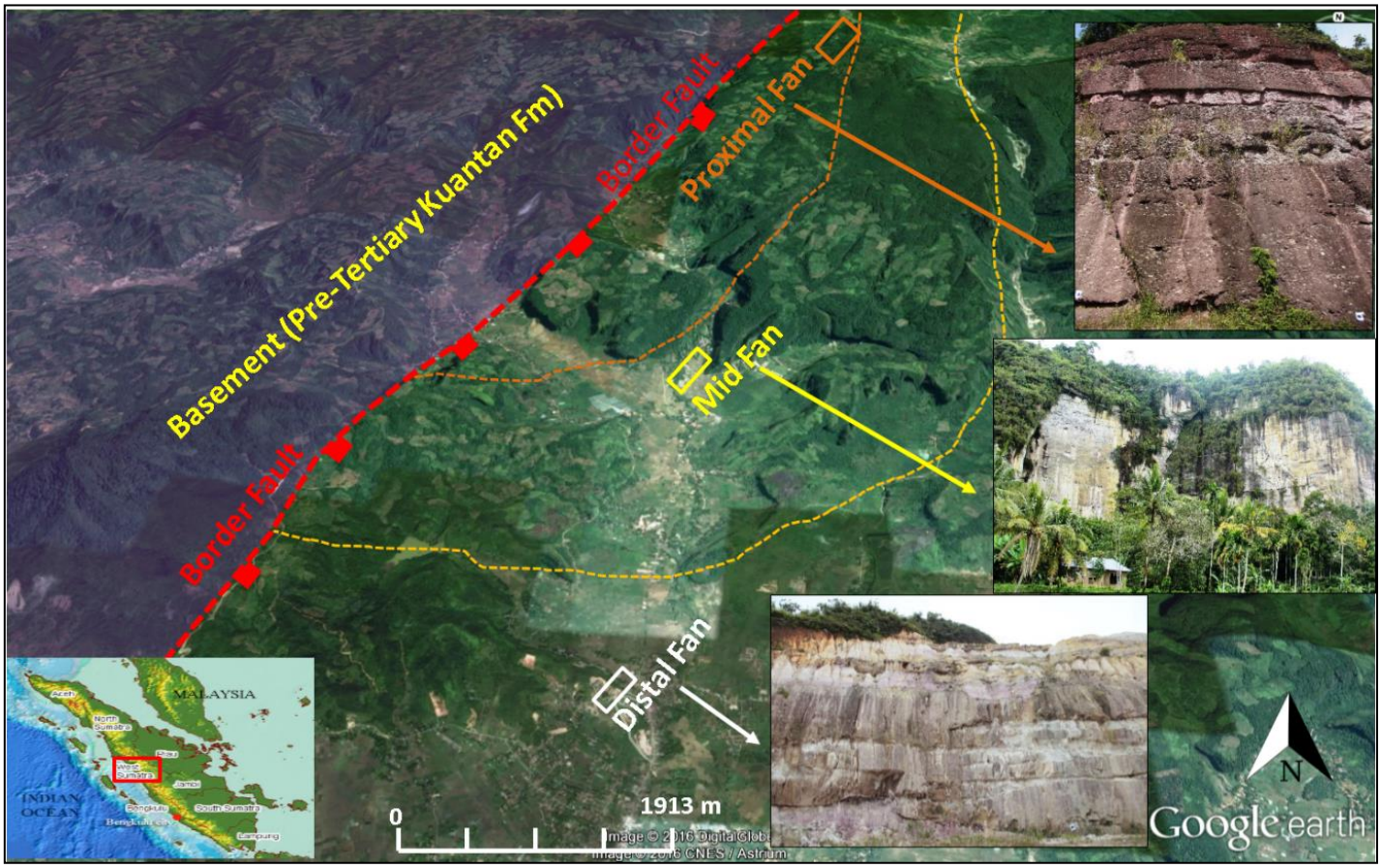


Figure 2. *Location of Brani Fm.'s outcrop from Google Earth.*

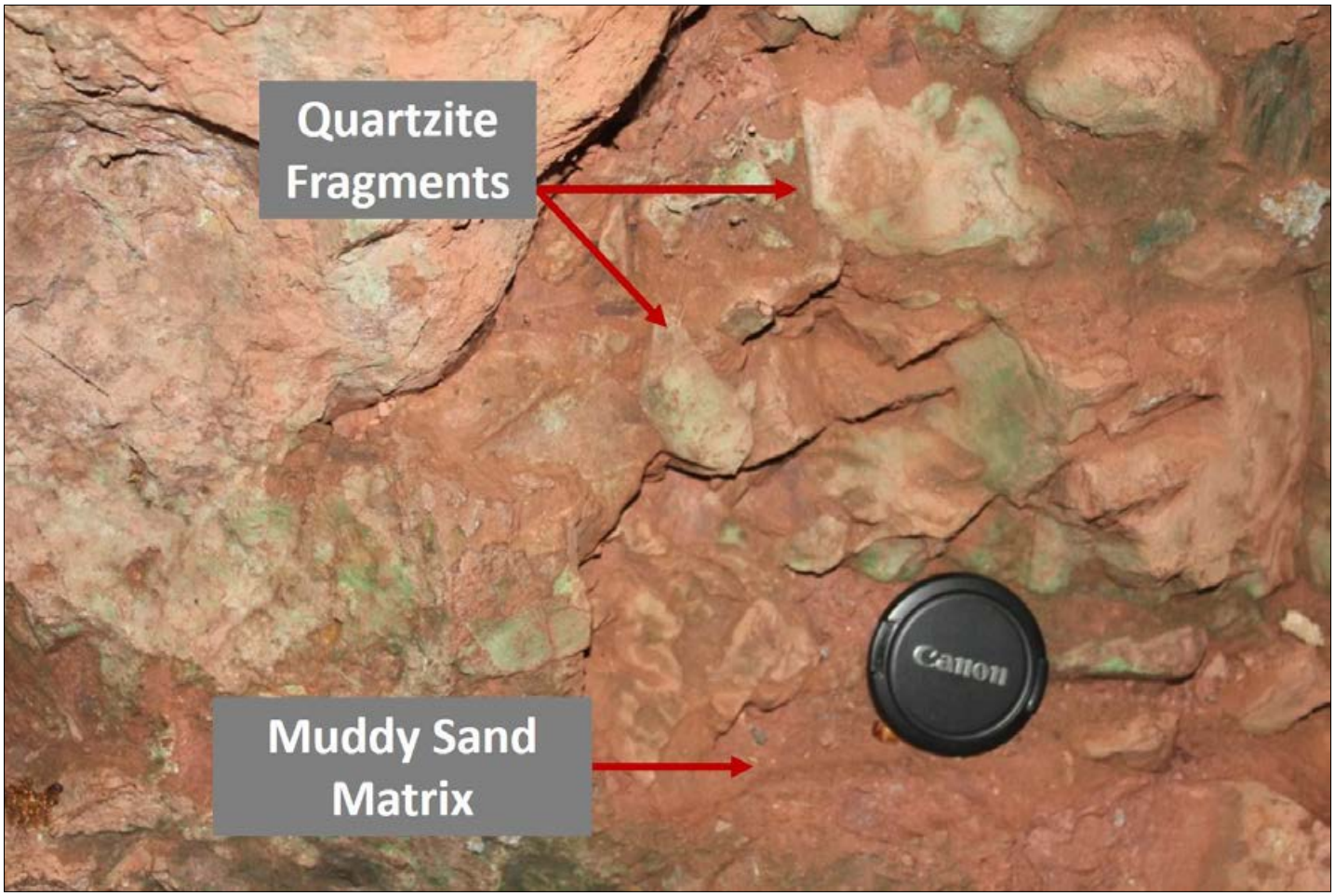


Figure 3. *A detailed view of oxidized quartzite fragments. Debris conglomeratic bed showing immature texture characterized by dominantly boulder-size grains, very poor sorting, matrix support, and few sedimentary structures.*

