Jurnal Geosaintek Vol 12. No. 3. Agustus 2026. p-ISSN : 2460-9072, e-ISSN : 2502-3659

PROVENANCE ANALYSIS OF SANDSTONE IN THE SEURELA FORMATION IN JEUMPA DISTRICT, BIREUN REGENCY, ACEH PROVINCE

Dewi Sartika[1], Shafira Putri Rizani[1], Rifqan[1], Akmal Muhni[1], Dina Gunarsih[1], Lia Fitra Rahmatillah[1], Fahri Adrian[1], Tika Hapsari[1]

Afiliasi : [1]Teknik Geologi, Fakultas Teknik, Universitas Syiah Kuala

e-mail : dewisartika@usk.ac.id

Abstrak. *Based on geological conditions, the research location is in the Seurela Formation. The Seurela Formation has a lithology consisting of sublitoral calcareous sandstone and mudstone with a Pliocene age. Although the Seurela Formation has been extensively studied regarding its stratigraphy and sedimentology, information concerning sandstone provenance—specifically based on quantitative petrographic analysis and tectonic setting interpretation—remains limited. Consequently, the origin of the sedimentary material and its relationship to the region's tectonic evolution are not yet comprehensively understood. Provenance analysis was conducted on the sandstone using geological mapping and petrography methods. The geological mapping method was carried out by collecting data directly in the field through observations of rock lithology. Meanwhile, the petrography method was analyzed using JMicrovision to calculate the mineral composition in thin sections of the rock. This study was conducted to determine the geological conditions and provenance of the sandstone in the Seurela Formation at the research location. Based on the research that has been done, the results indicate that the Seurela Formation is found with alternating carbonate silt sandstone. Provenance analysis at the research location was conducted on four sandstone samples with codes OC52, OC57, OC25, and OC27. Provenance analysis was performed using a QFL diagram. Based on the origin analysis, the sandstone in the Seurela Formation indicates from a tectonic recycling orogen and an eroded arc environment.*

Keywords: *seurela formation; petrographic analysis; sandstone provenance; QFL diagram*

INTRODUCTION

The research location is in Jeumpa District, Bireun Regency, Aceh Province. Geographically, the research location is at coordinates 5^0011'20.59" N and 96^0020'34.42" E. Based on regional geological conditions, the research location is in the Seurela Formation consisting of sandstone and sublittoral calcareous mudstone (Bennett et al., 1981) . This formation was formed during the Late Miocene to Early Pliocene, during a regression phase, resulting in the deposition of deltaic sediments and shallow deposits in the Keutapang Formation and Seureula Formation (de Smet & Barber, 2005). The biostratigraphic analysis of well X indicates that the age of the Seureula Formation is N18, with lithological characteristics of fine calcareous sandstone deposited in the slope to shelf area (Syavitri et al., 2019). The Seureula Formation is interesting to study as it is part of the North Sumatra Basin (de Smet & Barber, 2005). A study in Rantau Pereulak, Aceh, indicates that the Seureula Formation serves as a hydrocarbon reservoir (Clure, 2005). However, the presence of minor fault structures has caused hydrocarbon migration, leading to its remigration to the surface as oil seepage (Alfaiz et al., 2021). The Seurela Formation is a potential hydrocarbon reservoir area. Provenance studies at the study site area minimal. Therefore, sandstone provenance studies are essential to determine the origin of the sedimentary rocks. Furthermore, these provenance studies can be used to determine the constituents of the sandstone in relation to the host rock.

