INSOLOGI
INSOLOGI: Jurnal Sains dan Teknologi
https://journal.literasisains.id/index.php/INSOLOGI
ISSN 2828-4984 (Media Online) | ISSN 2828-4992 (Media Cetak)
Vol. 5 No. 1 (Februari 2026) 111-124
DOI: 10.55123/insologi.v5i1.7627
Submitted: 23-12-2025 | Accepted: 11-01-2026 | Published: 10-02-2026

Characteristics of the Viqueque Formation in the Caraubalo Area, Viqueque District, Timor-Leste

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Abstract

This research was conducted in the Cuha River, within the Buanurak area of Caraubalo Village, Viqueque District, Timor-Leste. The study area is geographically located between 08º49'29"S - 08º52'28"S and 126º23'8"E - 126º20'8"E. The objective was to characterize the facies of the Viqueque Formation through field data. The methodology involved measuring a stratigraphic cross-section, with subsequent analysis based on the parameters of the Bouma (1962), Walker (1979), and Mutti concepts. Analysis identified four main lithological units. Facies A1-A3 consist of gray marl, deposited by low-density turbidity currents in a lower fan setting (Td-Te Bouma intervals; F9a Fine Grain Facies). Facies B1-B2 feature interbedded sandstone and marl with parallel lamination, representing deposition in suprafan lobes (CT-2 sequence; F7 Fine Grain Facies). Facies C is characterized by normally graded conglomerates, interpreted as mid-fan channel deposits. Finally, Facies D comprises polymict conglomerates, deposited by high-density turbidity currents in an upper fan setting, corresponding to the CGL-7 facies (F9b) and the Ta Bouma interval.

Keywords: *Viqueque Formation, Facies Analysis, Turbidite Deposits, Submarine Fan Complex, Cuha River Timor-Leste.*

1. INTRODUCTION

The area of Caraubalo Village and its surroundings in Viqueque District, Viqueque Regency is the research area that will be studied stratigraphically under geological conditions. Regionally, one of the formations exposed in the research area is the rock composition of the Viqueque Formation dated Late Miocene to Pleistocene, composed of marl, claystone and sandstone (Audley-Charles, 1968) and the summarized lithofacies, illustrated from the Viqueque Formation found in the Cuha River has a rhythmic succession with characteristics or lithological characteristics of sandstone alternating with normal gradation, mudstone interbedded with conglomerate, and sandstone with laminated structure (Duffy et al., 2017; Duffy, 2012) which are characteristics of depositional products influenced by water media commonly found in deep marine environments as sedimentary rocks (Ghazanfar et al., 2025; Okiemute, 2025), which generally have potential for oil and gas presence (Astuti, 2023).

From a tectonic perspective, Timor Island is located within the active collision zone between the Banda Arc and the Australian Continent, making it one of the most complex orogenic systems in Southeast Asia. This convergent process has triggered intensive deformation, uplift, and rapid changes in basin configuration during the Neogene to Quaternary periods. In this context, the Viqueque Formation is interpreted as syn-orogenic deposits, formed concurrently with regional orogenesis and uplift.

This tectonic interaction has led to significant changes in basin depth, sediment supply, and depositional energy, which are reflected in the facies transition from deep-marine to shallow-marine environments. Therefore, understanding the stratigraphic and facies characteristics of the Viqueque Formation in the Caraubalo area is crucial for reconstructing the relationship between regional tectonic activity and sedimentary responses, as well as contributing to the basin evolution model of Timor Island.

Depositional environment has a general meaning across the entire earth's surface and can be simplified into three (3) classifications, namely: continental depositional environment (Continental), marine depositional environment (Marine) and transitional depositional environment (Oloo & Xie, 2018; Selley, 2000; Shaltami, 2024). To understand the characteristics of sedimentary rocks including depositional environment and determination of depositional characteristics from stratigraphic analysis measurements on each sedimentary rock body object can be interpreted in detail based on analysis of physical, biological and chemical characteristics (Jamaluddin & Rahmawati, 2024; Prasetya & Idarwati, 2025; Putra & Rochmana, 2024). Research studies that need to be investigated are determining the characteristics of sedimentary rocks, on one application of depositional facies characteristics of sedimentary rocks, namely conducting measured stratigraphic measurements (measuring section).

The Caraubalo region serves as a key location within the distribution of the Viqueque Formation on Timor Island. However, detailed studies regarding its stratigraphic characteristics and depositional environmental interpretations remain relatively scarce to date. Previous research has generally addressed the Viqueque Formation on a regional scale, often leaving local facies variations, inter-unit stratigraphic relationships, and outcrop-level depositional dynamics insufficiently defined.

Moreover, uncertainties persist in interpreting the depositional environment, especially concerning the transition from deep-marine to shallow-marine settings, commonly attributed to tectonic uplift. These differing interpretations highlight a research gap in understanding how sedimentary responses to tectonic deformation are specifically recorded in the Caraubalo area. Hence, this study aims to fill this gap through integrated stratigraphic and facies analysis, thereby providing a more comprehensive understanding of the sedimentary evolution of the Viqueque Formation at this location.

The study of facies characteristics in a formation is divided into several more detailed rock units (Andriansyah et al., 2024; Mioumnde et al., 2025). In rocks, deep marine products commonly have erosional surfaces and sea level changes (Astuti, 2022; Castro J. Dos S, 2021; Haig D, 2019). The Viqueque Formation which has the same characteristics as sedimentary rocks with flysch characteristics, is very necessary to conduct studies to determine its rock units in the Research area. The objectives of this research are to determine the characteristics of the Viqueque Formation based on field data records using the measured stratigraphic measurement method, and to determine the lateral and vertical distribution of the Viqueque Formation.