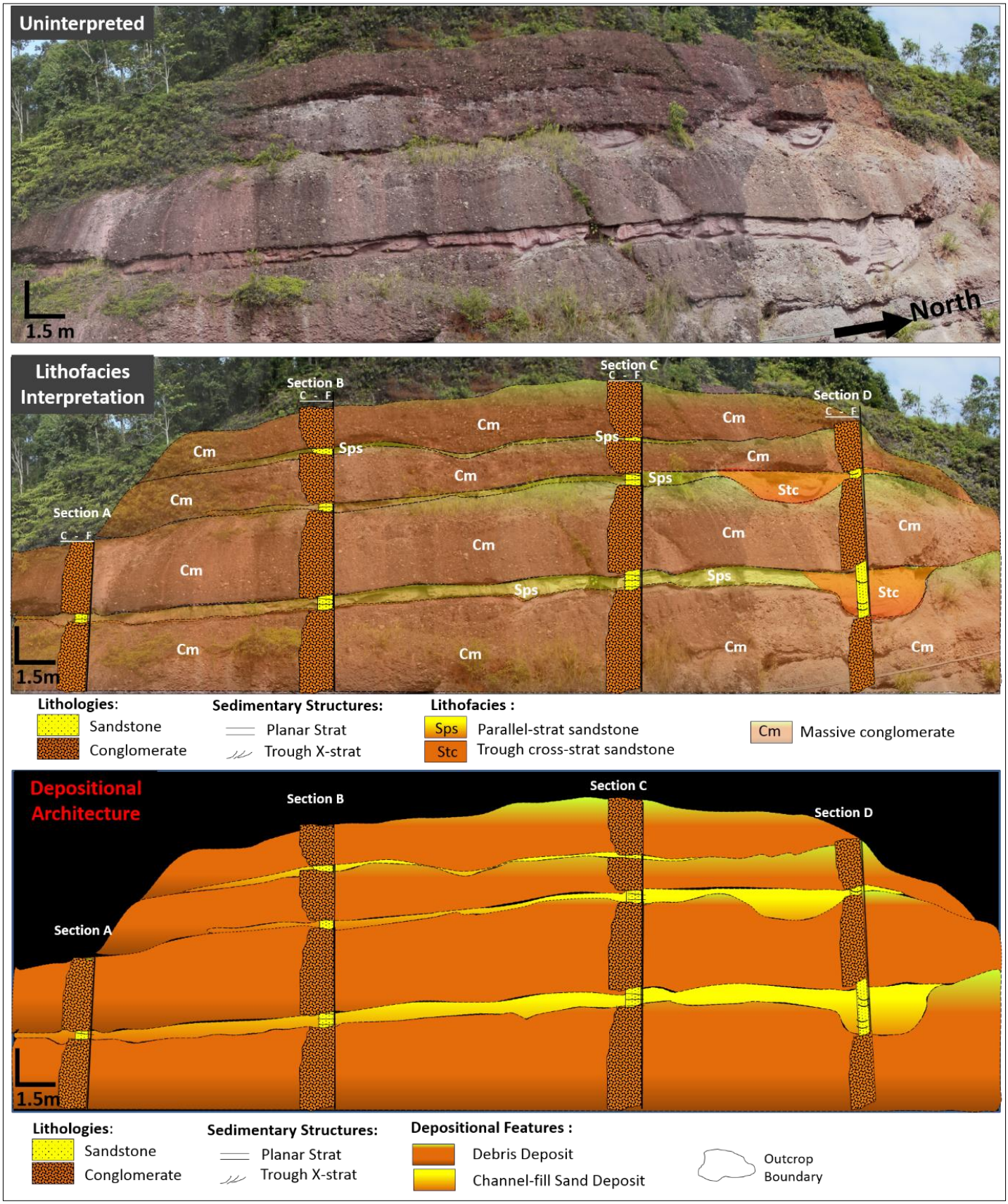


Figure 4. *Alluvial fan architecture from outcrop of Brani Fm. showing lithofacies distribution as a part of the alluvial system. The sediment is coarse, making provenance identification easy (fragments reflect Basement lithologies). The good exposure of its fan indicates evidence of tectonism.*

Because of these immature textures, no further laboratory work was conducted on this outcrop (Figure 4).

2. Braided-Fluvial Outcrop

Detailed sedimentary features observed physical sedimentary structures, the abundance of quartz, and existence of paleosol beds.

There are two groups of facies association, namely: fluvial channel complex deposit, consisted of pebble lag (*Sp*) with trough cross-stratified