Provenance studies were conducted on sandstone to determine the origin of sedimentary rocks. This is important to determine the constituent elements of sandstone related to the parent rock (Pettijohn et al., 1987). A provenance study conducted in the North Sumatra Basin using heavy minerals indicates a significant change in the source of clastic sediments due to the uplift of the Bukit Barisan (Morton et al., 1994). In the Belumai Member sandstone, the sediment source originates from the Malay Peninsula, whereas in the Keutapang Formation, it comes from the Barisan Mountains (Morton et al., 1994). On the other hand, the sandstone of the Rampong Formation, located in the North Sumatra sub-basin and dated from the Late Oligocene to Early Miocene, originated from a recycled orogen tectonic setting (Sartika et al., 2023). Meanwhile, a provenance study on the Seulimuem sandstone, dated to the Late Miocene – Early Pliocene in the Northwest Aceh Basin, indicates a recycled orogen tectonic setting (Nugraha et al., 2023). This is interesting for further study on the Seureula Formation, as it was deposited after the Keutapang Formation (Ryacudu et al., 1992; Tampubolon et al., 2017) and has an age comparable to the Seulimuem Formation in the Northwest Aceh Basin. Thus, a

DOI : http://dx.doi.org/10.12962/j25023659.v12i3.9194

Received: 03-02-2026 Reviewed: 04-04-2026 Accepted: 30-07-2026 Available Online: 22-08-2026

provenance study of the Seureula Formation can provide insights into whether the sediment source was still influenced by the Bukit Barisan or originated from other sources.

Provenance is a study to determine the source or origin of sedimentary rocks. Interpretation of provenance is important in siliciclastic sedimentary rocks because siliciclastic minerals and rock fragments stored in sedimentary rocks provide important evidence of the source rock (Pettijohn, 1975). To see the provenance of sandstone in the Seurela Formation, petrographic analysis is needed to identify the components, especially the content of quartz, feldspar, and rock fragments (lithic fragments). The composition of sandstone petrographic components can reveal the classification of sandstone and the arrangement of litho-tectonic origins (Baiyegunhi et al., 2017).

The method for determining the origin of sandstone discusses the relationship between grain composition and sedimentary rocks. The distribution of different types of sandstone is influenced by its tectonic setting. This concept is refined by separating various sandstone compositions into three provenance types, namely continental blocks provenance, recycled orogen provenance, and magmatic arc provenance (Dickinson & Suczek, 1979). The sandstone sedimentation process will be recorded in the mineral composition and texture produced. The composition of sandstone reflects the nature of the origin or source of sediment, namely by looking at the proportion of sedimentary detrital grains in sandstone, while texture plays a role in determining the depositional environment (Dickinson & Suczek, 1979).

Literature Review

Regional Stratigraphy

Stratigraphic conditions in the Seurela Formation are deposited unconformably above the Baong Formation. Based on geological age, the Seurela Formation has a Pliocene age (Figure 1). The rock units in the Seurela Formation consist of sublittoral clastic volcanic sandstone and sublittoral calcareous mudstone (Bennett et al., 1981).

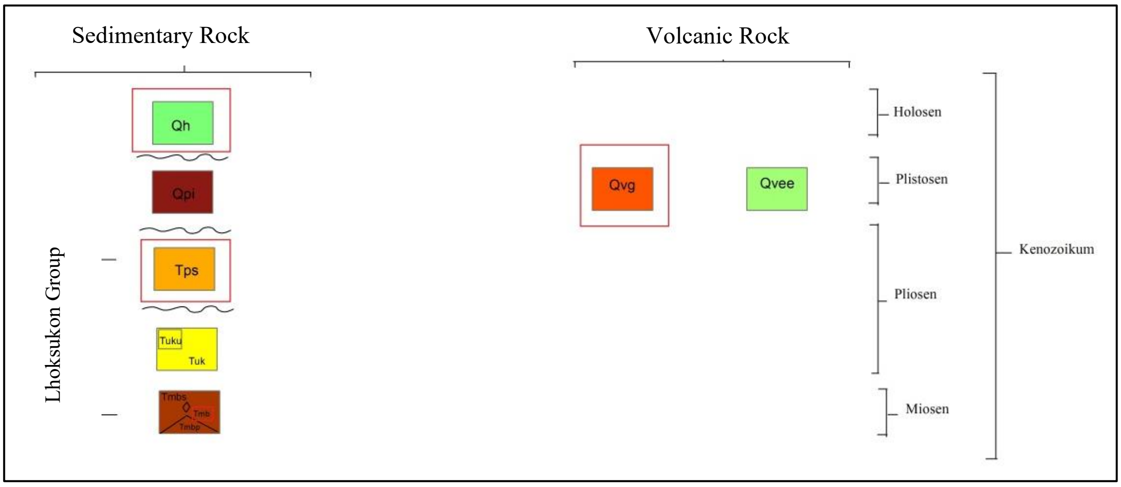


Figure 1. Regional Stratigraphy of the Research Area Modified from the Regional Geological Map of the Langsa Sheet (Bennett et al., 1981).