2. RESEARCH METHODOLOGY

This geological study was conducted through several main stages, including field research, laboratory analysis, and data compilation and presentation. The field research phase involved detailed geological mapping using the traverse method across rock outcrops to obtain data on lithology, geological structures, outcrop patterns, layer thickness, and geological environment interpretation. Additionally, measured stratigraphic sections were recorded to gather data on rock layer sequences, thickness, sedimentary structures, texture, fossil content, and inter-layer relationships. Stratigraphic measurements were carried out using traverses perpendicular to the strike of the layers, with dip corrections applied to determine the true thickness.

Sampling was conducted systematically for each representative lithological unit. A total of 12 rock samples were collected for petrographic analysis, including sandstone, marl, and conglomerate samples. Further, 10 fine-grained sediment samples (marl and calcareous claystone) were gathered for micropaleontological analysis, specifically for foraminifera, to determine relative age and depositional environment.

The laboratory research phase encompassed petrographic, micropaleontological, geomorphological, stratigraphic, and structural geological analyses to complement field data. Petrographic analysis involved preparing thin sections of rock samples and examining them under a polarizing microscope to determine mineral composition, texture, structure, and rock classification.

Micropaleontological analysis followed standard preparation procedures, including sample disaggregation, washing using water and a nested sieve set (63 µm and 125 µm mesh), drying, and sorting of foraminiferal fossils under a binocular microscope. Identification of planktonic and benthic foraminifera was based on the standard classification and biostratigraphic zonation proposed by Blow (1969) and Bolli and Saunders (1985).

All analytical data are presented in the form of measured stratigraphic columns, geological maps, geomorphological maps, geological cross-sections, and stratigraphic profiles to support interpretations of facies characteristics and depositional environments. Equipment used in this study included topographic maps, geological compasses, rock hammers, GPS devices, HCl solution, hand lenses, writing instruments, sample bags, and other field gear.

3. RESULTS AND DISCUSSION

3.1 Measured Stratigraphic Analysis

The researcher analyzed microfauna (planktonic and benthic foraminifera) from each facies to determine the age and depositional environment of the Viqueque Formation. Stratigraphic measurements were conducted along two traverse sections: Buanurak (L1, 220 m thick) and Lugatoy (L2, 268 m thick). Facies analysis followed the concepts of the Bouma sequence (1962), Walker (1979), and Mutti (1992) to interpret turbidite deposition.

3.1.1 Facies Characteristics of the Viqueque Formation

Facies analysis of the Viqueque Formation using several previous theoretical references, namely Bouma sequence (1962), Turbidite facies by Walker (1979), Facies Association in deep marine fans also from Walker (1979), as well as Turbidite facies by Mutti (1992). In the facies characteristics analysis, 4 references are used, both clastic and modified to become comparisons and means for interpreting the classification of turbidite facies more comprehensively.

The results of facies characteristics analysis data in this research area revealed 6 lithological facies characteristics that developed in the research area. However, there are several lithological characteristics that developed in the study area, with each characteristic having a different depositional system and also having different distinctive features. The results of the turbidite facies characteristics analysis in the research area are as follows.

Table 1. Results of Facies Characteristics Analysis showing 4 facies characteristics grouped based on lithological characteristics of the Viqueque Formation in the research area.

No.	Measured Path	Unit/Facies	Bouma (1962)	Walker (1979)	Mutti (1992)	Depositional Environment	Flow Mechanism
1	L1 & L2	Unit/Facies A1, A2, A3	Td Te	-	CT-1	F9a	LOWER FAN
2	L1 & L2	Unit/Facies B1, B2	Td Te	-	CT-2	F7	SUPRAFAN LOBES
3	L1 & L2	Facies C	Ta	CGL (6)	F9b	MID FAN	HDT
4	L1 & L2	Facies D	Ta Te	-	CGL	F9b	UPPER FAN

3.1.2 Facies Characteristics Unit Facies A1, A2 and A3; Marl

Unit A, comprising facies A1, A2, and A3, is dominated by white marl to massive marl, distributed across the Buanurak and Lugatoy sections (L1 & L2). Subunit A1 is situated at the lowermost part with a thickness of 25–38 m, followed by Subunit A2 at 11–19 m in the middle section, and Subunit A3 at 13–19 m in the uppermost part. Vertically, these three subunits exhibit a turbidite depositional pattern under low-energy conditions, characterized by massive structure, conchoidal fracture, carbonate clay texture, and dispersed, irregular micritic grains and sparry calcite. As noted by Bouma (1962), these subunits correspond to the Td–Te sequence, indicative of low-density turbidity current deposition in deep marine waters. Walker (1978) classifies this unit within Classical Turbidite-1 (CT-1) on lower fan lobes, while Mutti (1992) categorizes it as Fine Grain Facies (FGF) F9a with a slurry flow mechanism. Thus, Unit A constitutes a lower fan complex characterized by fine-grained lithology and low-density turbidity current deposition.

