J E M T
Journal of Earth and Marine Technology
homepage URL: ejurnal.itats.ac.id/jemt

Geological History Reconstruction using Stratigraphic Analysis: A Case Study of Kampung Baru, West Sumatra

Helen Dwi Putri [1], Budhi Setiawan [1], Yogie Zulkurnia Rochmana [1]*

[1] Department of Geological Engineering, Faculty of Engineering, Sriwijaya University; Indralaya Indah, Indralaya, Ogan Ilir Regency, South Sumatra 30862, Indonesia.
*e-mail: yogie.zrochmana@ft.unsri.ac.id (*corresponding author)

Article info

Received:
Jan 20, 2024
Revised:
Feb 20, 2024
Accepted:
Mar 20, 2024
Published:
Mar 31, 2024

Keywords:
Deposition, Formation, Historical Reconstruction, Ombilin Basin, Stratigraphy.

Abstract

The reconstruction of geological history includes the development of rocks and volcanic deposits on a depositional pattern consisting of various types of sedimentary materials accumulated over a long time, which involves depositional changes. Depositional changes require geological comprehension in analyzing and understanding the geological processes involved in their evolution. For this reason, stratigraphic analysis is a very relevant approach to discussing rock layers, including significant environmental changes during their geologic history. The purpose of this research is to find out the geological processes that have contributed to the formation of the earth in the past. The method in this research is a stratigraphic analysis carried out from field observation data carried out directly at the outcrop. Deposition began with the re-deposition of the Pre-Tertiary (Triassic)-aged Porphyry Quartz Dacite Formation. In the Late Oligocene Epoch, the Sawahtambang Formation was deposited, which formed in the braided river characterized by the presence of sedimentary structures in the form of lamination and cross-lamination. In the Early Miocene to Middle Miocene, the transgression process occurred, where the change in deposition was caused by the supply of larger land sediments that caused the deposition of the Ombilin Formation deposited in the marine environment of the Transition-Neritic Edge based on the bathymetry results. The research results are expected to enable geological information to gain in-depth knowledge and experience about the history of deposition and assist in geological modeling.

1. Introduction

Geologic history reconstruction aims to detail the events and processes that have shaped the current topography by involving an understanding of tectonic dynamics, climate change, and geomorphologic activities that occurred in the past [1]. By integrating data from various sources such as fossils and rocks, geological history reconstruction provides a more complete view of the changes that occurred on the earth's surface. Stratigraphic analysis allows to reconstruct the history of geological layers in the study site, by analyzing the physical, chemical, and paleontological properties of rock layers can reveal geological changes in the area and can illustrate how environmental conditions have changed over time.

The research was conducted in the Kampung Baru area in the Ombilin Basin which is geographically an intermontane basin in West Sumatra, based on the formation process the Ombilin Basin is a pull-apart basin and is a graben that stretches from South Solok to the Northwest with an area of about ± 120 km [2]. The Ombilin Basin is one of the intramontane basins or Tertiary basins found in the hill Barisan mountain zone with the island arc system on the island of Sumatra at the edge of the basin bounded by Pre-Tertiary rocks. The Ombilin Basin is the magmatic arc of the Bukit Barisan Mountains, the Sumatran horizontal fault with a northwest-southeast orientation greatly influences the formation process of the Ombilin Basin [3], [4]. The research aims to reconstruct the geological history by using the stratigraphic method to understand the sequence and interpretation of the depositional environment of the rock layers. The stratigraphic method allows to reconstruct geological history by analyzing various aspects such as lithological characteristics, fossils, sedimentation structures, and relationships within each rock layer. Thus, this study aims to build a better comprehension of the geological evolution of an area, including environmental changes, geological events, and processes of rock formation [5].

This research was conducted in the Ombilin Basin using a descriptive approach and depositional model, especially in the Sangkarewang Formation which was identified as a lake environment, with shale rock units contained in the formation. The existence of marine deposition can also be found through the existence of limestone units [6]. However, in this study, the method used is stratigraphic analysis which emphasizes understanding geological history through the stratigraphic order. The use of rock composition parameters from petrographic analysis and the determination of rock age through fossil content in paleontological analysis are the main focus of this research method. This approach enables the acquisition of in-depth geological information, provides a more comprehensive insight into depositional history, and provides a foundation for geological modeling.

