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The Characteristics Of Shoreface Deposits Based on Facies Analysis of Seulimum Formation, Aceh Besar

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Abstract
The shoreface deposits study commonly conducted to characterize the reservoir's physical properties carried out by surface geological data. The physical properties focused on pore space conditions controlled by sedimentary process and tectonic settings in Seulimum Formation. The method used as descriptive analysis and previous study of the area interested. The geological data showed shoreface environmental deposits that can be divided into two types of environmental deposits they are middle shoreface and upper shoreface deposits. These environmental deposits are proven by some features such as bioturbation with an abundant presence of Ophiomorpha in the second stop sites (total 5 stop sites). The first stop site indicates two kinds of environmental deposits by coarse sandstones and mudstones dominated facies presence in the specific beds. Mudclast and hummocky structures also present in the field observation that concludes complex environmental deposits during the quaternary period the formation. Based on characteristics of facies could suggest those sediment products deposited on shallow marine. These wave-dominated coasts generally have an excellent reservoir potential effect on shoreface sands that are laterally continuous and were orientated parallel to the shoreline.

Keywords*: Shoreface deposits; sandstones; reservoir; rock properties; Seulimum Formation.*

Abstrak
Penelitian terkait endapan *shoreface* umumnya dilakukan untuk menentukan karakteristik sifat fisik dari kondisi reservoir dari data geologi. Sifat fisik tersebut dikhususkan pada porositas yang terbentuk dalam proses pengendapan sedimen dan tatanan tektonik pada Formasi Seulimum. Metode yang digunakan adalah metode deskriptif dan analisis beberapa studi terdahulu. Berdasarkan data lapangan, teridentifikasi bahwa endapan shoreface pada Formasi Seulimum terbagi atas dua jenis yaitu *middle shoreface deposits* dan *upper shoreface deposits*. Interpretasi lingkungan pengendapan tersebut juga dibuktikan dengan keterdapatan Ophiomorpha dalam kondisi melimpah pada titik pengamatan kedua. Di titik pengamatan pertama menunjukkan dua tipe lingkungan pengendapan berdasarkan keterdapatan batupasir berukuran kasar dan batulumpur yang tersebar secara dominan pada lapisan-lapisan tertentu. Keterdapatan *mudclast* dan struktur *hummocky* juga tersebar cukup banyak berdasarkan pengamatan di lapangan yang mengindikasikan lingkungan pengendaan yanng cukup kompleks selama zaman Kuarter pada Formasi Seulimum. Berdasarkan karakteristik fasies, dapat disimpulkan bahwa produk sedimen terendapkan pada daerah laut dangkal. Kondisi ini juga disebut dengan *wave-dominated coast* yang berpotensi baik sebagai reservoir dan tersusun oleh batupasir *shoreface* yang menerus secara lateral dan paralel terhadap garis pantai.

Katakunci: Endapan *shoreface*; batupasir; reservoir; sifat batuan; Formasi Seulimum.

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INTRODUCTION

The study was conducted in Jantho to identify characteristics of Seulimum Formation and the possibility to be a reservoir rock body. The Seulimum Formation which is well exposed in Jantho, Aceh Besar is a calcareous sandstone formation dominantly deposited in an open marine area (Bennett et al., 1981). The previous study concluded that Seulimum Formation is classified into shallow to deep marine environmental deposits by descriptive data analysis in the field (Wahyu, 2018). The experimental study was also carried out to determine sandstone's porosity and show a very good value of about 22% that is generated by 45 samples in three different thicknesses (Marwan et al., 2019). Similar studies were conducted and show the facies study in Upper shoreface deposits and found the permeability changes because of mud and bioturbation presence (Ovinda dan Lambiase, 2017). The Shoreface Sandstone characteristics were also evaluated in determining reservoir quality by several indicators such as grain size, kaolinitization process, and the presence of illite, stylolites, and bitumen and saddle dolomite crystals along stylolites (Muftah and Sadoon, 2015). The shoreface deposit areas are commonly determined as a reservoir and have been proven by some hydrocarbon fields such as "CR" and "YB" reservoir from air benakat formation in Jambi subbasin, South Sumatera (Rhamayanti et al., 2014).