Sedimentary Rocks

Sedimentary rocks are one type of rock that fills almost three-quarters of the earth's surface (Boggs, Jr., 2009). Sedimentary rocks are formed from the accumulation of material resulting from the breakdown of pre-existing rocks or the results of chemical and organism activities, which are deposited layer by layer on the earth's surface which then undergoes rock formation (Pettijohn, 1975). Sandstone is a mixture of minerals and rock fragments originating from the erosion products of various types of rocks that are carried out naturally. The sedimentation process during deposition will affect the presence and changes in mineral grains in

DOI : http://dx.doi.org/10.12962/j25023659.v12i3.9194

Received: 03-02-2026 Reviewed: 04-04-2026 Accepted: 30-07-2026 Available Online: 22-08-2026

sandstone, such as the weathering process in the source rock, transportation and increasing distance from the source area of the sedimentation environment, and the diagenesis process (Pettijohn, 1975).

Sedimentary Rocks Provenance

Sandstone is generally composed of terrigenous material, namely material originating from land, which is a product of erosion of the source rock. The composition of sandstone is generally composed of quartz, feldspar, clay, rock fragments, and other unstable minerals. The difference in mineral abundance in each sandstone composition is a reflection of the mechanical and chemical processes of minerals, as well as the availability of minerals originating from the source rock (Folk, 1974).

Provenance studies aim to identify the source rock area, paleoclimate, and tectonic setting (Abhijit Basu, Steven W. Young, Lee, 1975). In addition, provenance studies can be useful in providing information related to oil and gas development to understand sediment transport channels, basin deposition patterns, and interpretation of the location of sandstone bodies in the basin (Zhang & Wang, 2019).

The method for determining the provenance of sedimentary rocks is by using petrographic analysis through optical observation of quartz minerals. Quartz minerals are the main minerals that make up sedimentary rocks, especially in sandstone because quartz is the most stable mineral during the sedimentation process (Folk, 1974).

The type of source rock is interpreted based on the percentage of monocrystalline and polycrystalline quartz grains (Abhijit Basu, Steven W. Young, Lee, 1975). Meanwhile, the degree of roundness and alteration level of feldspar is used to interpret the paleoclimate of the source area (Folk, 1974), while the percentage of quartz (Q), feldspar (F), and lithic (L) presence are used for analysis to determine the tectonic setting (Dickinson, 1985) (Dickinson & Suczek, 1979). The tectonic setting is classified into continental blocks, magmatic arcs, and recycled orogens, as seen in Figure 2.