sandstone (*Stc*), massive sandstone (*Sm*), and parallel cross stratified sandstone facies (*Sps*) and flood plain deposits, consisting of massive siltstone (*Fm.*) facies (Figures 5 and 6). These records may indicate that active migration of channel complex has occurred. It is interesting to note the existence of multiple paleosol beds, characterized by purplish color a few centimeters thick. The existence of paleosols represents temporary cessation of sedimentation (minor disconformity) that could be used as stratigraphic marker for correlation purposes (Figure 7).

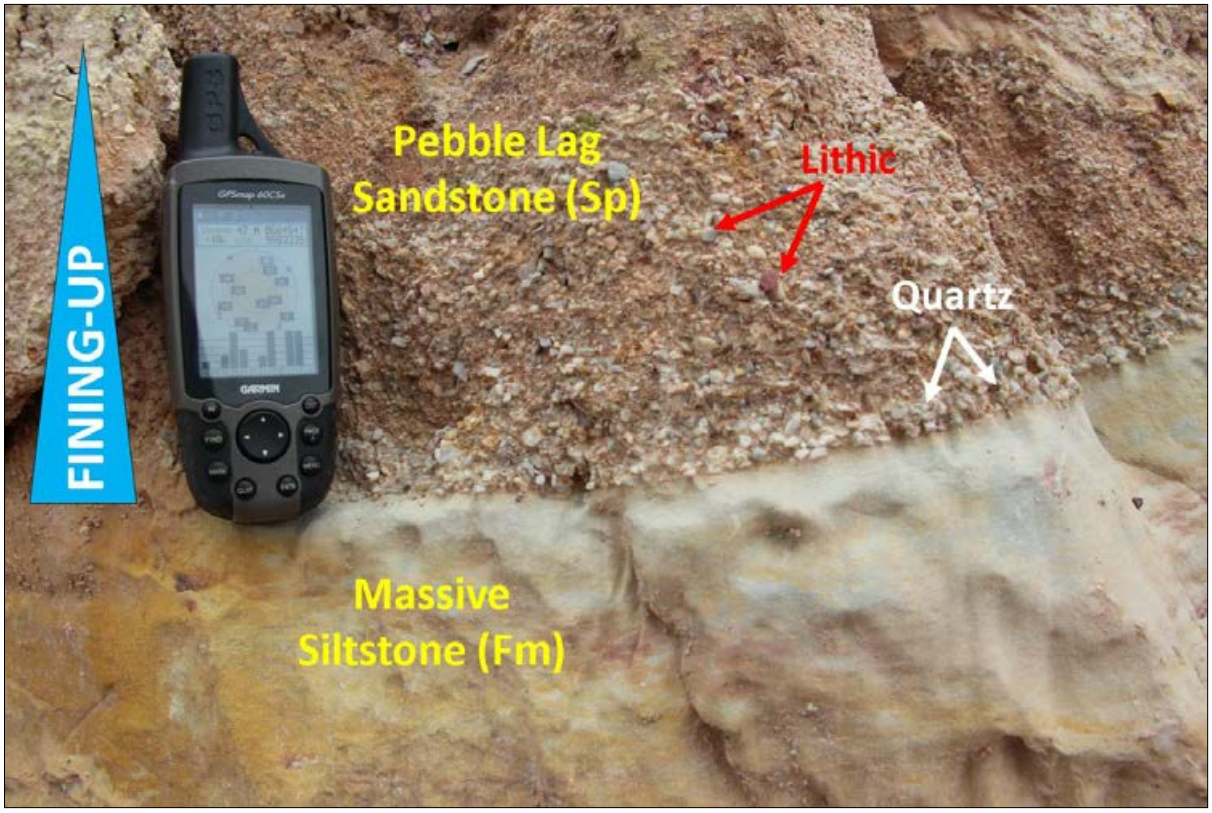


Figure 5. *Detailed view of fining-upward grain size succession with channel lag deposits overlying massive siltstone overbank deposits. The pebble lag sandstone (Sp) varies in grain size (pebble to medium sand) and mineral content (lithic, quartz and minor feldspar).*

