



Sedimentation Dynamics of Senoni Village, Sebulu Sub-District, Kutai Kartanegara District, East Kalimantan Province

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Abstract. The research area is in Senoni Village, Sebulu District, Kutai Kartanegara Regency, East Kalimantan Province. It is included in the Kutai Basin in the Pamaluan Formation and Balang Island Formation. Sedimentation dynamics analysis was conducted to illustrate how the stratigraphic conditions in this research area will facilitate further geological studies and plans for the development of the geological potential of the Senoni Village area and its surroundings, especially in the Pamaluan Formation and Balang Island Formation in the Kutai Basin. The method used in this study was carried out by taking lithological data on the surface as outcrops or outcrops in the field with an area of approximately 16 km². Lithological data taken in the form of lithological description data from several outcrops found in the research area will then be further analyzed in the research area. Based on the research results, seven types of facies form six facies' associations deposited in the depositional environment of a shelf, Pro-delta, delta front and lower delta plain. Based on the analysis of sedimentation dynamics, namely the stratigraphic sequence, two parasequence sets were gradually deposited. The first is in the Transgressive System Tract (TST) phase with a sediment pattern that smoothes upwards or retrogradation, which above it is bounded by the Maximum Flooding Surface (MFS) interpreted as the formation of crystalline limestone in the study area. The second is the Highstand System Tract (HST) phase, which has a sediment pattern that coarsens upwards or progradates.

Keywords: Geological Potential, Sedimentation Dynamics, Stratigraphy.

1 Introduction

Mineral and energy resources, such as oil and gas, are always in demand, and their use must be managed effectively and economically. In addition to oil and gas, Indonesia has many alternative natural resources, including coal. More than 14 km of sedimentary material has accumulated in the Kutai Basin since the Oligocene.

Kutai Basin is the largest East Kalimantan basin with significant oil and gas resources. The potential for oil and gas content in the Kutai Basin is very possible. This basin is supported by aspects of the petroleum system that are very supportive of the

accumulation of potential oil and gas in this area, especially in the research area's Pama-luan Formation and Balang Island Formation. This condition makes the location to be researched on its geology, especially on the science of stratigraphy related to the poten-tial of natural resources.

Sedimentation is the carrying of material from erosion and weathering by water, wind or glaciers to an area which is then deposited. All rocks from weathering and erosion deposited over time will become sedimentary rocks. The sedimentation process results in one place being different from another. In the context of the relationship with the river, the sedimentation process itself includes narrowing, erosion, sediment transport, deposition, and compaction of the sediment itself.

A depositional environment is a part of the Earth's surface that can physically, chemi-cally, or biologically differ from other places. Facies indicate their depositional envi-ronments, their relationships, and the processes and outcomes that occur. Therefore, this research is to illustrate how the stratigraphic conditions in this research area will facilitate further geological studies and plans for the development of the geological po-tential of the Senoni Village area and its surroundings, especially in the Pamaluan For-mation and Balang Island Formation in the Kutai Basin.

2 Material and Methods

The research methodology used in this study includes research location, research stages, and data processing and analysis methods.

2.1 Research Location

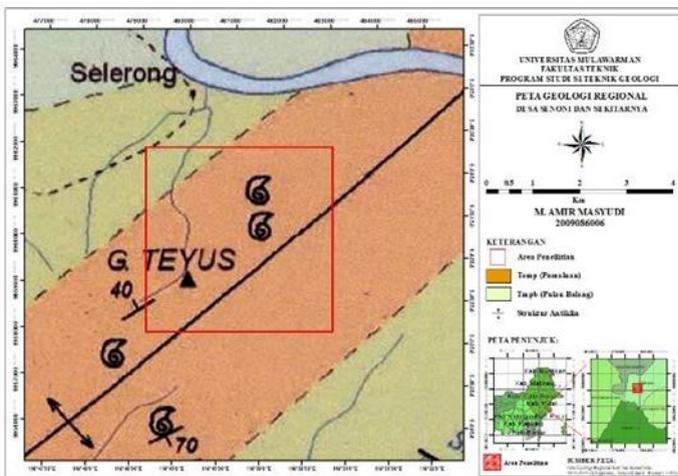


Fig. 1. Regional Geologic Map Section of the Senoni Area [3]