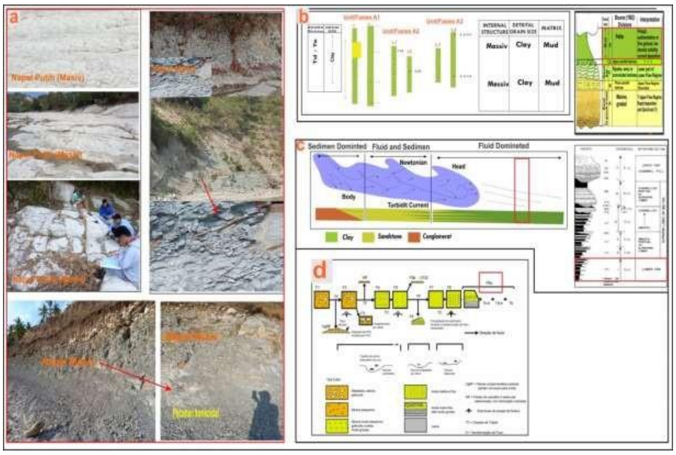


Figure 1. Characteristics & Depositional mechanism of massive packstone marl facies characteristics in the Viqueque Formation at Buanurak Traverse (L1 & L2), Interpretation in the unit/facies A1, unit/facies A2 and unit/facies A3 section, (a) Outcrop Photo, (b) Lithological Characteristics Relationship in Bouma Sequence (1962), (c) Association in Deep Sea Fan (Walker, 1979), (d) Mutti Classification (1992)

3.1.3 Characteristics Unit/Facies B1, B2: (Sandstone and Marl Interbedding)

Unit B, comprising facies B1 and B2, is characterized by alternating sequences of fine to coarse sandstone and marl, featuring internal structures such as parallel lamination and graded bedding, which indicate repeated deposition due to rapid turbidite mechanisms. According to Bouma (1962), this unit corresponds to the Td–Te interval; Walker (1978) classifies it as Classical Turbidite-2 (CT-2) within fine-grained suprafan lobes; while Mutti (1992) categorizes it as Fine Grain Facies (F7) with a fining-upward depositional pattern. Thus, Unit B forms a suprafan lobe complex characterized by vertically repeated deposition of low-density turbidity currents.

3.1.4 Characteristics Unit/facies C: Pebbly Conglomerate

Unit C consists of pebbly conglomerate with graded bedding (fining-upward), composed of mudstone, marl, and pebbly sand fragments within a clay matrix. This unit has a thickness of 7–11 m and exhibits characteristics of rapid autosuspension deposition, with an erosive base. As explained by (1962), Unit C corresponds to the Ta interval. Walker (1978) classifies it as facies CGL-6 within the channeled portion of suprafan lobes (mid-fan). Mutti (1992) categorizes it as F9b, dominated by high-density turbidity currents.

3.1.5 Characteristics Unit/Facies D: Polymictic Conglomerate

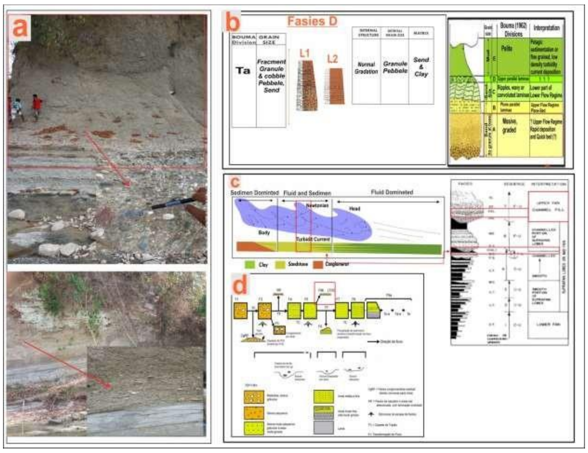


Figure 2. Characteristics & Depositional mechanism of polymictic conglomerate, deposits by normal gradation, in vertical succession showing fining upward in the Viqueque Formation at Buanurak Traverse (L1), Outcrop Photo, (b) Lithological Characteristics Relationship in Bouma Sequence (1962), (c) Association in deep sea fan (Walker, 1979), (d) Mutti Classification (1992)

Unit D consists of polymictic conglomerate with grain sizes ranging from 4–256 mm (pebbles, cobbles, gravel to sand) and a thickness of 14 m. It exhibits normal grading and a fining-upward pattern, indicating autosuspension deposition under high-energy turbidity currents. According to Bouma (1962), this unit corresponds to the Ta interval. Walker (1978) classifies it as Clast Supported Conglomerate (CGL-7) within the upper fan. Meanwhile, Mutti (1992) categorizes it as F9b, characterized by a hyperconcentrated flow mechanism. Thus, Unit D forms an upper fan complex dominated by clast-supported deposition under high-energy flow conditions.

3.2 Sedimentation Dynamics in the Research Area

Based on the characteristic analysis derived from the compilation of measured stratigraphic sections along the Buanurak Traverse (L1) and Lugatoy Traverse (L2) within the Viqueque Formation, the interpretation was conducted through an evaluation of facies characteristics and their subdivisions. Characteristics Unit/Facies A1-A3, Characteristics Unit/facies B1, B2, Characteristics Unit/Facies C and Characteristics D, as well as based on planktonic biozonation analysis results (Table 2) and benthic (Table 3) on certain species (fossils) taken from several locations representing the two columns L1, L2 (shown in Figure 7) and see in Table 2, sedimentation dynamics occurred, namely, experiencing two (2) times of shallowing (regression system) and deepening (transgression), where the researcher uses a compilation of the Walker (1979) model concept approach, starting with marl rock aged N17 (*Globorotalia plesiotumida*) from Characteristics Unit/Facies A1 with depositional environment LOWER FAN (*Laevidentalina inornata "d'orbigny*", *Psammosiphosinella cylindrica*) representing the

Sequence Classical Turbidity - 1 (CT-1) interval, then experiencing shallowing or regression system to Characteristics Unit/Facies B1 having lithology in the form of fine, medium to coarse grained sandstone interbedding, having internal parallel lamination sedimentary structure interbedded with massive marl aged N18 (*Globorotalia tumida*) and depositional environment according to Walker's concept is SUPRAFAN LOBES (*Psammosiphonella* discrete) from the Sequence Classical Turbidity -2 (CT-2) interval and then experiencing continued regression system experiencing sudden shallowing reflected in Characteristics Unit/Facies C where the lithology characteristics are in the form of pebbly conglomerate with graded bedding or normal gradation sedimentary structure, pebbly conglomerate, sandy with imbrication of mudstone fragments, marl, pebbly sand with clay matrix, having carbonate content from the Walker sequence interval Conglomerates-6 (CGL-6), MID FAN environment (*Bathysiphon sp*) representing the end of the first regression system marked by N18 (*Globorotalia tumida*).