2. Methodology

The method used in this research is stratigraphic analysis through field observations directly. This process involves data being collected through field surveys, where rock and stratigraphic identification is done through direct observation. The field survey included observations of lithology and stratigraphic sequence at several locations. Rock samples were collected from different observation sites, and these samples were analyzed in the laboratory using petrographic and paleontological analysis. The laboratory analysis process involved collecting macroscopic and microscopic data. Macroscopic data includes macroscopic descriptions of the rocks, including color, grain size, sedimentary structure, and mineral composition. Microscopic data, on the other hand, involves microscopic description by calculating the mineral content of the thin section, which is then used to name the rock. Laboratory analysis also involves paleontological analysis to determine the age and deposition of rock layers based on fossils found in rock samples. Stratigraphic analysis involves compiling a stratigraphy based on data obtained from field surveys, petrographic analysis, paleontological analysis, and related references to compile sequences of rock layers and reconstruct the geological history.

3. Results and discussions

The stratigraphic analysis in this study is based on the lithology of the rocks found and determined through observation of similar characteristics of each rock [7]. In the research area in the Solok Sheet, three formations were identified based on rock characteristics depicted in the map of the research area [8], [9]. The stratigraphic arrangement in this study was carried out through lithology obtained from field observations and laboratory analysis. Determination of rock age is based on the results of fossil analysis which is then studied with its regional context. The formations found in the research site include the Porphyry Quartz Dacite Intrusion Unit (Qd), the Sawahtambang Formation Unit (Tost), and the Ombilin Formation Unit (Tmo), which are depicted in the stratigraphic column (Figure 1). The geologic history reconstruction model in the study area is focused on one observation location for each formation, based on data that has been measured and observed directly in the field.

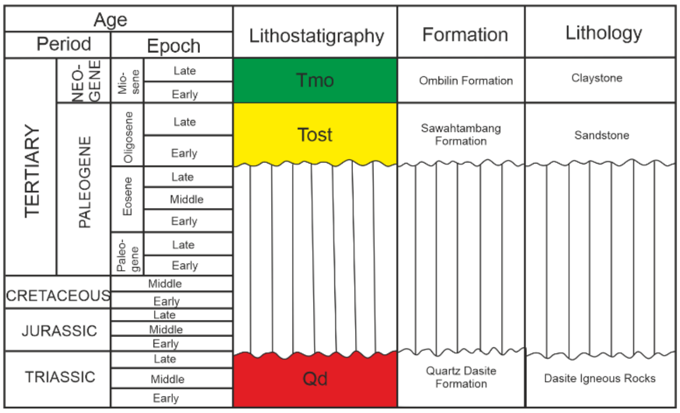
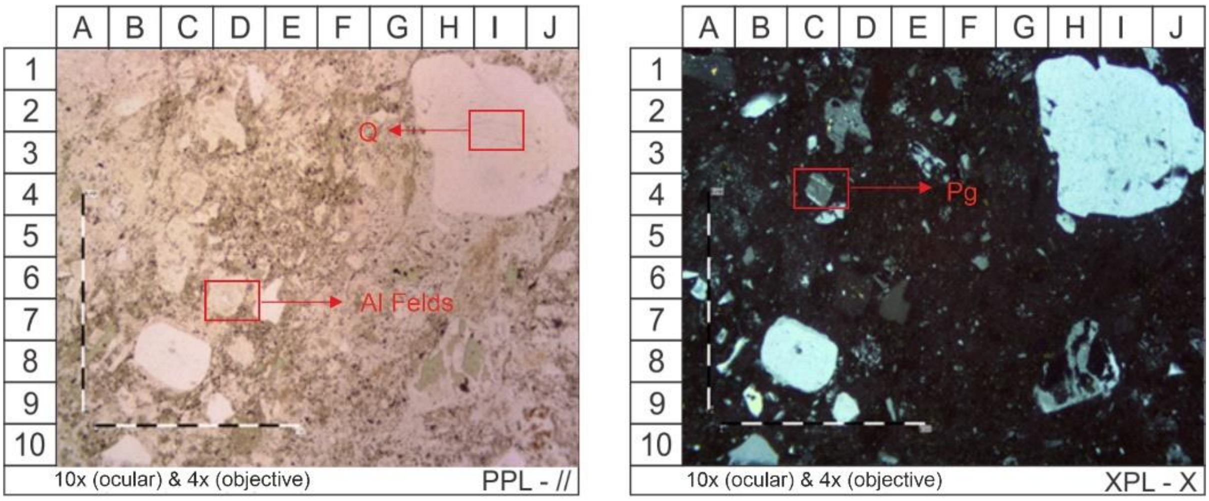


Figure 1. Stratigraphic Column of the Study Area.