The Seulimum Formation was deposited below the Padang Tiji group, Volcanics Lamteuba group, and Indrapuri Formation. The detailed location is shown in Figure 2. The Seulimum Formation consists of tuffaceous sandstones, calcareous sandstones, conglomerate, siltstone, and claystone in minority (Bennett et al., 1981). Carbonate facies succession on this formation proved that sea-level changes happened during the deposition of this formation. The facies analysis is potentially used as depositional environment determination. The depositional environment controlled by a geological process created variant lithological properties such as structure, texture, composition, and organic materials (Boggs, 1995).

The study area is also situated surrounded by two major segments of Great Sumatran Fault (GSF) with NW-SE oriented trend they are Aceh's and Seulimum's Segment. Based on the Sumatran Tectonic setting, the study area is located in a depression zone named Banda Aceh Basin caused by active faults activities. Thus, the area is showing the complicated structure as deformation was very intense and developed during the tertiary period (Fernandez-Blanco et al., 2015).

METHODOLOGY

The research integrated geological datasets from surface mapping and literature synopsis of the study area. Then the geological analysis applied in observed outcrops represents the vertical succession of the upper Seulimum Formation by considering the thickness and continuous sedimentary rock outcrops. The location of the studied area is shown in Figure 1.

The applied literature studies are some cases surrounded study area such as petrographic thin section provides fossils information, matrix, cement, and fragments.

RESULTS

The total number of stop sites they are 5 (five) STA. The characteristics of facies are founded in the field are relatively similar from one site to the others. The first three-stop sites (STA 3, STA 4, and STA 5) showed the beds with some differential thicknesses that are 20-30 cm and composed of very coarse grain to very fine grain sandstones interbedded by stormbed products with a small amount of conglomerate presence which visible in below part of outcrop. The dominant sedimentary structures presence in the outcrop were Inverse Bedding (Coarsening Upward) and Cross Bedding. The beds deposited in some orientation they are N230ºE/30º (STA5), N273ºE/25º (STA4), and N290ºE/15º (STA3).

Upper Shoreface Deposits

Upper Shoreface Deposits (Bed A and D, figure 5) are fine to very coarse sand with thickness beds of 1,7 m - 2 m. Sedimentary structures presented in the outcrop were Inverse Bedding and Cross Bedding. The main components of the sandstones are lithic fragments with quartz and feldspar as minerals. Sandstones are cemented by silica and grain shape ranges from rounded to well-rounded with good sortation. Lithic Conglomerate is presented in the upper part of Upper Shoreface Deposits (Bed A, Figure 5).