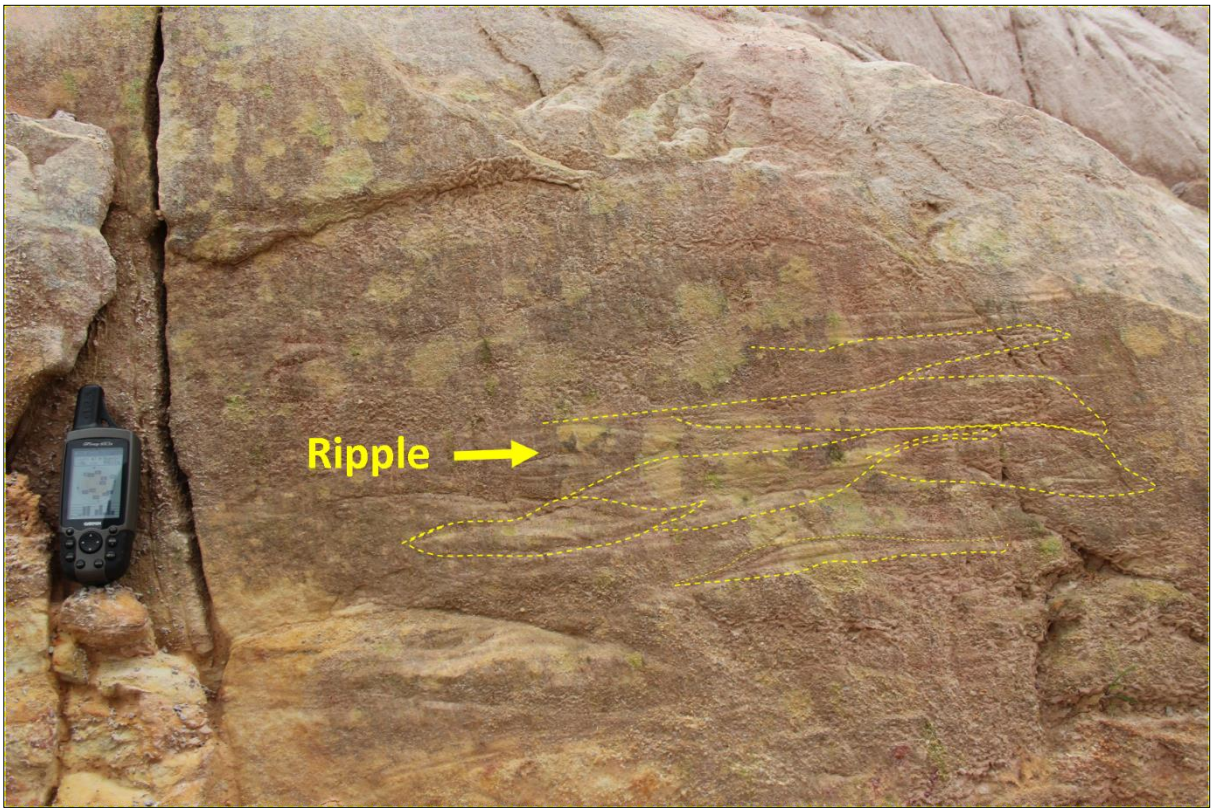


Figure 6. *Detailed view of ripple sandstone (Sr) with 25 cm thick. Light yellowish and moderate consolidated sand with medium to coarse grain size interpreted as lateral accretion features.*