Porphyry Quartz Dacite Formation (Qd)

The Quartz Dacite Porphyry Formation is the oldest age formation in the study area and is the pre-tertiary rock underlain by the Ombilin Basin [10], [11]. These rocks are revealed in the western and eastern parts of the basin with dacite rocks having a blackish ash color with a porphyritic texture, the relationship between inequgranular crystals has a subhedral to anhedral shape which can be seen in (Figure 2). Observation of the Porphyry Quartz Dacite Formation with a polarizing microscope has a primary mineral composition in the form of quartz by 20%, plagioclase 60%, alkali-feldspar 8%, and there are alteration minerals in the form of chlorite by 7%, from the results of naming rocks based on the percentage of minerals, the rock name is dacite [12], [13] as found in (Figure 3).

Figure 2. Outcrop of the Porphyry Quartz Dacite Formation.



Description :

Q : Quartz

Al Felds : Alkali Feldspar

Pg : Plagioclase An32

Figure 3. Thin Section View of Rocks of the Porphyry Quartz Dacite Formation.

Sawahtambang Formation (Tost)

The Sawahtambang Formation is characterized by a variety of sedimentary structures such as sandstones, indicating changes in the depositional environment [14]. Complex tectonic activity in the basin, influenced by the Sumatra Fault System, has led to the formation of graben as well as the deposition of fan-delta sediments and coal seams in the formation [10], [15]. The Sawahtambang Formation is a Formation that was deposited out of harmony with the deposition of the previous Formation, with sandstones that dominate having a grayish brown color, fine sand-medium sand grain size, there are also sediments in the form of parallel layers and cross layers that show the deposition of braided rivers [16] which can be seen in (Figure 4) and (Figure 5). Observation of the Sawahtambang

Formation microscopically with a polarizing microscope has a primary mineral composition of primary minerals in the form of plagioclase of 14%, quartz 30%, alkali feldspar 7%, and lithic 18%, from the results of naming the rock based on the percentage of minerals, the rock name is feldspatic wacke [13], [17] as found in (Figure 6).

Figure 4. Outcrops of the Sawahtambang Formation.

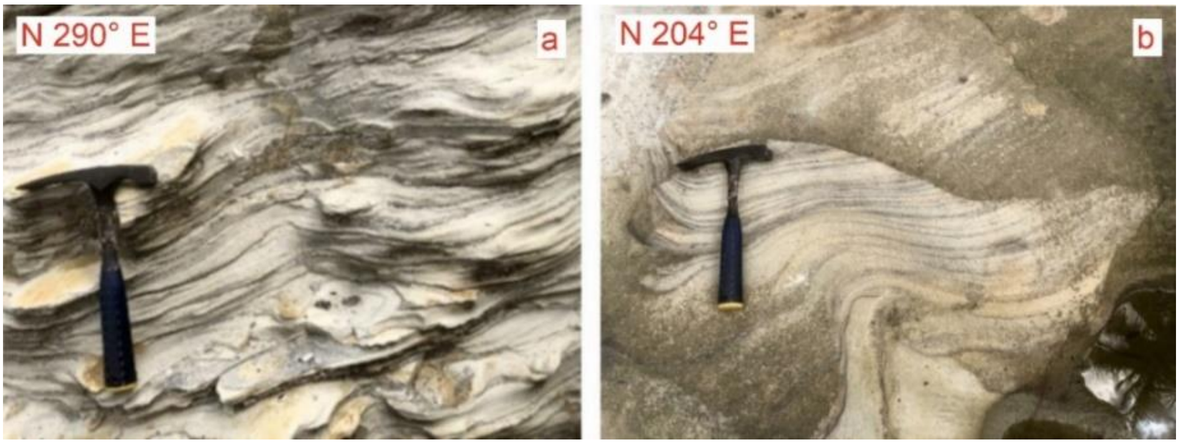
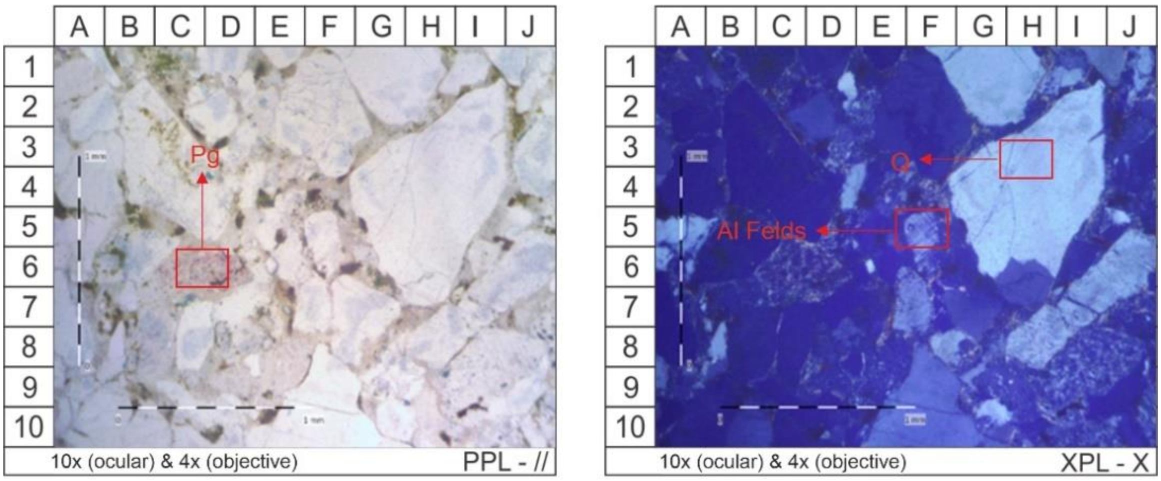