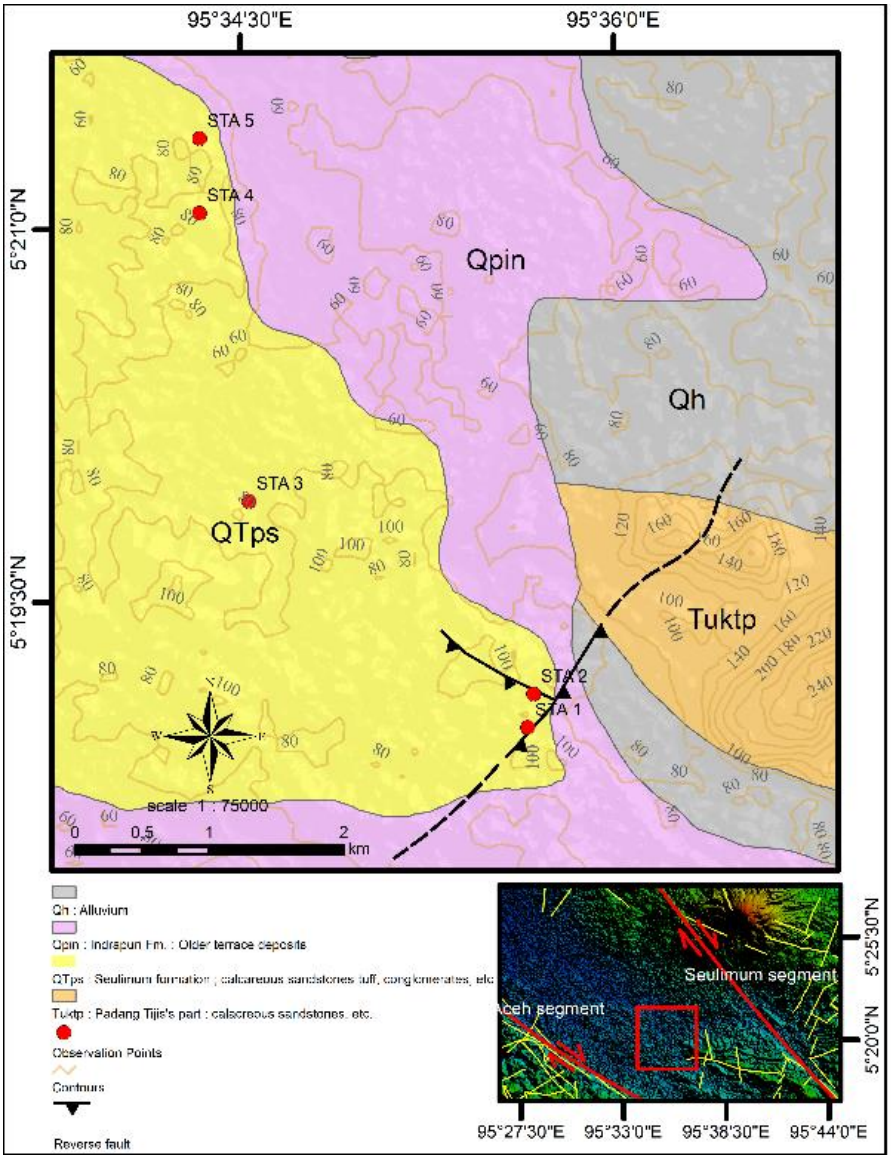


Figure 1. The location of the study area is shown by a red rectangle as a depression zone.

The components are matrix-supported with 65% matrix, 25% lithic fragments, and cement 10%.

Cross bedding features in different scales are developed within these deposits and are common in the upper part of the sandstones (Figure 2). Individual sets of cross-bedding range from 10 cm – 30 cm in thickness. There are a few mud drapes in the individual sandstone beds, located near contacts between mudstone (Middle Shoreface products) and sandstone.

The Ophiomorphas are rare in the lower part of facies (Figure 2). The individual beds are separated marked by erosional surfaces and sharp contact. There are Calcite veins also in the lower and upper parts of the facies. The distribution of those veins is rare found in sandstone beds.

Middle Shoreface Deposits

Middle Shoreface Deposits (C and B) are mud to pebble material and mud with thickness beds of 1 m – 1,25 m (Figure 4). Sedimentary structures presented in the outcrop were Parallel Bedding and Cross Bedding. The thickness of sandstones varies from 30 cm – 3 m, nearly all the individual sandstones are 30 - 40 cm thick (Figure 4). The thickness of individual mudstone varies from 20 cm – 1 m. The main components of the sandstones are lithic fragments with quartz and feldspar as minerals and some clay and silt minerals as components of mudstones. Sandstones are cemented by silica and grain shape ranges from sub-rounded to well-rounded with moderate to good sorting.