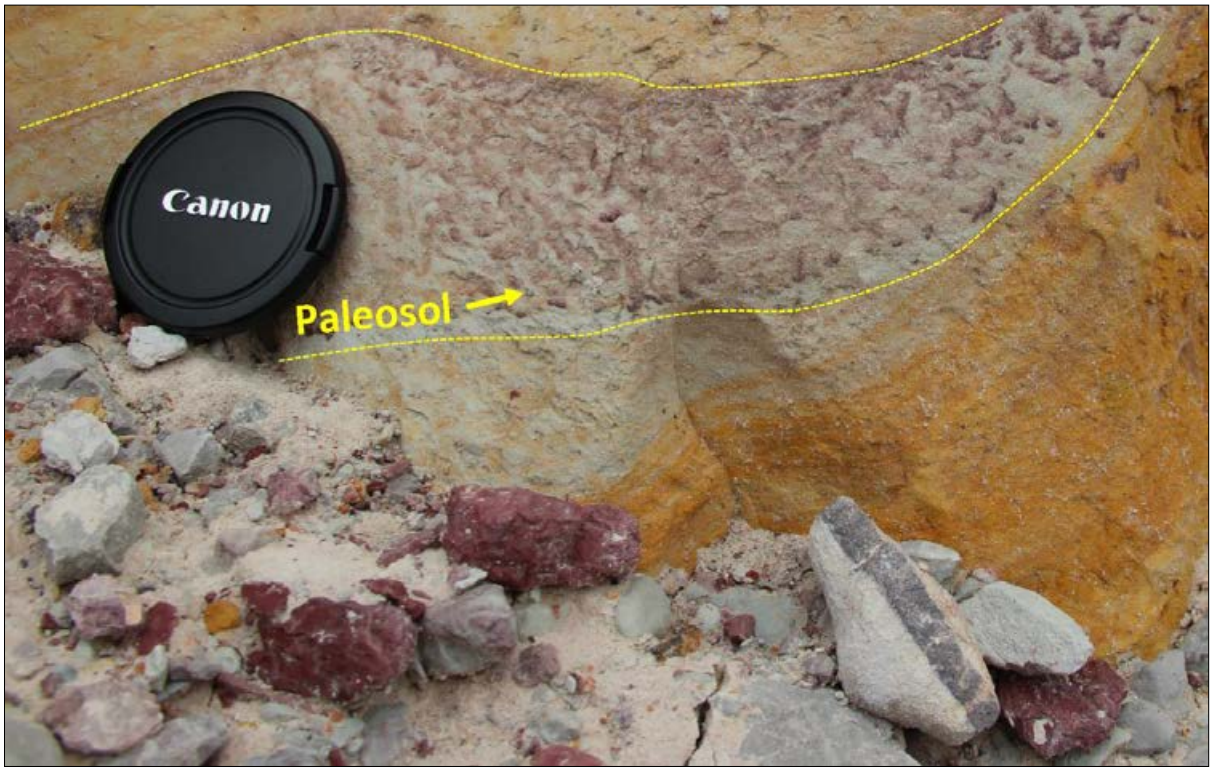


Figure 7. *Detailed view of purplish paleosol that is common in fluvial sediment products. It belongs to weakly developed soil that represents the rate of sedimentation exceeding rate of erosion.*

Laboratory work

Six sandstone samples were taken from five sand bodies representing the channel assemblage deposit, and cores cut. Based on core analysis, ranges are: grain density 1.72 to 2.72 gm/cc, effective porosity from 13.7 to 20.8 %, and permeability from 10.7 to 3294.8 mD. Petrography shows mature sand, with composition dominated by quartz and some matrix. Minor monocrystalline quartz, indicated by wavy undulatory extinction under crossed polars, is interpreted as volcanic. Minor plagioclase and detrital clay content are observed. Grain size, roundness, sphericity and sorting depend on lithofacies type. Visible porosity is ranging from 10.5 – 14.2 % with mainly intergranular pore type (Figure 8).

In plan (birds' eye view), the outcrop is interpreted as most likely a channel evolved upwards from fine-grained sediment to soils, indicated by existence of fine-grained sediment below (massive siltstone facies) and paleosols upward. There is no indication of active channel switching to different direction. (Figures 9 and 10).

Outcrop view of the Brani Fm. provides high resolution, surface geological data of alluvial fan and braided fluvial deposits. The alluvial fan deposit comprises a thick conglomeratic bed with a thin sandstone layer. Conversely, the braided fluvial deposit consists of interbedded sandstone with siltstone with more common sedimentary features. (Figure 11).

DISCUSSION

In term of depositional environment, macroscopic and microscopic observations reveal these outcrops are distinctive of an alluvial-fluvial system deposited during an early synrift event. Alluvial fans are interesting for their petroleum exploration significance. Alluvial fans are always near the mountain range, thus they are very near their sediment source and usually coarse, aiding sediment provenance identification easy. Quartzite and andesite (volcanic) fragments may reflect the various Basement lithologies since those are near the border fault, they are very strong indicators of what portions of the adjacent basement were exposed at any given time.

The fluvial deposits are interpreted as a braided system, indicated by existence of multiple channels deposited along lower fan lobes (Figure 11). Field observation and laboratory measurements defined sand body dimensions, petrographic properties, lithofacies and depositional facies models that subsequently can be applied to subsurface reservoir interpretation. Sixteen sand bodies geometry were measured with widths (maximum, average and minimum) of 25.5m, 13.57m and 6.57m, respectively, and thicknesses max/ave/min, of 2.2m, 0.91m and 0.33m, respectively. Cross-plots of channel width vs sand body thicknesses show a linear trend with thicker the sand bodies corresponding to the wider channels. Sand-shale ratio indicates that shale composition is relatively high (50 to 65%), which indicates that the braided stream deposit belongs to a distal stage (Figure 12).