After the first regression or shallowing system sequence, then at age N19 (*Sphaeroidinella dehiscens*) experiencing transgression system sequence reflected in Characteristics Unit/facies A2 (Figure 2) having lithology in the form of marl with gray color characteristics, irregular fragment shape consisting of muddy carbonate rocks, occurrence of mud (micrite), allochemic bioclast framework and area distributed irregularly with sparry calcite supported by grains with characteristics indicating deposition in turbulent waters (Grain Support) with calm water energy which is an infiltration characteristic, namely Mudstones with depositional environment of Walker sequence system at Classical Turbidity-2 (CT-2) interval from SUPRAFAN LOBES (Lagena sp). Transgression in this basin ended during the N20 interval, marked by the appearance of the foraminifera *Pluneatina plaecursor* and *Globorotalia hirsuta*. Within this interval, a stratigraphic hiatus is evident, characterized by the absence of continuous sediment records, particularly in column L1, while column L2 only contains the uppermost part of N21 (*Globorotalia acostaensis*). This hiatus does not merely reflect shallowing due to sea-level fluctuations but rather represents a disturbance in sedimentation processes associated with regional tectonic uplift and probable erosion within the deep-marine system of the Viqueque Formation during the Late Neogene. Then experiencing sudden shallowing again reflected in characteristics Unit/Facies D, having lithology characteristics in the form of polymictic conglomerate, having normal gradation structure, grain size 4-256 mm (fragments: pebble, cobble, gravel-sand). Characteristics Unit/Facies D occurred in the UPPER FAN environment at the sequence interval Conglomerates-7 (CGL-7). Then massive marl rock aged at N22-N23 (*Globorotalia hirsuta*) experienced transgression again, reflected in characteristics Unit/Facies A3, having lithology in the form of marl with gray color characteristics, irregular fragment shape consisting of muddy carbonate rocks, occurrence of mud (micrite), bioclast framework and area distributed irregularly with sparry calcite supported by grains with characteristics indicating deposition in turbulent waters (Grain Support) with calm water energy which is an infiltration characteristic, namely Mudstones. Characteristics Unit/Facies A3 has a depositional environment based on the Walker (1979) model in the LOWER FAN section (*Lagena sp, Nodasria filiformis*) representing part of the sequence Classical Turbidity - 1 (CT-1).

3.2.1 Biostratigraphy

Changes in sedimentation dynamics in the rock characteristics composition of the Neogene-aged Viqueque Formation are marked by differences in lithological characteristic variables at each age level showing the role of sedimentation dynamics activities on the observation traverse path of Buanurak Traverse and Lugatoy Traverse in the research area, precisely located at Cuha River. Paleontological analysis results of samples from 2 (two) traverses can identify several age levels. Biozonation marked by index fossils of first appearance and last appearance.

Table 2. Planktonic Foraminiferal Fossils as Biostratigraphy on the observation path of Buanurak traverse (L1) research area

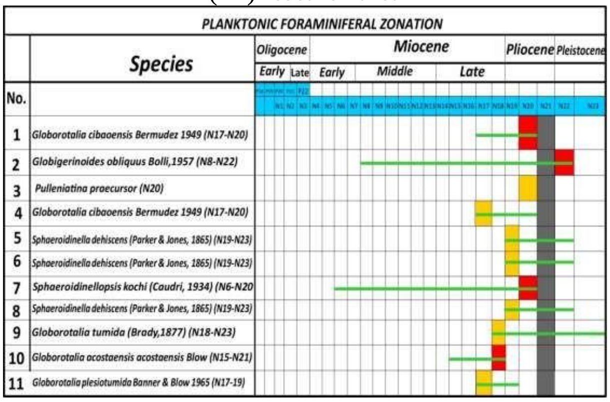
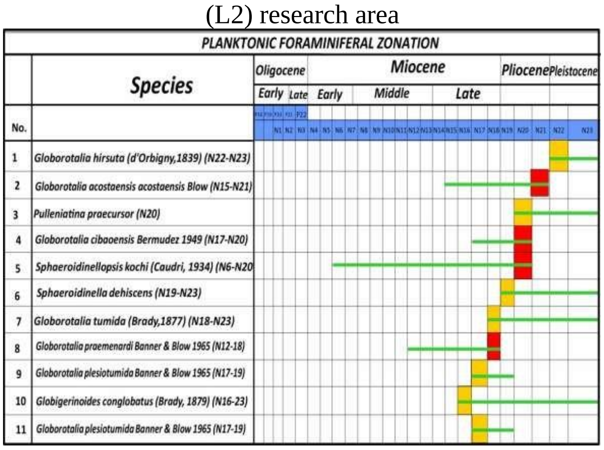


Table 3. Planktonic Foraminiferal Fossils as Biostratigraphy on the observation path of Lugatoy traverse (L2) research area



Investigation from Table 2, Table 3 recognized above, the biostratigraphy of the research area is compiled. Based on biostratigraphic analysis, the Viqueque Formation at the type locality was deposited from N17 (late Miocene) up to N22 (Pleistocene). There is a time gap (depositional hiatus) N20 (L1, Table 2), as well as stratigraphic reconstruction (Figure 3). The gap is also shown by an erosional surface occurring as a time gap.