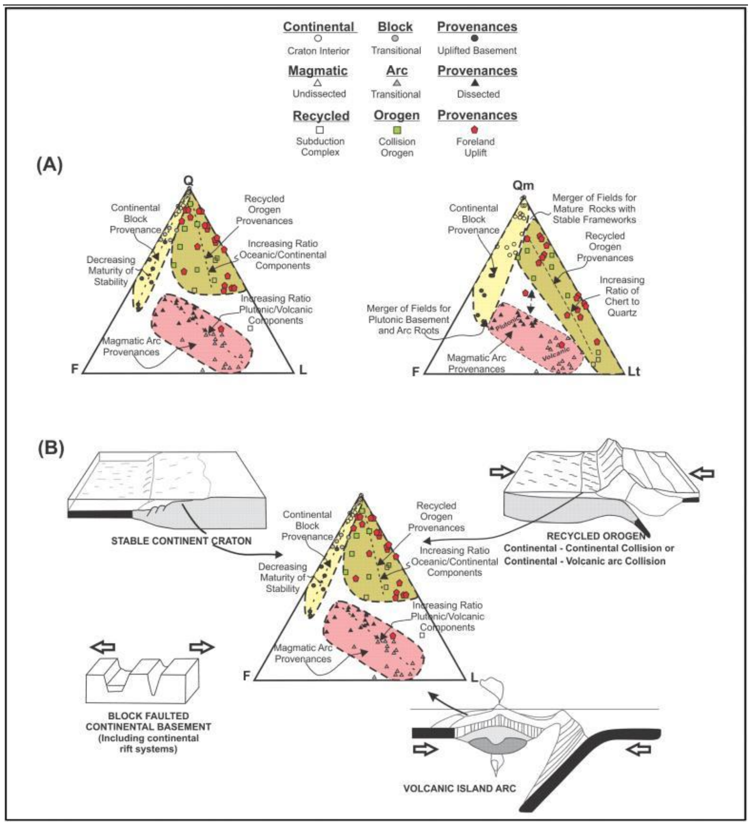


Figure 2. (a) Q-F-L and Qm-F-Lt diagrams and (b) illustration of the tectonic setting (modified from Dickinson & Suczek, 1979).

DOI : http://dx.doi.org/10.12962/j25023659.v12i3.9194

Received: 03-02-2026 Reviewed: 04-04-2026 Accepted: 30-07-2026 Available Online: 22-08-2026

METHODOLOGY

The research method used in analyzing sandstone provenance in the Seurela Formation uses two methods, namely geological mapping and petrographic analysis. The geological mapping method is carried out by observing rock outcrops directly in the field, while petrographic analysis is carried out on thin section samples of rocks in the optical mineral and petrography laboratory of Syiah Kuala University. The method of collecting data in the field by geological mapping is carried out using the measuring section method. This is done to obtain field data descriptively and systematically. Petrographic analysis is carried out by observing the percentage of quartz, feldspar, and rock fragment mineral content. The results of the observation of the thin section of the rock will later be used as a quartz mineral variable which is matched using genetic classification and empirical classification in determining the type of provenance of the rock (Folk, 1974). Petrographic observations were carried out with thin section samples of rocks with a thickness of 0.03 millimeters (MacKenzie et al., 2017). The method for calculating the percentage of minerals that make up the rock is carried out by point calculations using JmicroVision software (Larrea et al., 2014). In this study, the calculation of the percentage of minerals in rocks using JmicroVision software with a number of points of 1.500 refers to (Larrea et al., 2014).

Based on the data obtained in the field, petrographic analysis for provenance studies was carried out at 4 thin section rock sample points (Figure 3). At the location where the sandstone samples were made, only four samples were suitable for thin sectioning. This was because the sandstone in these four samples was compact compared to the other sandstone observation points, which were already heavily weathered. The four samples used for thin sectioning had well-preserved textures in terms of grain size, sorting, cementation, and mineral composition. Futhermore determination of sample points for provenance analysis was carried out based on data on differences in grain size found in sandstone. However, given the limited number of sandstone samples (only four) in this study, the provenance analysis for the research site is based on the observed trends or shared characteristic of the sandstones rathet than serving as an absolute conclusion.