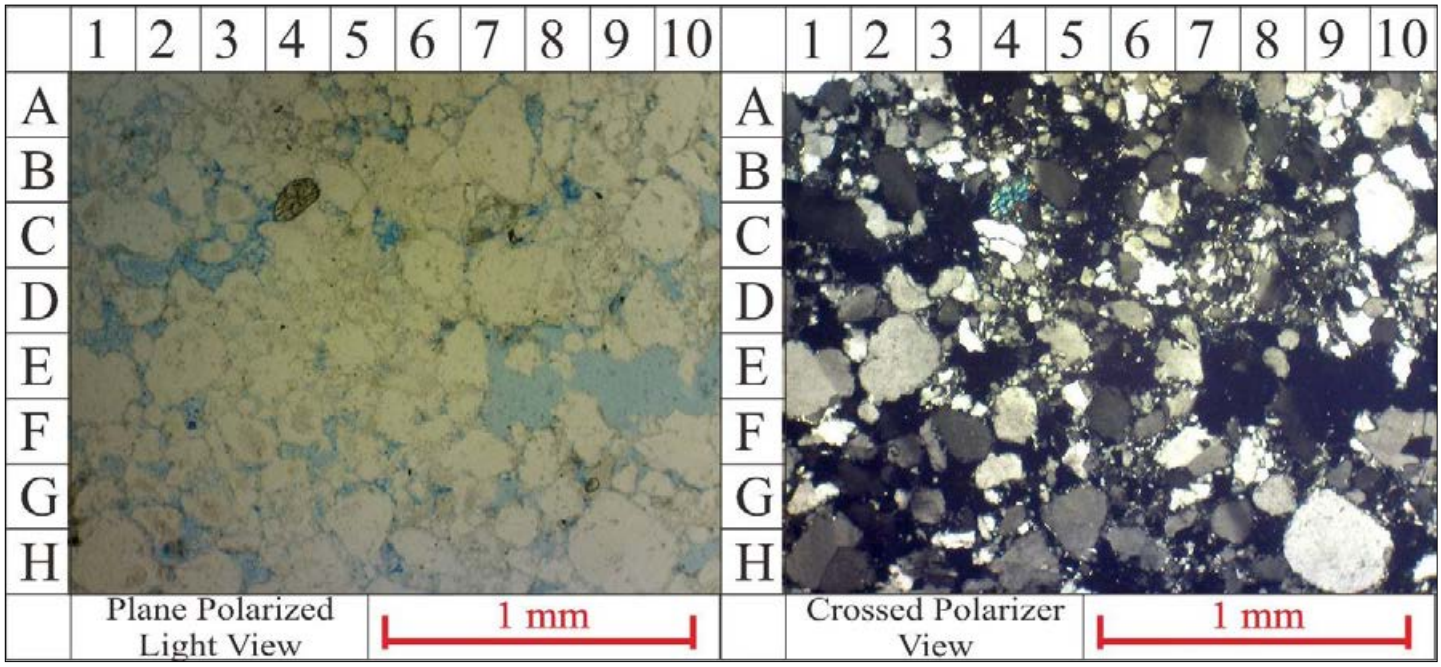


Figure 8. *Petrographic view of sandstone sample 4.4 showing grain size ranges from 0.3 to 1mm (medium-coarse), angular to sub rounded, poorly to moderately sorted, low to moderate sphericity. At left, dark brown on at C1-C3 is replacement of feldspar mineral into clay. Intergranular pore type up to 14% is marked by blue color. Abundant monocrystalline quartz with undulatory extinction is interpreted to be of volcanic origin. Minor plagioclase and detrital clay content are observed.*