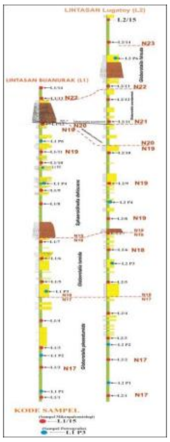


Figure 3. Biostratigraphic section of Buanurak traverse (L1) and Lugatoy (L2) at Cuha River research area

3.2.2 Lithostratigraphy

Based on stratigraphic measurements from the Buanurak (L1) and Lugatoy (L2) traverses, the rock characteristics of the Viqueque Formation can be grouped into main and sub-rock units according to lithological features and bedding patterns. Each unit is separated by either a conformable (conformity) or unconformable (unconformity) boundary in certain sections. In general, the Viqueque Formation is dominated by massive marl rocks interbedded with fine- to coarse-grained, parallel-laminated sandstones, as well as gravelly conglomerates and polymict conglomerates observed in traverses L1 and L2, distinguished by their respective rock associations.

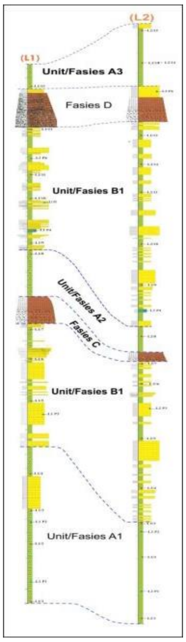


Figure 4. Section grouping Facies Characteristics of Buanurak traverse (L1) and Lugatoy in the research area

3.2.3 Facies/Unit Characteristics A1, A2 and A3: (Marl)

Facies A1, A2, and A3 are units predominantly composed of marl, as detailed in Section 3.1.2. Stratigraphically, these three facies form marl intervals in the lower, middle, and upper parts of the Viqueque Formation, reflecting the repeated deposition of fine-grained turbidite deposits. The dominance of marl lithology indicates depositional processes controlled by low-density turbidity currents under relatively calm hydrodynamic conditions in a deep-marine environment. Variations in thickness and the vertical stacking patterns of facies A1, A2, and A3 reflect changes in sediment supply and accommodation space influenced by submarine fan dynamics, rather than being solely a result of bathymetric depth changes.

3.2.4 Facies/Unit Characteristics B1 and B2: Sandstone Interbedding with Marl

Facies B1 and B2 are composed of interbedded sandstone and marl, as described in Section 3.1.3, and reflect intervals of increased supply of clastic sediment into the deep-marine system. The alternating pattern between sandstone and marl indicates depositional conditions that cycled between traction and suspension processes associated with classic turbidity currents. Stratigraphically, these facies mark a phase of submarine fan progradation, where the rate of sediment supply exceeded the available accommodation space, resulting in lobe deposits within the suprafan zone of the Viqueque Formation submarine fan system.

3.2.5 Facies/Unit Characteristics C: Pebbly Conglomerate

Facies C is a conglomerate unit, as explained in Section 3.1.4, and reflects a significant increase in depositional energy within the submarine fan system. The presence of pebbly conglomerate with normal grading indicates depositional processes controlled by high-energy turbidity currents, likely developing within channel or proximal lobe zones in the mid-fan area. This facies records a shift towards more proximal depositional conditions and marks a phase of increased sediment supply into the basin.

3.2.6 Facies/Unit Characteristics D: Polymictic Conglomerate

Facies D is composed of polymictic conglomerate deposits, as previously outlined, and represents the most proximal depositional conditions within the studied submarine fan system. The presence of fragments with diverse compositions indicates a heterogeneous sediment source and depositional processes controlled by high-density, high-energy turbidity currents. Stratigraphically, this facies marks a strong phase of fan progradation and reflects a high sediment supply into the upper fan zone of the Viqueque Formation.

3.3 Viqueque Formation Characteristics Succession

3.3.1 Vertical Succession

In vertical succession, rock characteristics from the measurement path results of Buanurak Traverse (L1) and Lugatoy on the Viqueque Formation in the research area, according to the reflection of lithostratigraphic characteristics and compared to biostratigraphy, described sequentially vertically that; the lower part shows characteristics (Characteristics Unit/Facies A1), namely N17 marl rock with massive structure as the lower boundary and subsequently in the time period N18 deposited by fine, medium to coarse grained sandstone interbedding. All of this sandstone has internal parallel lamination structure associated with massive marl interbedding representing Characteristics Unit/Facies B1, then overlain by characteristics Unit/Facies C, lithology in the form of conglomerate, having normal gradation structure, texture in grain size 4-64 mm, rounded grain shape, composition having fragments (pebble, cobble), sand-carbonate clay matrix.

Then in the time period N19 deposited by Characteristics Unit/Facies A2, this characteristic has lithology in the form of marl, clay texture, massive sedimentary structure, carbonate composition. Then still in the time period N19 deposited by Characteristics Unit/Facies B2 lower part, lithology in the form of sandstone and marl interbedding and there is one silt layer at the bottom (Characteristics Unit/Facies B2). Sandstone has sand, having fine, medium and coarse grained sandstone texture, good porosity, all internal sedimentary structure is parallel lamination, composition of sand, clay, carbonate, and marl having characteristics of greenish-gray color, massive structure and (Characteristics Unit/Facies B2) upper part is bounded by N20, lithology is still the same as Characteristics Unit/Facies B2 lower part.