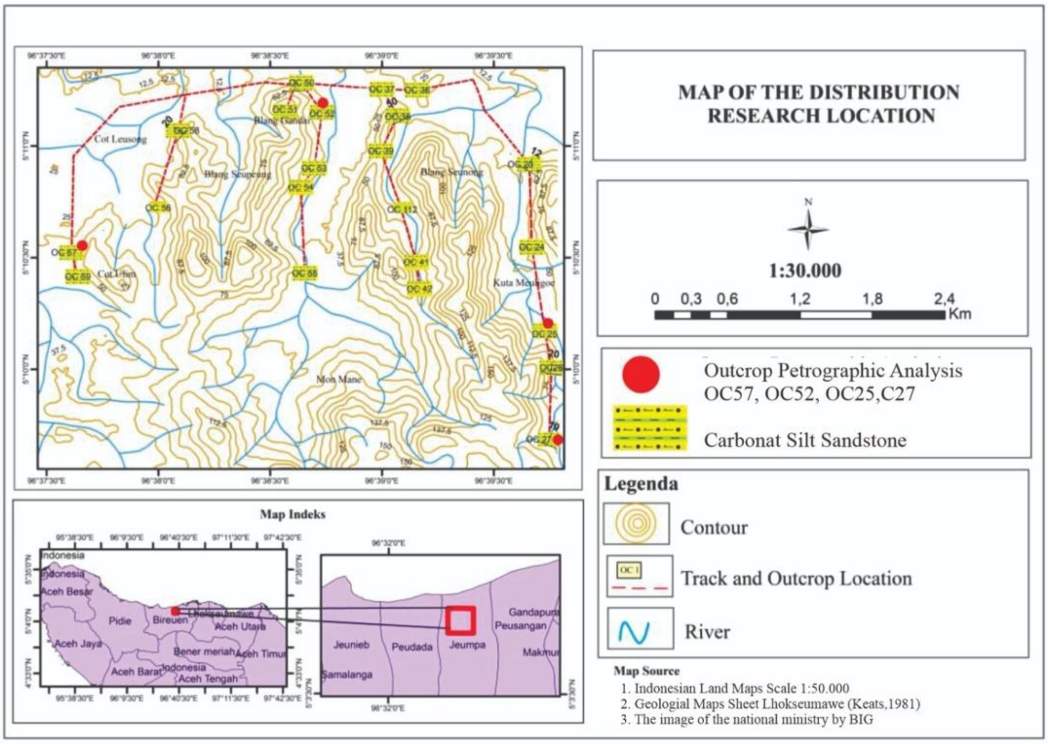


Figure 3. Distribution Map of Sandstone Unit at the Research Area

The minerals that makeup sandstone are classified according to their composition: monocrystalline and polycrystalline quartz, k-feldspar, plagioclase, rock fragments, and matrix. The percentage composition of

DOI : http://dx.doi.org/10.12962/j25023659.v12i3.9194

Received: 03-02-2026 Reviewed: 04-04-2026 Accepted: 30-07-2026 Available Online: 22-08-2026

quartz (Q), feldspar (F), and lithic (L) is plotted in a Q-F-L diagram to classify sandstones (Dickinson, 1988; Dickinson & Suczek, 1979), to analyze tectonic settings (Dickinson, 1983), paleoclimate (Nelson, 2007), and the type of original rock (Boggs, Jr., 2009; Nugraha et al., 2023).

RESULT AND DISCUSSION

Seurela Sandstone

The carbonate siltstone intercalation unit in the Seurela Formation has a brownish-yellow color, with a laminated structure, coarse sand-fine sand grain size with a size of 0.50 – 0.125 mm, well sorted, roundness with subrounded – rounded, open packing, reacts to HCL (Hydrogen Chloride). The sedimentary structure found is fining upward, where there is a change in grain size from coarse at the bottom of the outcrop, gradually becoming finer at the top of the outcrop. This is caused by a decrease in current strength or energy when sedimentation takes place. Fining upward is a sediment deposition pattern in which the size of sediment grains gradually decreases towards younger layers (Figure 4).

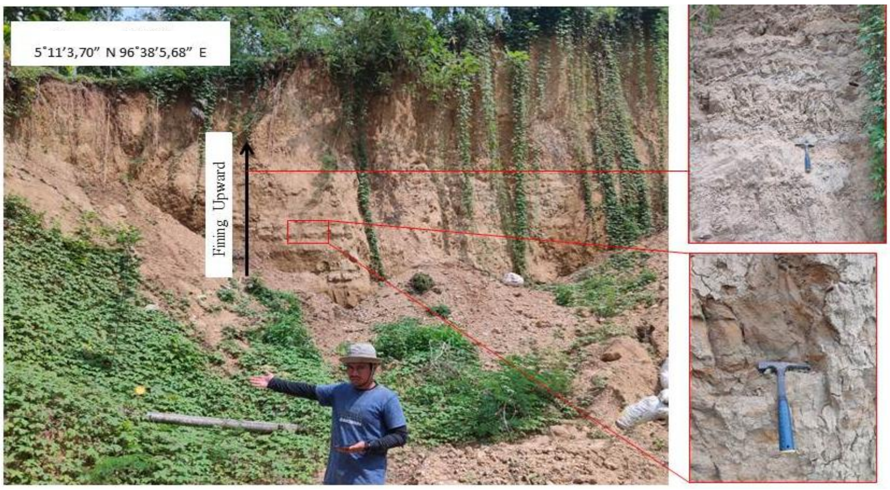


Figure 4. The appearance of the Carbonate Silt Intercalated Sandstone Unit in the Research Area at OC52.