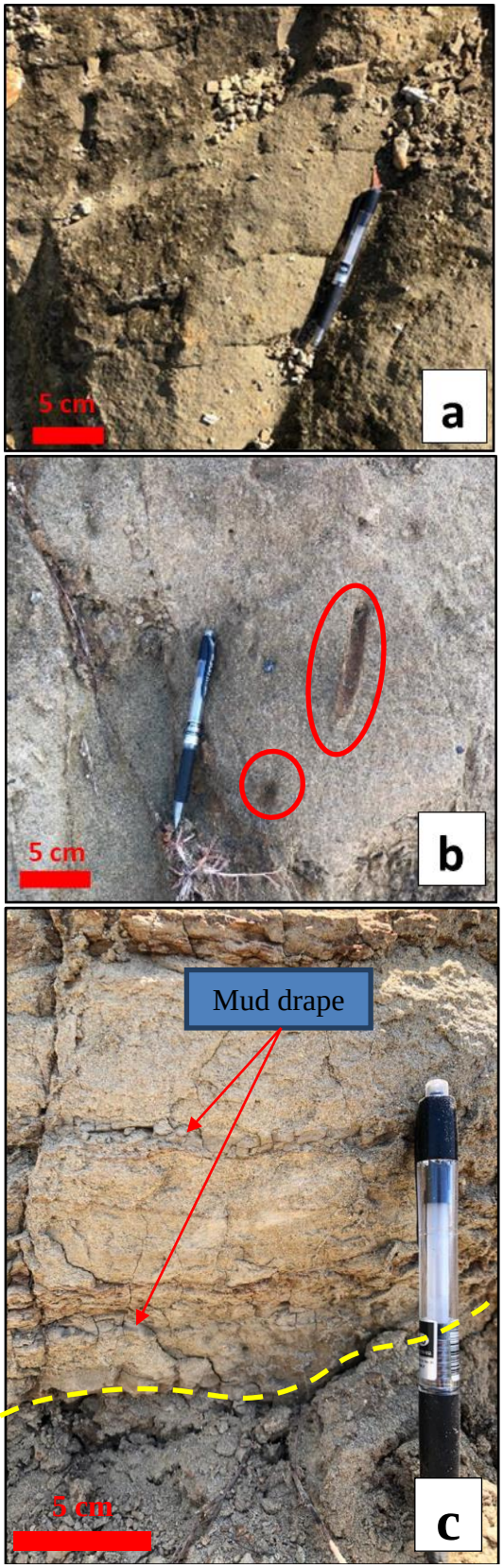


Figure 2. Cross Bedding (a); *Ophiomorpha* (b); Mud drape and contact between mudstone and sandstone (c).

Figure 3. Lithic fragments matrix-supported conglomerate (a); Calcite veins (b).

Lithic fragments matrix-supported conglomerate is also present in this facies. This bed is granule to pebble lithic fragments with a thickness bed of 20 cm. This bed is matrix-supported poorly sorted sediment, characterized by sub-angular to angular fragments. The Clast size varies from 2 cm to 5 cm. Matrix consist of fine-grained sandstone to very coarse-grained lithic sandstone, fragments of volcanic material are rare in the bed. Components are matrix-supported with 60% matrix and 30% lithic fragments and 10% cement. There are no sedimentary structures in the bed. The individual beds are separated by a marked erosional surface.

Cross bedding is also developed within these deposits. Individual sets of cross bedding range from 10 cm–25 cm in thickness. The sedimentary structures (cross bedding) are common in the middle part of the sandstones.

Bioturbation rarely appeared in this facies. The type of bioturbation founded on a bed is

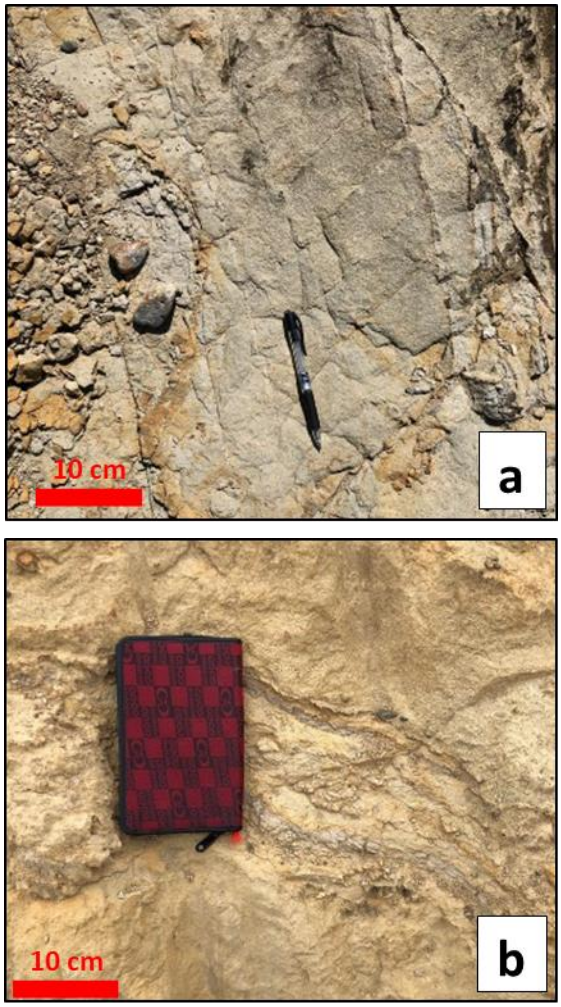


Figure 4. Cross Bedding (a); interbedded of sandstone and thin mudstone (b).