Then a time gap occurred on traverse path L1, (Characteristics Unit/Facies B2) directly overlain by Characteristics Unit/Facies D, lithology in the form of polymictic conglomerate, while the observation traverse in this part did not experience a time gap with deposition characteristics continuing to N21, then continuing to be deposited in the time period N22 by Characteristics Unit/Facies D (L2), lithology in the form of polymictic conglomerate, having normal gradation sedimentary structure from various fragments of quartz, black schist, brown schist, basalt, limestone and sand and carbonate clay matrix. And in the time period N22 - N23 deposited Characteristics Unit/Facies A3, lithology in the form of marl, massive structure, concoidal fracture properties, representing the uppermost characteristics boundary.

3.3.2 Lateral Succession

Based on Figure 6 and Figure 7, laterally the Viqueque Formation reflected in the observation traverse path of Buanurak and Lugatoy in the research area reflects that horizontally identified through unit/facies that the researcher has classified based on each characteristic, namely:

a. Unit/facies A1 observation traverse path of Buanurak Traverse (L1) compared with Lugatoy traverse path (L2), this characteristic in the lower part is marked by lithology in the form of white marl and upper part is marked by lithology in the form of massive marl. This marl has the same characteristics, massive sedimentary structure, lateral thickening direction toward the south.
b. Unit/facies B1 observation traverse path of Buanurak Traverse (L1) compared with Lugatoy traverse path (L2) shows bedding pattern representing fine to coarse grained sandstone interbedding with gray massive marl. Laterally, all sandstone associations have internal parallel lamination sedimentary structure, spreading from north toward south (L2) or thickening direction from traverse L1 to L2.
c. Unit/facies observation traverse path of Buanurak Traverse (L1) compared with Lugatoy traverse path (L2), facies characteristics lithology in the form of pebbly conglomerate, having normal gradation sedimentary structure. In vertical succession showing upward fining, thickness on path L1 is thicker compared to traverse path L2 representing lateral succession thinning toward the south (L2).
d. Unit/facies A2 observation traverse path of Buanurak Traverse (L1) compared with Lugatoy traverse path (L2) shows lithology in the form of marl with massive structure, with thinning direction from north (L1) to south (L2).
e. Unit/facies B2 observation traverse path of Buanurak Traverse (L1) compared with Lugatoy traverse path (L2) shows bedding pattern in the form of fine, medium and coarse grained sandstone interbedded with massive marl. Sandstone has internal planar lamination structure. Laterally, the bedding thickening pattern on path L1 is thinner compared to traverse path L2 or the bedding pattern on traverse path L2 is thicker than traverse path L1.
f. Unit/facies D observation traverse path of Buanurak Traverse (L1) compared with Lugatoy traverse path (L2) shows lithology in the form of polymictic conglomerate, having normal gradation structure. In this unit facies characteristics, a time gap occurred specifically on traverse path L1, while laterally on traverse path L2 no time gap occurred.
g. Unit/facies B1 observation traverse path of Buanurak Traverse (L1) compared with Lugatoy traverse path (L2) laterally both show lithology in the form of marl, having massive structure, and visible on path L2 is thicker compared to traverse path L1.

3.4 Lithological Association Characteristics and Relationships

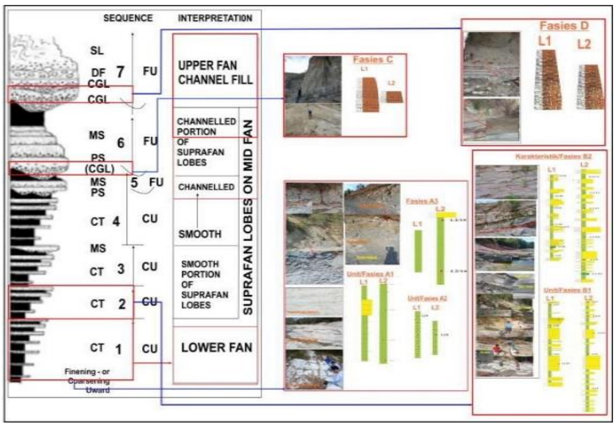


Figure 5. Characteristics and relationships of lithological association of Viqueque Formation turbidite facies in Walker Sequence (1979) in the research area

3.5. Discussion

Provenance analysis is a vital aspect in interpreting deep marine sedimentary systems, as it provides information on sediment source material, tectonic evolution, and the relationship between source areas and depositional basins. In this study, provenance discussion is critical given the discovery of metamorphic rock fragments, specifically schist, within the polymict conglomerate unit of the Viqueque Formation in the Caraubalo area. The presence of schist fragments, observed macroscopically in Unit/Facies D (polymict conglomerate), indicates that the sediment source of the Viqueque Formation is not only derived from reworked sedimentary or carbonate rocks but also involves exposed and eroded basement rocks. Schist fragments are generally associated with low- to medium-grade metamorphic rocks that are widespread on Timor Island, particularly within the Lolotoi Complex and Aileu Formation, known as part of pre-Permian to Paleozoic basement. Regionally, the Lolotoi Complex and Aileu Formation are composed of phyllite, schist, gneiss, and other metamorphic rocks formed by tectono-metamorphic processes before or during the early stages of Timor orogenesis. Intense tectonic uplift during the Late Miocene to Pliocene arc–continent collision phase of the Australia–Banda Arc led to the exposure of these basement units at the surface, making them a source of clastic material for syn-orogenic sedimentary basins, including the Viqueque Formation.