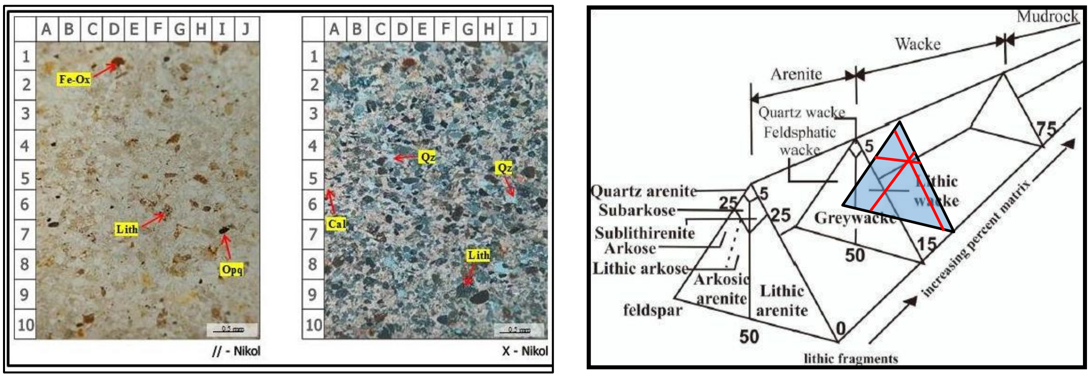
Based on petrographic analysis of four thin sections of sandstone, the texture consists of grains measuring 0.1 mm to 0.5 mm, well sorted, and slightly rounded to rounded. Petrographic analysis conducted in the research area to determine the provenance in the research area was conducted on 4 Sandstone Samples with codes OC52, OC57, OC25, and OC27 (Tabel 1 ,and Figure 5).

Based on the petrographic results of four rock samples from the research site, the mineral composition found consisted of quartz, feldspar, lithic, and matrix. The lithic found in samples OC 52 and OC 57 was sedimentary lithic, while in samples OC 25 and OC 27 it was volcanic lithic. However, volcanic glass was not found in the sandstone petrographic samples at the research site. Furthermore, volcanic lithis fragments were found in the sandstone samples form the research area, the grain characteristics indicating a relatively high degree of transport suggest that the sediment consist of volcanic material that has undergone reworking.The percentage composition of the presence of minerals in sandstone at the research location can be seen in Table 1.

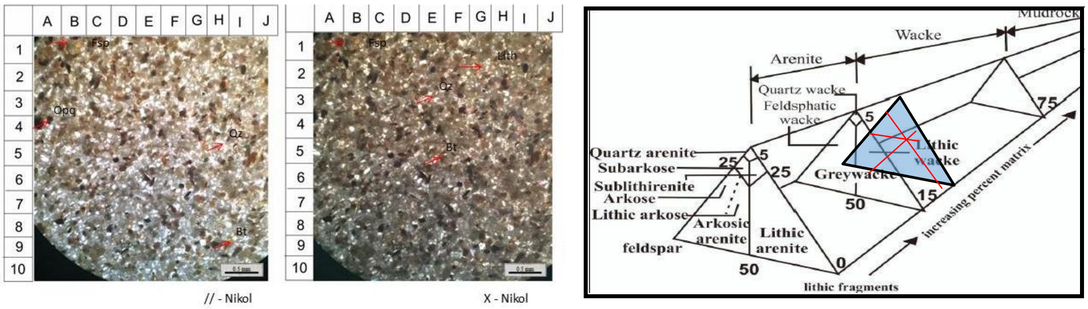
Tabel 1. Results of Sandstone Calculations at the Research Location