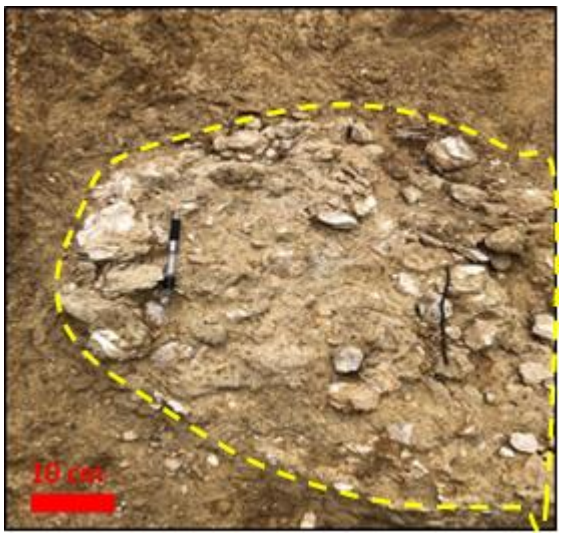


Figure 7. fragment of *Mollusca* are abundantly found locally in Second Outcrop.

Figure 8. Present of Hummocky Cross Stratifications in the second Outcrop.

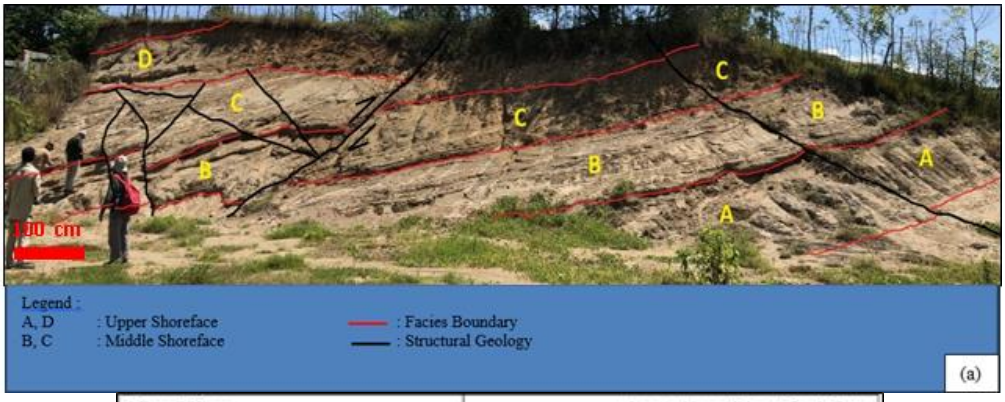
Ophiomorpha which represents the shoreface environment (MacEachern et al., 2012). The vertical shape is the dominant form of the burrow that present in both part and lateral form not much appears in these deposits. The individual beds are separated by marked erosional surfaces which occurred in the lower part and upper part.

Tidal influences clearly happen in these deposits. This is proven by interbedded sandstone and thin mudstone dominantly appear in the lower part. Calcite veins are also abundantly found in almost all parts of these facies.

Another outcrop (STA 2) which is close to the STA 1 shows the fragment of *Mollusca* are abundantly found locally with incomplete forms. Present of Ophiomorpha is abundant almost in all parts in the second outcrop.

Hummocky Cross Stratification (HCS) also present in the facies. The HCS cannot be found in full appearance, only part of the structure's form can be interpreted. The full form of HCS looks like onion skins which tapered at both ends on those lithologies, the structure partially visible only. Not easy to find HCS on beds, therefore limited distribution.

Bioturbation appearance is abundant in the second site. The kind of bioturbation that is founded on a bed is Ophiomorpha which represents the shoreface environment (MacEachern et al., 2012). A vertical burrow is obviously observed in this site.