Figure 5. View of Sediment Structure (a) Lamination and (b) Cross Lamination.



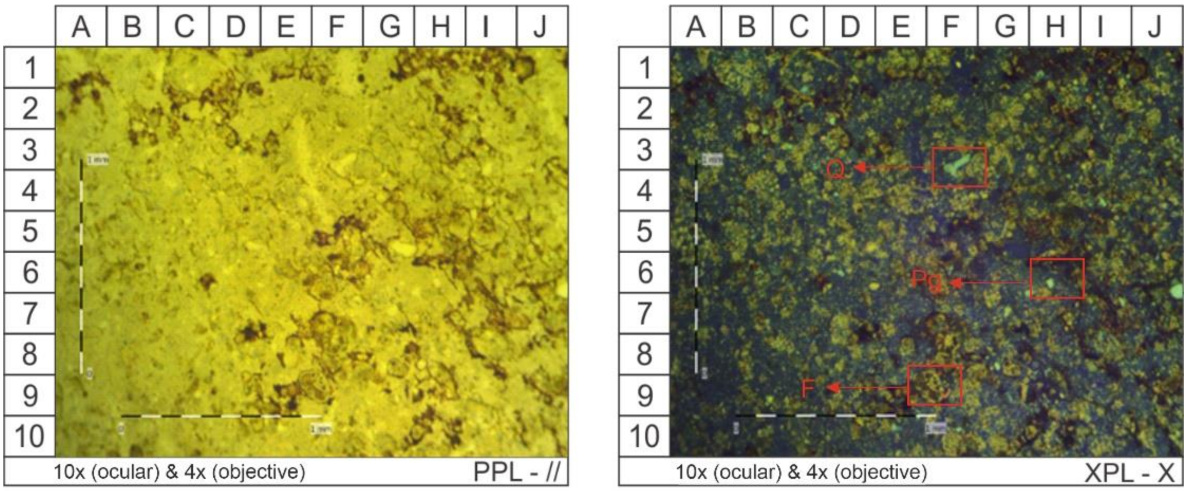
Description :
Q : Quartz
Al Felds : Alkali Feldspar
Pg : Plagioclase

Figure 6. Thin Section View of the Sawahtambang Formation.

Ombilin Formation (Tmo)

The Ombilin Formation is the youngest age formation in the research site which was deposited in harmony with the previous formation having carbonate mudstone with a grayish brown color, clay grain size (<1/256) with well sorted sorting degree as in (Figure 7). Observation of the Ombilin Formation microscopically with a polarizing microscope has a primary mineral composition of primary minerals in the form of plagioclase by 6%, quartz by 10%, and fossils by 25%, from the results of naming rocks based on the percentage of minerals obtained rock names in the form of wackestone [18], [19] as found in (Figure 8). The results of the paleontological analysis found that fossils in the Ombilin Formation have an age range of Middle Miocene range with planktonic foraminifera fossils such as *Orbulina bilobate*, *Globorotalia arceomenardii*, *Orbulina universa*, and *Globorotalia mayer* obtained that the age of deposition in this formation is middle Miocene N9-N11. The age of deposition in this formation is the middle Miocene N9-N11, in the benthonic foraminifera fossils *Epistomaroides polytomelloides*, *Tinoporus spengleri*, *Vertebralina striata*, and *Miliolinella ausralis* which are located in the Transitional to Neritic Edge (Table 1). In the Late Oligocene - Early Miocene there was a transgression mechanism followed by an increase in part of the Ombilin Basin and a decrease in part of the place where the Ombilin Formation was deposited in the marine environment [20], [21]. The change in sedimentation from a riverine environment in the Sawahtambang Formation to a marine environment in the Ombilin Formation has led to a more significant increase in sediment volume known as the Terban [14].

Figure 7. Outcrops of the Ombilin Formation.



Description :
Q : Quartz
F : Fossil
Pg : Plagioclase

Figure 8. Thin Section View of Ombilin Formation.

Table 1. Age and Bathymetric Environment of the Ombilin Formation.