The lithological characteristics of Facies D, dominated by polymictic conglomerate with fragments composed of quartz, black schist, brown schist, basalt, and limestone, provide important information regarding the sediment source (provenance) of the Viqueque Formation. The presence of metamorphic rock fragments such as schist indicates a contribution from exposed and actively eroding basement rocks during deposition. In the Timor region, these metamorphic rocks are regionally associated with the widely exposed Lolotoi Complex and Aileu Formation, which served as the main source of coarse clastic sediment during the Neogene. In addition to metamorphic fragments, the presence of basalt fragments suggests a contribution from mafic igneous rock units, likely derived from ophiolitic complexes or uplifted oceanic crust fragments during tectonic processes. The occurrence of limestone fragments indicates erosion of previously deposited carbonate units, whether from carbonate platform deposits or structurally uplifted deep marine carbonate sequences. This combination of metamorphic, igneous, and carbonate sedimentary fragments reflects a heterogeneous sediment source and active tectonic conditions that allowed the uplift of various rock units from different crustal levels.

In terms of process, the coarse fragment size, polymictic nature, and presence of normal grading structures in Facies D suggest that sediment material was transported by high-density turbidity currents with substantial energy. These currents played a role in transporting coarse material from relatively proximal source areas to deep marine basins. These conditions indicate that during the deposition of Facies D, topographic relief in the source area was well-developed, and the supply of coarse clastic sediment was intensive.

Thus, the provenance of the polymictic conglomerate deposits in Facies D demonstrates a close relationship between the regional tectonic dynamics of Timor Island and the evolution of the Viqueque Formation submarine fan system. Tectonic activity that led to the uplift and erosion of basement rocks played an essential role in enhancing the supply of coarse sediment into the basin, which is subsequently recorded as upper fan deposits within the submarine fan system.

4. CONCLUSION

Based on field data results and discussion from research presented in previous chapters, representing research results from measured stratigraphic measurements to determine the characteristics of the Viqueque Formation, there are four deep marine facies characteristics that developed in the research area.

The first facies include Unit A1, A2 and A3, with lithology in the form of marl, having massive structure with distinctive concoidal fracture properties. The measured stratigraphic observation traverse profile of Traverse L1 and L2 on these facies characteristics were deposited in a submarine fan complex in the lower fan section with fine grained, low density turbidity current depositional. Based on sequence interval, they are located in facies section Td - Te and included in the Fine Grain Facies section F9a.

Unit B1 and Unit B2 facies characteristics have lithology in the form of interbedding between fine to coarse grained sandstone, having internal parallel lamination sedimentary structure, interbedded with marl with massive structure. These characteristics were deposited in the Bouma interval Td - Te and in a submarine fan complex in the suprafan lobes section with fine grained, low density turbidity current depositional, and also included in the Fine Grain Facies section F7.

Unit C has lithology characteristics in the form of pebbly conglomerate, normal gradation structure, texture in grain size 4 - 64 mm, rounded grain shape, poor sorting, composition of fragments including pebble, cobble, sandy, and mudstone imbrication, with sand-carbonate clay matrix. This facies type was deposited in a submarine fan complex in the mid fan section, specifically the channelled portion of suprafan lobes.

Unit D has lithology characteristics in the form of polymictic conglomerate, having physical characteristics of gray, white, and black color, texture in grain size 4 - 64 mm and 64 - 256 mm, rounded grain shape, having normal gradation sedimentary structure, composition of fragments including quartz, black schist, basalt, limestone, and slate, with sand-carbonate clay matrix. This characteristic was deposited in a submarine fan complex in the upper fan section, showing sedimentary structure appearance indicating turbidite current symptoms, namely the Bouma interval Ta, showing that this traverse is included in Clast Supported Conglomerate facies F9b, representing an autosuspension depositional mechanism working in a high flow regime from turbidite currents by hyperconcentrated flow transporting grain-sized to gravel material.

The Viqueque Formation characteristics succession in vertical and lateral succession on the observation traverse path of Buanurak and Lugatoy based on lithostratigraphy and biostratigraphy reflects several time periods. Time period N17 shows characteristics unit facies A1 with lithology in the form of white marl located in the lower part and massive marl in the upper part, deposited in depositional environment lower fan, with lateral thickening succession toward the south, where traverse L2 thickening is thicker than L1.

Time period N18 experienced shallowing or regression system marked by Unit B1 having lithology in the form of sandstone and marl interbedding, deposited in suprafan lobes environment. The shallowing continued with Unit C where the lithology characteristics are in the form of pebbly conglomerate with normal gradation sedimentary structure, with lateral thickening from L1 thinning to L2, meaning the thickness of pebbly conglomerate on path L1 is thicker than path L2, deposited in mid fan environment.

Transgression occurred in time period N19, reflected in Unit A2, having lithology in the form of marl with massive structure, experiencing concoidal fracture. Laterally, there was thinning of this marl lithology thickness from path L1 to L2, where the thickness of section path L1 is thicker. Vertical shallowing continued in time period N20 from Unit B2, with lithology in the form of sandstone and marl interbedding, deposited in depositional environment suprafan lobes. Laterally visible based on biozonation, path L1 experienced time gap absence of time period N21 but still compared to path L2 upper part there is time period N21.

Sudden shallowing was reflected in Unit D, having lithology characteristics in the form of polymictic conglomerate with normal gradation structure and grain size 4 - 256 mm including fragments of pebble, cobble, and gravel-sand. This occurred in the upper fan environment. Massive marl rock aged at N22 - N23 experienced transgression again, reflected in Unit A3, having lithology in the form of marl with massive structure. This unit has a depositional environment based on the Walker model in the lower fan section.