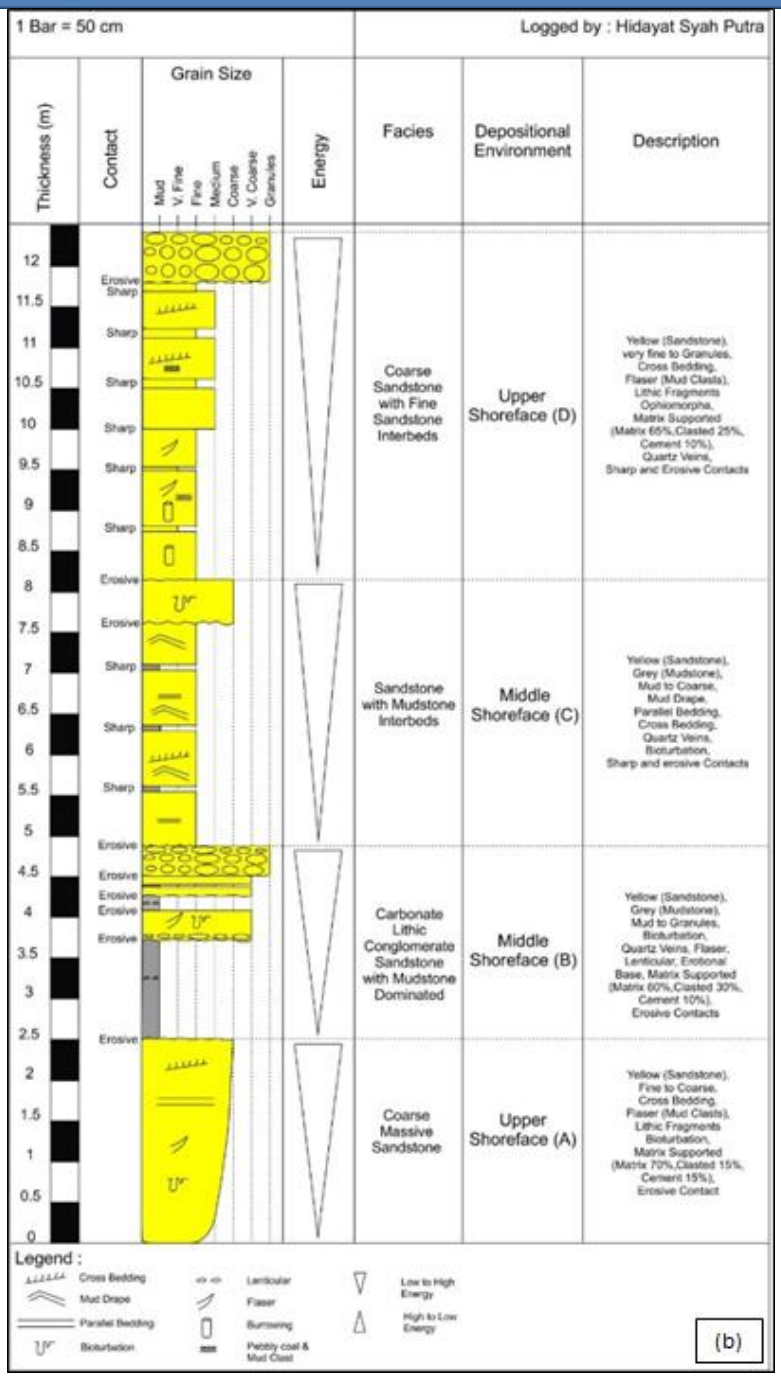


Figure 5. First Outcrop in STA 1 (a). Geological profile of Seulimum Formation presents shoreface deposits (b).

Figure 6. The STA 2 as a second stop site's view showed an outcrop of Seulimum Formation controlled by a reverse fault.

Figure 9. Very clear Ophiomorpha which abundant at STA 2.

The conglomerate with lithic fragment matrix and mud clast also present in the facies. Coal fragments also present close to mud clast. The conglomerate developed in a moderate textural maturity under silica cement and well-rounded fragments. The mud clast founded abundant in high textural maturity and consider a wave-dominated environments (Shun Li et al., 2017).