AGE	EOCENE					OLIGOCENE					MIOCENE																		PLIOCENE		PLEISTOCENE / Holocene		
	middle		late			early	middle	late			early					middle						late											
	a		b			c	d	e.1-4			e.5					f.1		f.2		f.3				g			h						
Planktonic Foraminifera	P13	P14	P15	P16	P17	P18	P19	N1/P20	N2/P21	N3/P22	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21	N22	N23			
1 Orbulina bilobata (R)																																	
2 Globorotalia archeomenardii (C)																																	
3 Orbulina universa (R)																																	
4 Globorotalia mayeri (R)																																	
5 Sphaeroidinella subdehiscens (C)																																	

Environmental Batrimetry		Transition	Neritic			Bathial		Abyssal
			Edge	Mid	Outer	Upper	Lower	
Benthonic Foraminifera		0	20	100	200	500	2000	4000
1	*Epistomaroides polytomelloides (R)*	●						
2	*Tinoporus spengleri (C)*		●					
3	*Vertebralina striata (A)*	●						
4	*Oolina apiculata (R)*			●				
5	*Miliolinella ausralis (R)*		●					

The data collected from the research, including macroscopic and microscopic description data, profile measurements, and paleontological analysis, form the basis for preparing historical reconstruction in this research. The reconstruction of geological history includes the formation process of rock formations in the research area, where the determination of the age of rock formations is carried out through the results of the analysis as supporting data in compiling the geological history of this research location.

1. Pre-Tertiary (Triassic) Period

In this era, the first tectonic phase of the formation of a tectonic system with a northwest-southeast direction took place in the early Tertiary [15], [22]. In the western and eastern parts of the Ombilin Basin there are Pre-Tertiary rocks which are rocks that act as the basement of Tertiary deposits, in the northern part of the Ombilin Basin there are igneous rock units which are the result of intrusion undergoing an uplift process into dacite rocks as a basement [23], [24] which can be seen in Figure 9.

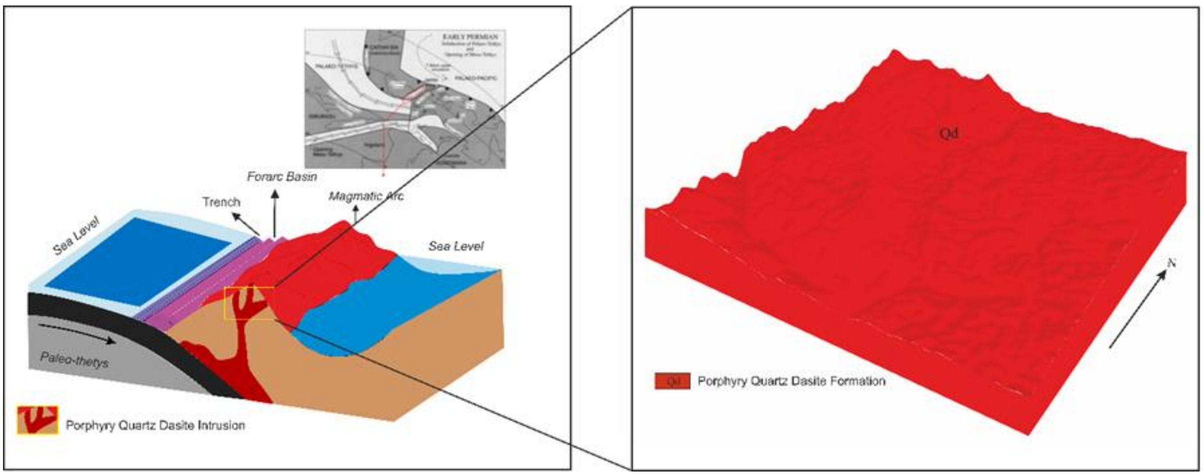


Figure 9. Deposition Process of Porphyry Quartz Dacite Formation as Basement (Molds, 1984).

2. Late Oligocene Epoch

The next geological history deposited the Sawahtambang Formation formed on the braided river which is characterized by a sedimentary environment with medium sandstone characteristics and as evidenced by the sedimentary structure in the form of lamination, and cross-bedding. The process of deposition of rock layers that occurred in the Late Oligocene Period research area occurred nonconformity deposition between the Porphyry Quartz Dacite Formation and the Sawahtambang Formation [3], [25] which can be seen in Figure 10.