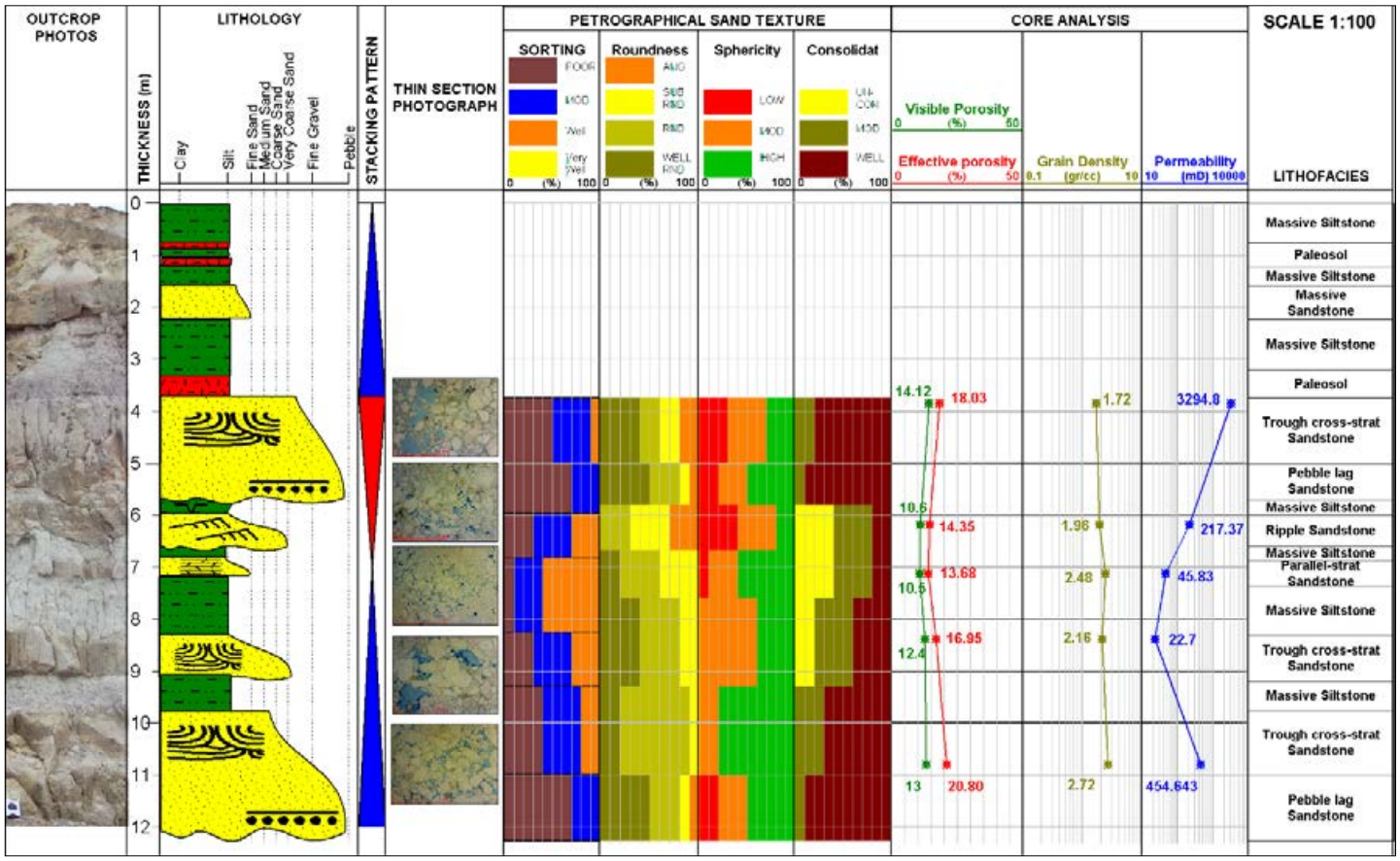


Figure 9. *Sedimentary log analysis showing a vertical succession of interbedded sandstones with siltstones and thin layers of paleosols. Trough cross-stratified sandstone facies demonstrates good reservoir properties, such as high porosity (up to 20.8%) and high permeability (up to 3294.8 mD). This facies can be interpreted as part of main channel with high energy turbulence that is proven by poor-well sorted, sub-well rounded, moderate-high sphericity, and moderately-well consolidated.*

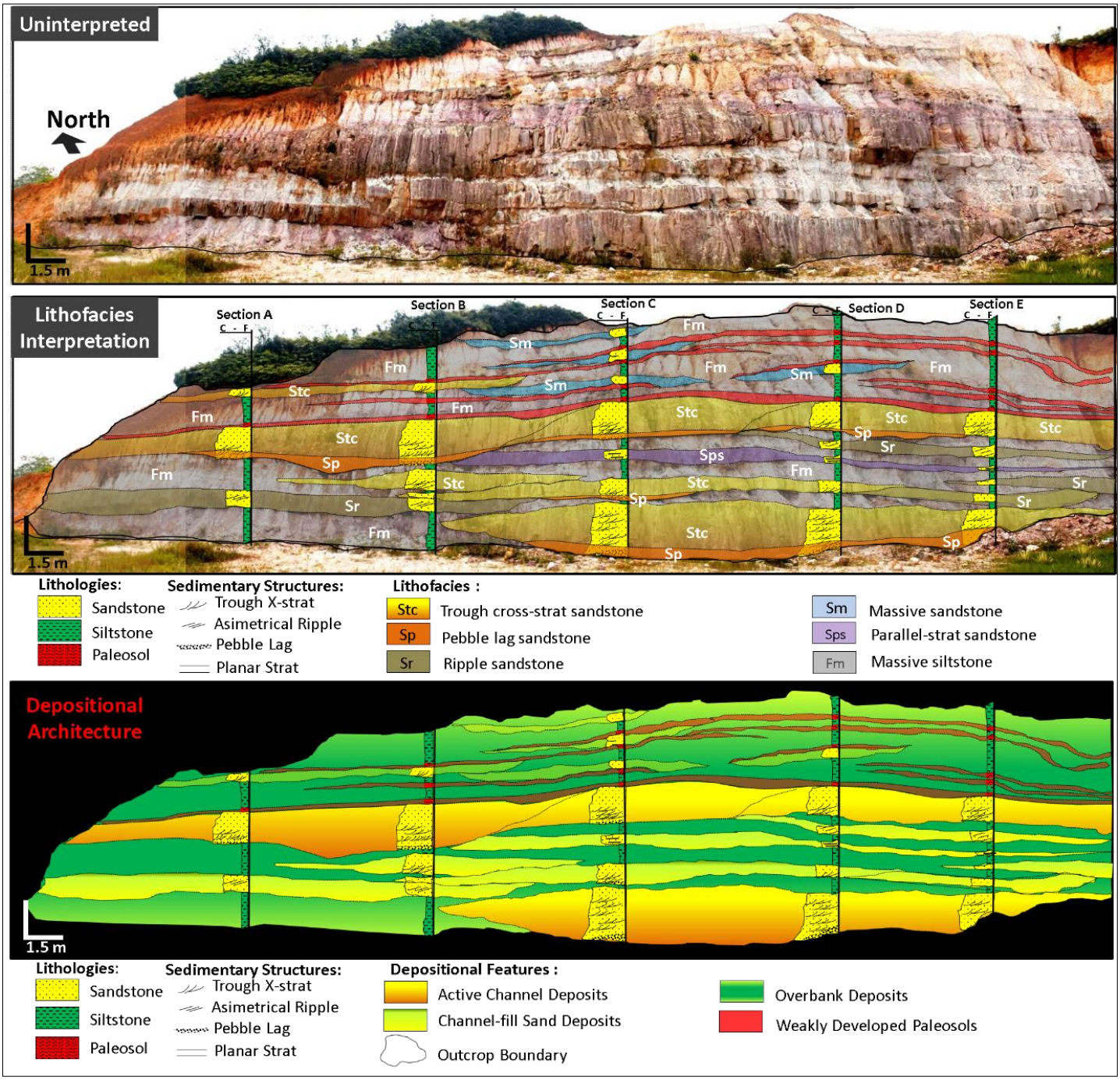


Figure 10. *Architecture from outcrop of Brani Fm. showing lithofacies distribution as a part of braided-fluvial system. Thick sand bodies with good connectivity is suggested by reservoir geometries. The existence of paleosols was used as stratigraphic markers for correlation purposes.*