The study site is in East Kalimantan and belongs to the Kutai Basin. The Kutai Basin occupies the mainland area of Kalimantan Island, with a small part occupying the wa-ters of the Makassar Strait and has a depth of up to 14 km with a basin area of up to ±

60,000 km² [1]. The basin is bounded north by the Mangkalihah Plateau, south by the Adang Fault, west by the Kuching Plateau and east by the Makassar Strait [2]. Based on the Samarinda Sheet Regional Geology, the study area consists of two formations, namely the Pamaluan Formation and the Balang Island Formation, the age of the Pamaluan Formation being older than the Balang Island Formation. From the plotting results of the research location against the Samarinda Sheet Regional Geology. The research location plot is represented with a red square symbol in Fig. 1.

2.2 Research Stages

In the research stage, several things must be done to get good, correct, and accurate data. The stages of this research are divided into two stages, namely, the preparation stage and the data collection stage.

2.3 Data Processing and Analysis Methods

After the primary and secondary data collection stage, initial information on the condition of the research area was obtained. With primary and secondary data that have been prepared, the following method can be carried out: data processing and analysis in the studio. A literature study and discussions with the supervisor support this stage. The data processing and analysis method is divided into the geological condition analysis stage, stratigraphic analysis stage, facies and depositional environment analysis stage, and sedimentation dynamics analysis stage.

3 Results

This study investigates a Delta that has a dominant fluvial and tidal mixture, namely the Mahakam Delta. After interpretation of the depositional environment that formed the rocks at the study site, the depositional pattern, or stacking pattern, can be identified to identify the tract system so that its stratigraphic sequence can be analyzed.

3.1 Facies of the Study

The facies classification divides the facies into facies codes, each with a different sedimentary structure, so the processes that formed the facies can be identified.

Table 1. Facies at the Study Site.

Facies Code	Litofacies	Sedimentary Structure
Sm	Very fine to very coarse sand	Massive
St	Very fine to very coarse sand	Trough cross beds
Sh	Very fine to very coarse sand	Bedding, Laminated, Flasher
Fsm	Silt, clay	Massive
Fl	Silt, clay	Bedding, Laminated, Lenticular

Facies Code	Litofacies	Sedimentary Structure
C	Coal, Shaly Coal	Weaning
Cr	Crystalline	Crystalline

1. Massive Sandstone Facies (Sm)

Massive sandstone facies (Sm) were found at STA 2, STA 6, STA 8, STA 9, STA 11, STA 12, STA 16, STA 17, STA 18 and STA 19.



Fig. 2. Massive Sandstone Lithofacies (Sm)

2. Sandstone Facies Trough Cross Beds (St)

Trough cross-beds sandstone facies (St) found at STA 6.



Fig. 3. Lithofacies Sandstone with Through Cross-beds (St)

These facies are fine to coarse sand-sized lithofacies with trough cross-beds sedimentary structure. These lithofacies originate from migration by small current ripple, which produces small-scale cross-bed assemblages, or by migration of large-scale trough-shaped dunes. Trough crossbedding formed by the migration of large-scale ripple generally ranges from a few tens of centimetres in thickness and less than 1 m to more than 4 m in width.

3. Bedding, Lamination, & Flasher Sandstone Facies (Sh)

Bedding, Lamination & Flasher (Sh) Sandstone facies found at STA 1, STA 3, STA 4, STA 5, STA 9, STA 10, STA 11, STA 12, STA 13, STA 15, STA 17, STA 19 and STA 20.



Fig. 4. Sandstone Lithofacies Bedding (left), Lamination (mid) & Flasher (right) (Sh)

Bedding is a characteristic of sedimentary rocks. Layers are defined as strata thicker than 1 cm with thicknesses less than 1 cm called laminae. Most beds have been formed very quickly by a single event, such as a flood that lasted only a few hours or days. Flasher beds are bidirectional sediment bed patterns created when sediments are exposed to intermittent flow, which causes alternating layers of sand and mud. Although flasher beds usually form in tidal environments, they can (rarely) form under fluvial conditions at bar points, in ephemeral streams, or deep water environments when seasonal bottom currents reshape turbidite sediments.

4. Facies of Massive Claystone-Siltstone (Fsm)

Facies of massive mudstone - mudstone (Fsm) found at STA 6, STA 8, STA 9, STA 11 and STA 12.