Structural Geology

The structural geology features are found as joints in a cross-cutting relationship, slickensides, and keybed fault in the right corner of the Seulimum Formation. The STA 1 and STA 2 that are relatively close provide two minor faults with NW-SE and NE-SW directions. The first fault gives an average rake/dip of 46º/52º and the second fault with a rake/dip of 47º/50º. According to translational fault movements analysis, classify these two faults into right reverse slip fault (Rickard, 1972).

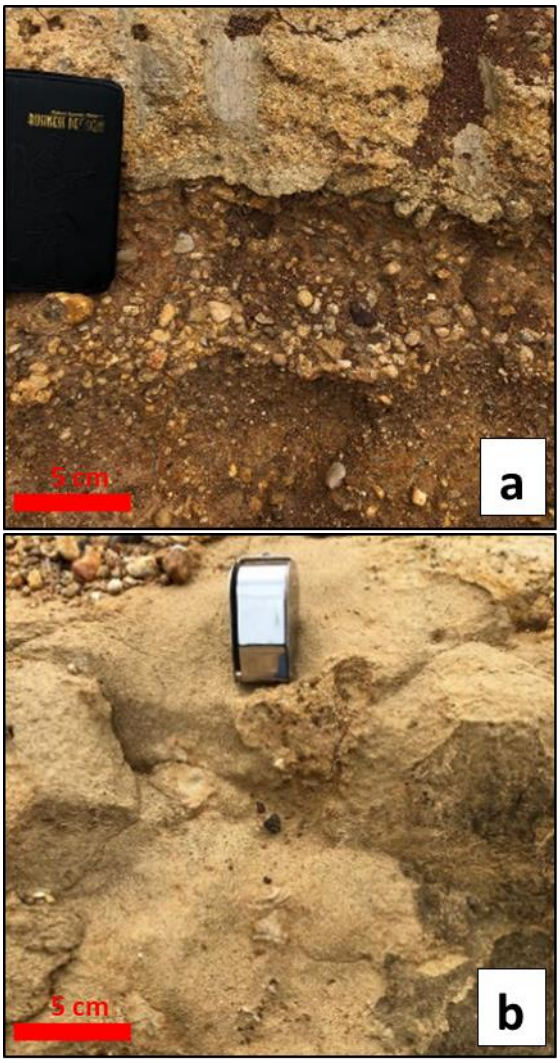


Figure 10. Lithic fragments matrix-supported conglomerate (a); Mud Clast and coal fragment (b).

The tectonic features of the study area controlled by two active major segments influenced intensely even in sedimentary deposits. The probability of other faults' presence relatively moderate but not observable because they are covered by the deep sediments

supply from Seulawah high and the surrounded areas that fill the Banda Aceh Basin.

DISCUSSION ~~CONCLUSION~~

Based on characteristics of facies, the lithology in studied area is product of shallow marine deposits. Presence of bioturbation, burrow, and conglomerate in the facies is the evidence of high wave energy process involved. Moreover, sandstone interbedded with thin mudstone suggest that there was a tidal influence in wave dominated shoreface environment. Almost all sandstone and mudstone bedding reacted to Hydro Chloric Acid (HCL) indicated the lithologies deposited in the marine environment. Traction currents such as cross-bedding and normal grading suggest that the facies are deposited underwater. Calcite veins that appear abundant in Outcrops suggest that there were tectonic activities after the deposition of these facies.

Reservoir Implication

Some of the more porous and permeable sandstone reservoirs are deposited in the coastal inter-deltaic realm of sedimentation. They consist of well-sorted shoreface sands associated with barrier islands and tidal channels with occur between barriers (Rufus, 1972).

Shoreface sands on wave-dominated coasts generally have excellent reservoir potential. Sands are clean and homogeneous viewed at a second outcrop with significant thickness. Sand bodies are laterally continuous and were orientated parallel to the shoreline. Visually, the outcrops especially the second outcrop have good porosity with homogeneous grain size relatively.

CONCLUSION

The characterization of shoreface deposits of Seulimum Formation can be concluded that the study area divided into two types enviromental deposits, they are: middle shoreface deposits and upper shoreface deposits. The rock properties also showed the excellent porosity to be a good reservoir in intra arc basin of Sumatera.

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