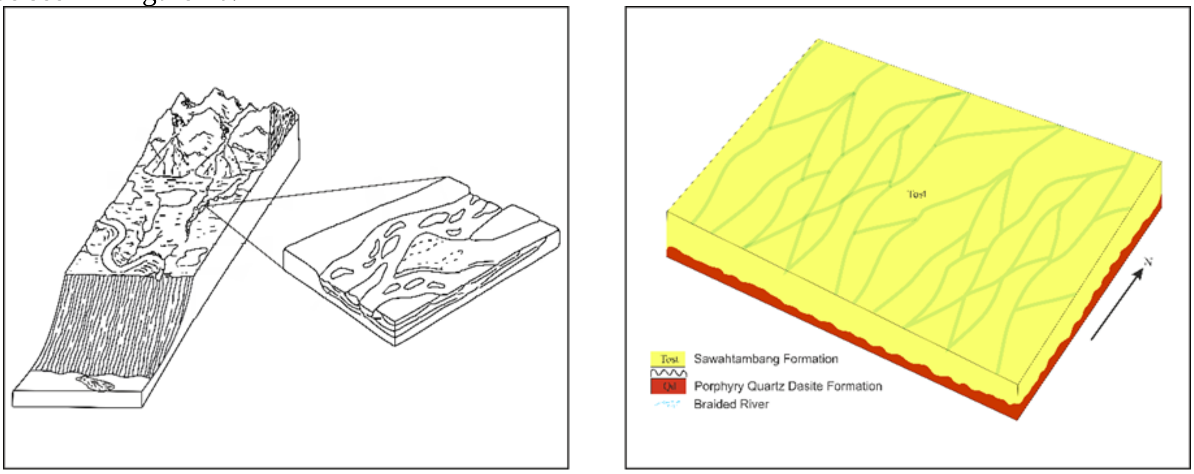


Figure 10. Deposition Process of the Sawahtambang Formation (Modification of Einsele, 1992 & Selley, 1988).

3. Early-Middle Miocene Epoch

In the Miocene, a transgression process occurred when the Ombilin Formation was deposited in conformity with the Sawahtambang Formation, then the Ombilin Formation was deposited on top of it. During the Middle Miocene time (N9-N11), a transgression process occurred where sea level rise occurred [26], which made the deposition process of the next formation in the shallow sea. According to Blow's calcification, rock deposition based on the bathymetry of benthonic foraminifera fossils from rock samples in the Ombilin Formation shows neritic to transitional zonation, where deposition in this formation is Transitional-Neritic Edge [27], [28]. There is also benthonic foraminifera *Oolina apiculata*, which is in the Middle Neritic. This is due to the transgression process, which is the process of seawater rising or falling from the sea surface of the land slowly, which causes one of these benthonic foraminifera to have different depths, as can be seen in Figure 11.

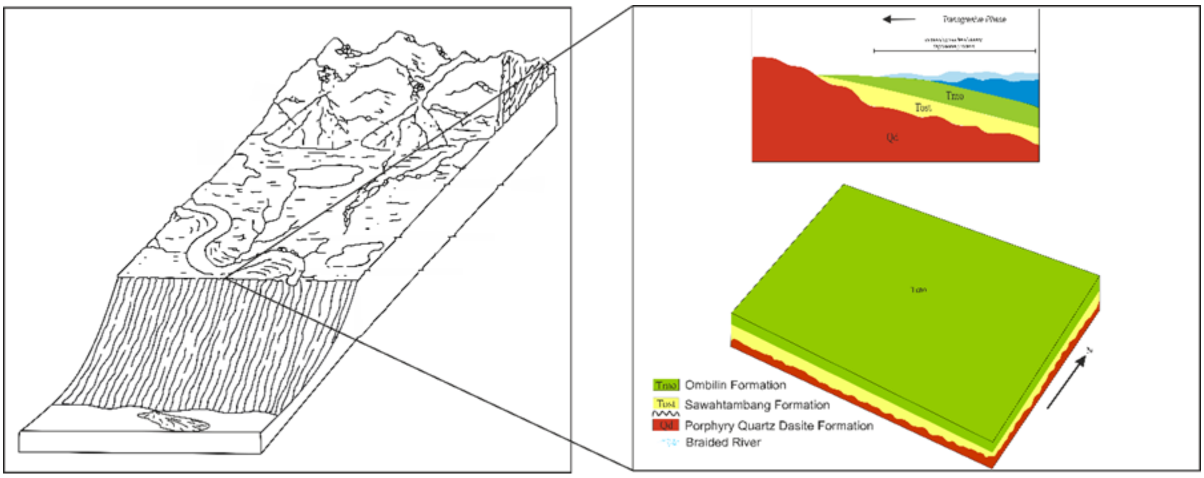


Figure 11. Deposition process of the Ombilin Formation (Selley, 1988).