Fig. 5. Lithofacies of Massive Mudstone - Siltstone (Fsm)

This facies is a clay-silt sized lithofacies with massive sedimentary structures. The term massive beds describes beds that exhibit uniformity and are poor in internal structure. It is assumed that these gigantic, minimally stratified layers are the main features that

occur without radial transport and result from the rapid deposition of suspended material or highly concentrated sediment dispersions during sediment gravity flow.

5. Bedding, Lamination, & Lenticular Limestone – Siltstone Facies (F1)

Bedding, Lamination & Lenticular (F1) facies found at STA 2, STA 8, STA 11 and STA 20.



Fig. 6. Lithofacies of Limestone - Siltstone (left) Bedding, (mid) Lamination & (right) Lenticular (F1).

This facies is a clay-silt lithofacies with a massive sedimentary structure. Bedding is a characteristic of sedimentary rocks. Layers are defined as strata thicker than 1 cm with thicknesses less than 1 cm called laminae. Even faster deposition may only occur in a few seconds or minutes in some specific environments. Lenticulars are structures formed by interbedding mud and ripple cross-laminated sand where the ripple or sand lens is not continuous and isolated in both vertical and horizontal directions. Although usually formed in tidal environments, these layers can (rarely) form under fluvial conditions at bar points, in ephemeral streams, or in deep water environments when seasonal bottom currents reshape turbidite sediments.

6. Shaly Coal Facies (C)

Shaly Coal (C) facies found at STA 1.



Fig. 7. Shaly Coal Lithofacies (C)

The Facies is a blackish-grey colour with a shale structure. Shaly coal rocks are coal rocks that have a small shale content. These facies only form in basins with large organic accumulations and minimal disturbance, known as swamps/peat.

7. Crystalline Facies (Cr)

Crystalline (Cr) facies were found at STA 7 and STA 14.



Fig. 8. Crystalline Lithofacies (Cr)

These facies are lithofacies with a crystalline sedimentary structure. Depositional processes do not form crystalline facies limestones but result from the recrystallization of clastic, aphanitic, and reef limestones. This recrystallization process is a neomorphic diagenesis process. Initially, this limestone underwent dolomitization diagenesis with its diagenesis environment in the mixing zone. The ongoing tectonic process caused this limestone to be uplifted and underwent a crystal coarsening process (neomorphism).

3.2 Facies Association of The Study Area

Since there is too little information on facies to know the depositional environment, the facies developed at the study site must be grouped and known as facies associations. The facies association determines the depositional environment formed at the study site. The facies at the study site are divided into six (6) facies associations that indicate three (3) deltaic depositional environments.

Table 2. Facies Association at The Study Site

Facies Code	Facies Association	Interpretation of Deposition Environment
Sm, Sh, Fl	Tidal Crevasse Splay	Lower Delta Plain
Sh, C	Tidal Swamp	Lower Delta Plain
Sh	Distributary Mouthbar	Delta Front

Facies Code	Facies Association	Interpretation of Deposition Environment
Sm, St,Fsm, Fl	Distal Bar	Delta Front
Sm, Sh,Fsm, Fl	Pro-delta Mud	Pro-delta
Cr	Reef Facies	Crystalline

1. Tidal Crevasse Splay Facies Association

The associated facies make the Tidal Crevasse Splay facies association Sm, Sh and Fl. Crevasse splay is a sedimentary fluvial deposit that forms when a river breaks its natural or artificial level and deposits sediment on the floodplain. The cracks that form the crevasse splay deposit sediments in a pattern similar to alluvial fan deposits, which are areas of tidal and backflow. In this facies association, it can be interpreted that the depositional environment is the lower delta plain.

2. Tidal Swamp Facies Association

The associated facies make the Tidal Swamp facies association Sh and C. Freshwater tidal swamps occur in estuaries where freshwater from rivers meets the ocean tides. By definition, swamps are frequently or continuously inundated and are characterized by soft-stemmed vegetation. Although tides dominate the rise and fall of water in freshwater tidal marshes, the wetlands are not saline. In this facies association, it can be interpreted that the depositional environment is the lower delta plain.

3. Mouth bar Distributary Facies Association

The associated facies make the Distributary Mouthbar facies association Sh. It has the highest velocity in the deltaic depositional system. The sediments are generally composed of sand deposited through fluvial processes and are the place of accumulation of sediments transported by the distributary channel. Fine-sized sediments will be deposited between the mouth bars. The continuous sediment supply will cause the deposition of mouth bars towards the sea. In this facies association, it can be interpreted that the depositional environment is the Delta Front.