REFERENCES

Andriansyah, R., Syaputra, R., Robbani, N. I., & Tabri, K. N. (2024). Facies and Depositional Environment Analysis of Limestone in Citeureup Area, West Java, Indonesia. *EKSPLORIUM*, *45*(2), 99–110. https://doi.org/10.55981/eksplorium.2024.6953

Astuti, B. S. (2023). *Suksesi Fasies Formasi Rambatan sebagai Respons Sedimentasi dan Tektonik pada Miosen sampai Pliosen di Kali Rambatan, Brebes, Jawa Tengah*. Kandaga Repository.

Astuti B. S. (2022). *Suksesi Fasies Formasi Rambatan Sebagai Respon Sedimentasi Dan Tektonik Pada Miosen Sampai Pliosen Di Kali Rammbatan, Brebes Jawa Tengah*. Disertasi UNPAD, Bandung.

Audley-Charles, M. G. (1968). The Geology of Portuguese Timor. *Geological Society, London, Memoirs*, *4*(1), 4–84. https://doi.org/10.1144/GSL.MEM.1968.004.01.02

Bouma, A. H. (1962). *Sedimentology of Some Flysch Deposits: A Graphic Approach to Facies Interpretation*. Elsevier Publishing Company.

Castro J. Dos S. (2021). *Cartografia Geolólogica Da Área De Caraubalo E Circundantes Do Posto Administrativo De Viqueque, Município De Viqueque. Monografia para obtenção do Grau de Licenciatura de Geociência, UNTL*.

Duffy, B. G. (2012). *The Structural and Geomorphic Development of Active Collisional Orogens, from Single Earthquake to Million Year Timescales, Timor Leste and New Zealand*. University of Canterbury-Department of Geological Sciences. https://doi.org/10.26021/5900

Duffy, B., Kalansky, J., Bassett, K., Harris, R., Quigley, M., van Hinsbergen, D. J. J., Strachan, L. J., & Rosenthal, Y. (2017). Mélange versus forearc contributions to sedimentation and uplift, during rapid denudation of a young Banda forearc-continent collisional belt. *Journal of Asian Earth Sciences*, *138*, 186–210. https://doi.org/10.1016/j.jseaes.2017.02.008

Folk, R. L. (1959). Practical Petrographic Classification of Limestones. *AAPG Bulletin*, *43*. https://doi.org/10.1306/0BDA5C36-16BD-11D7-8645000102C1865D

Ghazanfar, A., Muntaha, M., & Machsus, M. (2025). Alternative Design of Abutment Damage Management for Glendeng Bridge Tuban Regency. *INTERNATIONAL JOURNAL ON ADVANCED TECHNOLOGY, ENGINEERING, AND INFORMATION SYSTEM*, *4*(1), 111–123. https://doi.org/10.55047/ijateis.v4i1.1592

Haig D, W. (2019). *Middle Eocene neritic limestone in the type locality of the volcanic Barique Formation, Timor-Leste: Microfacies, age and tectonostratigraphic affinities. School of Earth and Environment, the 154 University of Western Australia, 35 Stirling Highway, Crawl*.

Jamaluddin, J., & Rahmawati, D. (2024). Analisis Lingkungan Pengendapan dan Karakteristik Material Organik Daerah Air Putih, Kota Samarinda, Indonesia. *Jurnal Geosains Dan Teknologi*, *6*(3), 203–214. https://doi.org/10.14710/jgt.6.3.2023.203-214

Mioumnde, A. P., Zhang, L.-Q., Yan, Y.-M., Twinomujuni, L., Ran, H.-W., Sedziafa, V., Djuka, K. Z., Bessong, M., & Kouame, E. M. (2025). Sedimentary facies architecture and terminal fan systems of the lower Palaeogene Shahejie Formation in Bonan sag, Bohai Bay Basin, China: Implications for hydrocarbon exploration. *Journal of Palaeogeography*, *14*(4), 100268. https://doi.org/10.1016/j.jop.2025.100268

Mutti, E. (1992). *Turbidite Sandstones*. Agip, Istituto di geologia, Università di Parma.

Okiemute, E. A. (2025). Exploring the Functional Potentials of Hydric Soils of Low and Wetlands of Delta State Nigeria. *INTERNATIONAL JOURNAL ON ADVANCED TECHNOLOGY, ENGINEERING, AND INFORMATION SYSTEM*, *4*(1), 174–184. https://doi.org/10.55047/ijateis.v4i1.1688

Oloo, M. A., & Xie, C. (2018). A method to integrate geological knowledge in variogram modeling of facies: a case study of a fluvial deltaic reservoir. *International Journal of Geosciences*, *9*(06), 337–353. https://doi.org/10.4236/ijg.2018.96021

Prasetya, D., & Idarwati, I. (2025). Studi Litofasies dan Lingkungan Pengendapan Berdasarkan Analisis Stratigrafi Daerah Tanjung Baru, Ogan Komering Ulu, Sumatera Selatan. *Jurnal Penelitian Sains*, *27*(2), 1–10. https://doi.org/10.56064/jps.v27i2.1175

Putra, H. K., & Rochmana, Y. Z. (2024). Analisis Stratigrafi dan Sejarah Pengendapan Daerah Batu Ampar, Kabupaten Bengkulu Selatan, Bengkulu. *Jurnal Penelitian Inovatif*, *4*(3), 1515–1526. https://doi.org/10.54082/jupin.547

Selley, R. C. (2000). *Applied sedimentology*. Elsevier.

Shaltami, O. R. (2024). Determine the Depositional Environment of Limestones Using Major Oxide Data–A Review. *International Journal of Research Publication and Reviews*, *5*(5), 11374–11382.

Walker, R. G. (1979). *Facies Models*. Geological Association of Canada.