Based on the results of the stratigraphic analysis carried out, it is known that the rock formations in this study were originally formed in the Pre-Tertiary (Triassic) period. Then, in the Late Oligocene phase, there was the deposition of rock formations with different characteristics. This formation was deposited inconsistently with the previous formation, showing deposition characterized by braided river activity, as evidenced by the presence of laminated and cross-laminated sedimentary structures [29]. Subsequently, there was the deposition of rock formations in a harmonious manner, accompanied by the process of transgression. This transgression process caused a change in deposition, switching from a riverine environment to a marine environment [14]. Compared to earlier research, it can be concluded that the deposition of rock formations in this study shows a more complex environmental variation. In the previous study, deposition was thought to have occurred in a lake to the shallow marine environment, with the presence of slump sediment structures and the presence of freshwater fish fossils interpreted to have formed around the meandering river [6]. This difference highlights the depositional changes that can develop over time and the importance of stratigraphic understanding in reconstructing the geological history of a region.

4. Conclusion

The stratigraphy in the research area is in the order of old to young rocks: the Porphyry Quartz Dacite Formation (Qd) is the oldest formation of the Triassic age; the Sawahtambang Formation (Tost) has a Late Oligocene age; and the Ombilin Formation (Tmo) has an Early-Middle Miocene age. The reconstruction of geological history begins in the Pre-Tertiary period. In this era, the first tectonic phase took place in the early Tertiary, along with the formation of the pull-apart system. Then, in the Late Oligocene, the Sawahtambang Formation was deposited inconsistently with the Porphyry Quartz Dacite Formation, and in the Miocene, there was a transgression process during the deposition of the Ombilin Formation, which was deposited in harmony with the Sawahtambang Formation.

References:

[1] J. B. Hutomo and Y. Firmansyah, "Analisis Stratigrafi Dan Rumusan Sejarah Geologi Daerah Cibodas Dan Sekitarnya, Kecamatan Majalengka, Jawa Barat," *Padjadjaran Geosci. J.*, vol. 4, no. 3, pp. 214–219, 2020.

[2] C. C. Oei, N. N. Ilmi, and E. Sunardi, "Karakteristik Geokimia Batuan Induk Formasi Sangkarewang Dan Sawahtambang, Cekungan Ombilin," *Padjadjaran Geosci. J.*, vol. 4, no. 3, pp. 252–260, 2020.

[3] P. Koesoemadinata, "Stratigraphy and sedimentation: Ombilin Basin, Central Sumatra (West Sumatra Province)," 1981.

[4] A. A. Patria and F. Anggara, "Microfacies and Depositional Environment of the Eocene Sawahlunto Coal, Ombilin Basin, Indonesia," *Iraqi Geol. J.*, vol. 55, no. 1, pp. 128–146, May 2022.

[5] R. C. Rohmana, A. Achmad, and Suyoto, "Analisis Sedimentologi dan Stratigrafi untuk Rekonstruksi model Paleogeografi: Mengungkap Proses Pembentukan Formasi Tapak, Sub-Cekungan Banyumas," *J. Geosains dan Teknol.*, vol. 2, no. 3, p. 126, 2019.

[6] R. Qodri, "Identifikasi Lingkungan Pengendapan Daerah Kolok Mudik Dan Sekitarnya Pada Cekungan Ombilin Sumatra Barat," *Semin. Nas. 'Mitigasi Dan Strateg. Adapt. Dampak Perubahan Iklim Indones.*, pp. 224–230, 2020.

[7] Abbas, A. H. Hamdani, and M. Faizal, "Stratigrafi Batuan Daerah Selajambe Dan Sekitarnya, Kecamatan Selajambe, Kabupaten Kuningan Propinsi Jawa Barat," *Bull. Sci. Contrib.*, vol. 13, no. April, pp. 16–29, 2015.

[8] Silitonga and Kastowo, "Geological Map pf the Solok Quadrangle," *Geol. Surv. Indones. Minist. Mines, Bandung*, 1975.

[9] W. T. Koesmawardani, M. E. M. Nurshal, B. Sapiie, and A. Rudyawan, "Karakteristik Rekahan Alami, Studi Kasus Model Singkapan Digital (Dom) Batuan Granitik Di Muaro Silokek, Sumatera Barat," *Bull. Geol.*, vol. 3, no. 3, pp. 387–397, 2019.

[10] B. Situmorang, B. Yulihanto, A. Guntur, R. Himawan, and T. G. Jacob, "Structural Development of the Ombilin Basin West Sumatra," *20th Annu. Conv. Proc.*, vol. Volume 1, no. Pages 1-15, 1991.

[11] K. Anggayana, A. H. Widayat, and S. Widodo, "Depositional environment of the sangkarewang Oil Shale, Ombilin Basin, Indonesia," *J. Eng. Technol. Sci.*, vol. 46, no. 4, pp. 420–435, 2014, doi: 10.5614/j.eng.technol.sci.2014.46.4.6.