4. Distal Bar Facies Association

The associated facies make the Distal Bar facies association Sm, St, Fsm, Fl. Distal Bar has a facies sequence that tends to smooth upwards. Generally composed of fine sand with laminated sedimentary structure, trough cross-stratification, and burrowing structure. In this environment, fossils are rarely found. In this facies association, it can be interpreted that the depositional environment is in the Delta Front.

5. Pro-delta Mud Facies Association

The associated facies make the Pro-delta Mud facies association Sm, Sh, Fsm, Fl. Pro-delta is part of the sub-delta transition between delta front deposits and the outer marine shelf of the delta front. In the Pro-delta sediment system, there is a change in the

lithology of sandstone bars towards claystone deposits characterized by a clay zone. Changes occur in the distal part of the sub-delta accumulation of silt and clay dominantly coarsening upwards, indicating the transition of the nature of the dominant pro-delta clay facies compared to the sandstone facies of the delta front. The dominant pro delta lithology characterizes the marine sedimentary deposits. Deposition of very fine sedimentary material deposited from suspension currents. In this facies association, it can be interpreted that the depositional environment is in Pro-delta.

6. Reef Facies Association

The associated facies make the Reef Facies facies association Cr. Crystalline limestone is a rock that is formed in situ, meaning that this rock is formed without experiencing transportation, where it is formed in shallow seas or on the coastal fringe. These rocks are formed from calcite skeletons that undergo a process of deposition and lithification glued together by silt or clay so that the rocks give the impression that they are composed of crystals. In this facies association, it can be interpreted that the depositional environment is on the Shelf. In determining the depositional environment, which will then be slightly modified to adjust the conditions of the field data of the research site. In the 3D model of the depositional environment created, there are 5 (five) kinds of depositional environments, namely Upper Delta Plain, Lower Delta Plain, Delta Front, Prodelta and Shelf, each of which will be further divided into several facies associations according to the condition of field data in the research area. Among them are 6 (six) facies associations: Tidal Crevasse Splay, Tidal Swamp, Distributary Mouth bar, Distal Bar, Prodelta Mud and Reef Facies. Fig. 9. shows its parts with arrow lines and dotted lines.

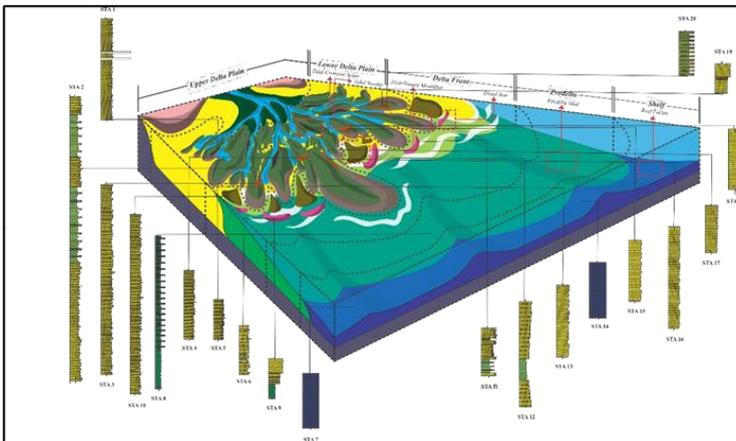


Fig. 9. 3D Model of the Depositional Environment of the Study Area

3.3 Analysis of Sedimentation Dynamics of the Study Area

In analyzing the study area's sedimentation dynamics, 20 outcrop surface data or outcrop track lines were obtained. Then, a measured stratigraphic cross-section column

will be made from the data (Measuring Section). Then, from the 20 MS data, two composite log lines will be made again, adjusting from the dip direction or the oldest layer to the youngest layer because, in the research area, there is a geological structure in the form of anticline folds, this causes two lines to be made on the composite log.

Log composite line A is a combination of stratigraphic cross section STA 1 - STA 10 with the order of log composite from STA 10 to STA 1 at the research location, which is in the middle to Southeast, from the youngest layer extending to the Southeast from the northwest along 898.43 meters.