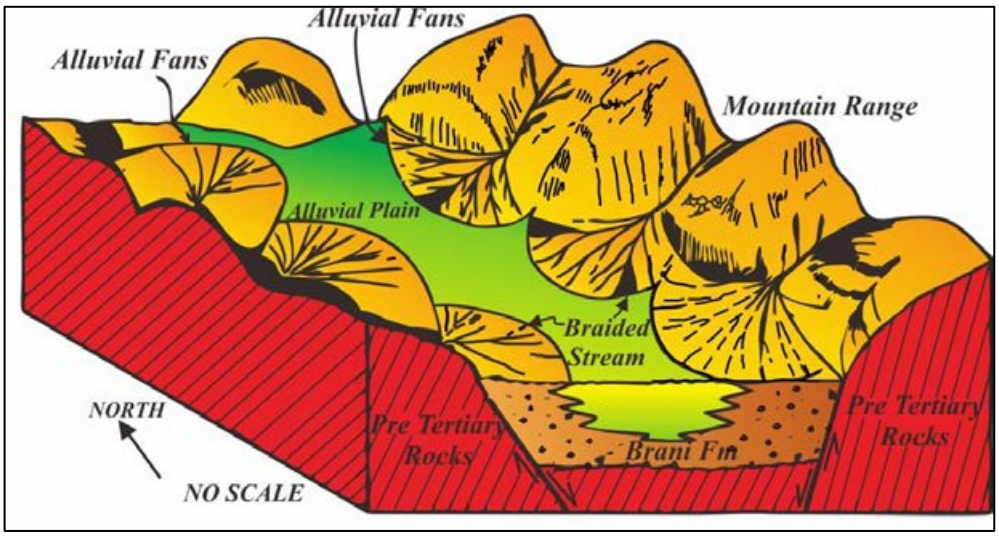


Figure 11. *Simplified block diagram showing depositional condition during the deposition of the Brani Fm. (modified after Koesoemadinata and Matasak, 1981).*

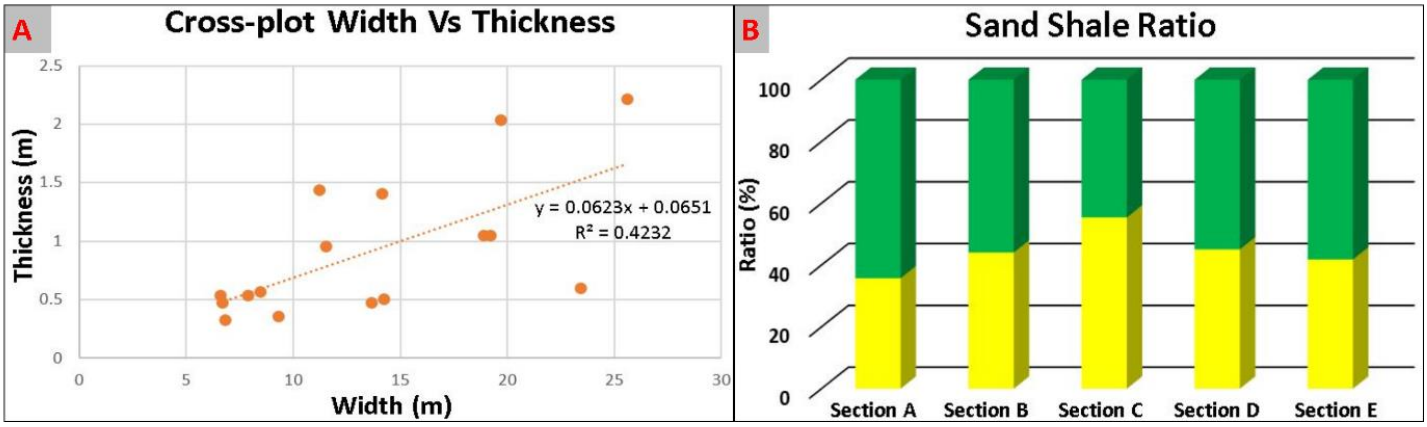


Figure 12. *(A) Cross-plot of channel width versus sand bodies thickness on braided-fluvial outcrop showing linear trend. (B) Bar diagram of sand-shale ratio presenting a different composition ratio on each section.*

CONCLUSION

The exposure of Paleogene outcrops along the Harau valley brings valuable insight to the complexity of fluvial reservoirs within a synrift system. The wide ranges sandstone porosities & permeabilities are due to weathering and diagenetic processes. However, these actual data can still be used for petrophysical assumptions. The best reservoir candidates regarding the lithofacies and properties are cross-stratified sandstone (*Stc*), massive sandstone (*Sm*), and parallel cross-stratified sandstone facies (*Sps*) which all are a part of channel assemblage. These measurements are very beneficial to understand the relationship of reservoir geometry, estimates of properties, to guide subsurface stratigraphic correlation, and variogram geo-modeling of Paleogene fluvial systems in the Central Sumatera and Ombilin Basins in particular.

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