[12] A. Streckeisen, "Classification and Nomenclature of Plutonic Rocks, Reccomendation of the IUGS Subcommision on the Systematic of Igneous Rock," *Reccomendation IUGS Subcommision Syst. Igneous Rock*, vol. 12, 1974.

[13] E. Garzanti, "Petrographic classification of sand and sandstone," *Earth-Science Reviews*, vol. 192. Elsevier B.V., pp. 545–563, May 01, 2019.

[14] B. Prayitno, M. Riva'i, A. Suryadi, H. Kausarian, and F. Rozi, "Analysis of Stratigraphy and sedimentation dynamics of coal, Sawahlunto formation, Ombilin basin," *Int. J. GEOMATE*, vol. 17, no. 63, pp. 255–262, 2019.

[15] R. S. Adrianda and E. Sutriyono, "Kajian Struktur Geologi Daerah Muaro, Kabupaten Sijunjung, Sumatera Barat," vol. 10, no. August, pp. 209–219, 2022.

[16] I. K. Nasution and E. Sutriyono, "Karakteristik Morfometri Dan Morfodinamika Sub Daerah Aliran Sungai Batang Sukam, Kabupaten Sijunjung, Sumatera Barat," vol. 04, no. 02, pp. 83–93, 2022.

[17] F. j Pettijohn, "Sedimentary Rocks," *Harper Row New York, 3rd Ed.*, vol. 3, no. 3, p. 562, 1975.

[18] R. . Dunham, "Classification of carbonate rocks according to depositional texture," *AAPG Mem. 1*, vol. 1, 1962.

[19] N. T. Al-taee, A. I. Al-juboury, I. M. Ghafor, G. Zanoni, and H. Rowe, "Depositional environment of the late Paleocene-early Eocene Sinjar Formation , Iraq : Implications from facies analysis , mineralogical and geochemical proxies," *Heliyon*, vol. 10, no. 4, p. e25657, 2024.

[20] J. P. Zonneveld *et al.*, "Ichnological constraints on the depositional environment of the Sawahlunto Formation, Kandi, northwest Ombilin Basin, west Sumatra, Indonesia," *J. Asian Earth Sci.*, vol. 45, pp. 106–113, 2012, doi: 10.1016/j.jseaes.2011.06.017.

[21] N. Abbassi and H. Dashtban, "Vertebrate footprints from the agha jari formation (Late miocene–pliocene), zagros mountains, and a review of the cenozoic vertebrate ichnites in the persian gulf region," *Bull. Geosci.*, vol. 96, no. 2, pp. 159–179, 2021.

[22] H. Sulistya, Sukandarrumidi, and S. Pramumijoyo, "Kendali Tektonik Terhadap Cekungan Ekonomi Tersier Ombilin, Sumatera Barat.," *Teknosains*, vol. 14, no. 1. 2001.

[23] Moulds, "Model Cekungan Sumatra Tengah yang berbentuk dog-legs mengacu pada model sub-Cekungan Bengkalis," *Proc. 18th Annu. Conv. Indones. Pet. Assoc. 217-245*, 1984.

[24] A. P. Permana and S. S. Eraku, "Analisis Stratigrafi Daerah Tanjung Kramat Kecamatan Hulonthalangi Kota Gorontalo," *J. Geomine*, vol. 5, no. 1, pp. 1–6, 2017.

[25] B. Mulyana and R. M. G. Gani, "Litostratigrafi Cekungan Ombilin dalam kerangka tectono-sedimentation rift basin," 2015.

[26] A. N. Afifah, N. Khoirullah, K. Arfiansyah, I. Sophian, and M. F. Rosana, "Karakteristik Geologi Permukaan Daerah Cikadu Wetan Dan Sekitarnya, Kecamatan Luragung, Kabupaten Kuningan, Provinsi Jawa Barat," vol. 4, no. 6, pp. 478–488, 2020.

[27] W. H. Blow, "Late Middle Eocene to Recent Planktonic Foraminifera Biostratigraphy," *Proc. 1st Internat. Conf. Plank. Microfossil. Leiden E.J. Brill, v. 1*, 1969.

[28] M. D. K. Adam and Y. Z. Rochmana, "Analisis stratigrafi dan sejarah pengendapan Daerah Cibenda, Kabupaten Ciamis, Jawa Barat dan sekitarnya," *Ophiolite J. Geol. Terap.*, vol. 4, no. 2, p. 69, 2022.

[29] Y. Yuniardi, "Litostratigrafi Cekungan Ombilin Berdasarkan Interpretasi Citra Satelit," *Bull. Sci. Contrib.*, vol. 8, pp. 15–21, 2010.