Log composite line B is a combination of stratigraphic cross sections STA 11 - STA 20 at the research location, which is in the middle to the northwest, from the youngest layer extending to the northwest from the Southeast along 566.5 meters.

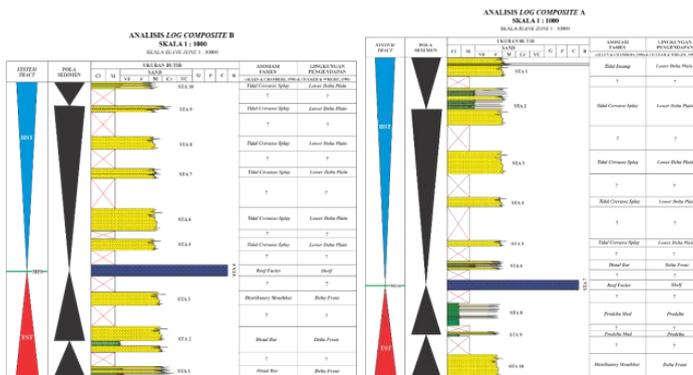


Fig. 10. Log Composite Analysis of Path A & B

Based on the results of the stratigraphic sequence analysis, It can be seen that in the composite B log line, there are two types of system tract, namely the Transgressive System Tract (TST) characterized by a retrogradation or smooth upward depositional pattern in the first parasequence bounded by the Key Surface (KS) in the form of the Maximum Flooding Surface (MFS) which is interpreted from the formation of crystalline facies or crystalline limestone and afterwards the deposition phase begins with a system tract in the form of the Highstand System Tract (HST) characterized by a progradation or coarsening upward depositional pattern in the second parasequence.

4 Discussion

The limestone facies in the research area cannot be interpreted as a reservoir rock or source rock saying that the potential parent rock in the research area comes from coal and carbonaceous mudstone [4]. In the Kutai Basin, two types of sandstone facies are recognized in Miocene delta deposits: fluvial dominated to distributary channel and

tidally dominated delta front deposits. The sandstones included in the reservoir characteristics generally belong to lithic arenite with textural properties of grains supported by matrix, fine to medium size grains, medium to good sorting, and medium hardness. The rock composition is predominantly sandstone with monocrystalline quartz, polycrystalline quartz, andesite and quartzose rock fragments, and very little K-feldspar plagioclase.



Fig. 11. Sandstone Facies of STA 10 (left) & Sandstone facies of STA 13 (right)

Fig. 11. is an interpretation of facies that have the potential for reservoir formation. In the research location, facies are obtained that are close to these characteristics, first at STA 10, which has been described macroscopically, the degree of rounding is rounded, the degree of sorting is well sorted, closed packaging, quartz composition, has no fragments, iron oxide cement, moderate weathering rate, fine sandstone. Secondly, at STA 13, with a macroscopic description of the degree of rounding, the degree of sorting is good, closed packaging, quartz composition, has no fragments, non-calcareous cement, moderate weathering, and fine sandstone. The facies association and depositional environment of the two facies, which are interpreted to be deposited in the distributary mouth bar and delta front depositional environment [4]. This interpretation study is expected to show that the sandstone facies may be a supporting layer for reservoir formation in the Kutai Basin. However, whether this layer can function as the main reservoir to support good hydrocarbon formation is unclear. This study will not succeed well due to the research and supporting limitations. In addition, the study has not conducted an operational research trip nor explored the resource thoroughly because it only examines the surrounding area using surface data, namely with outcrop data.

5 Conclusions

In the analysis of the depositional environment that has been carried out in the research area, there are four (4) types of depositional environments, namely Lower Delta Plain, Delta Front, Prodelta and Shelf, each of which will be subdivided into several facies associations according to the condition of field data in the research area. Among them are six (6) facies associations: Tidal Crevasse Splay, Tidal Swamp, Distributary Mouth

bar, Distal Bar, Prodelta Mud and Reef Facies. There are two types of system tracts, namely the Transgressive System Tract (TST) in the first parasequence, which is bounded by the Key Surface (KS) in the form of the Maximum Flooding Surface (MFS), and afterwards the deposition phase begins with a system tract in the form of the High stand System Tract (HST) in the second parasequence. This interpretation study describes the sandstone facies as a potential reservoir support layer in the Kutai Basin, especially in the Pamaluan Formation and Balang Island Formation.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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