Rock Sampels	Mineral Composition				Total	Rock Names (Pettijohn, 1975)
	Kuarsa	Feldspar	Litik	Matriks		
OC52	68%	5%	27%	25%	100%	Lithic Wacke
OC57	60%	5%	35%	15%	100%	Lithic Wacke
OC25	20%	50%	30%	16%	100%	Lithic Wacke
OC27	32%	40%	28%	19%	100%	Lithic Wacke

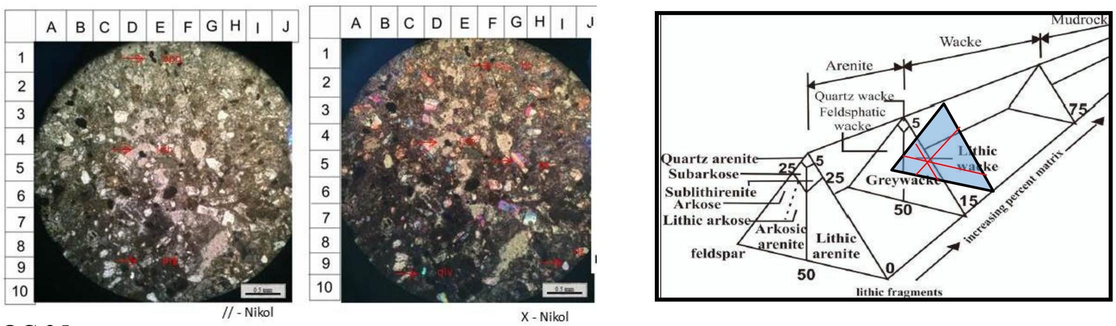
DOI : http://dx.doi.org/10.12962/j25023659.v12i3.9194
Received: 03-02-2026 Reviewed: 04-04-2026 Accepted: 30-07-2026 Available Online: 22-08-2026



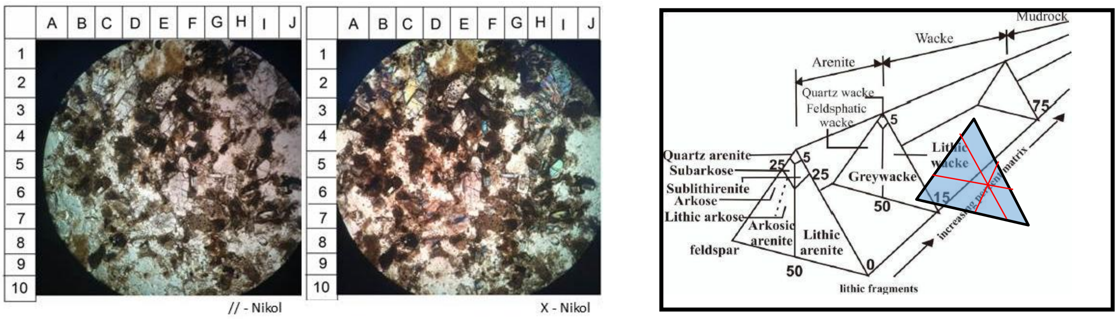
OC 52



OC 57



OC 25



OC 27

Figure 5. Results of interpretation of petrographic analysis of code samples OC 52, OC 57, OC 25, dan OC 27

Provenance analysis at the research location was carried out on 4 sandstone samples that had undergone petrographic analysis. The characteristics of the four sandstone samples observed include quartz minerals (Q), feldspar (F), and rock fragments (L). Monocrystalline quartz (Qm) consists of quartz with wavy extinction (undulatory quartz) and quartz with non-undulatory extinction (non-undulatory quartz), while polycrystalline quartz (Qp) has characteristics consisting of 2 or more quartz grains, feldspar grains, and rock fragments

DOI : http://dx.doi.org/10.12962/j25023659.v12i3.9194
Received: 03-02-2026 Reviewed: 04-04-2026 Accepted: 30-07-2026 Available Online: 22-08-2026

contained. The results of the provenance analysis of the 4 sandstone samples can be seen in Figure 6 and Table 2.

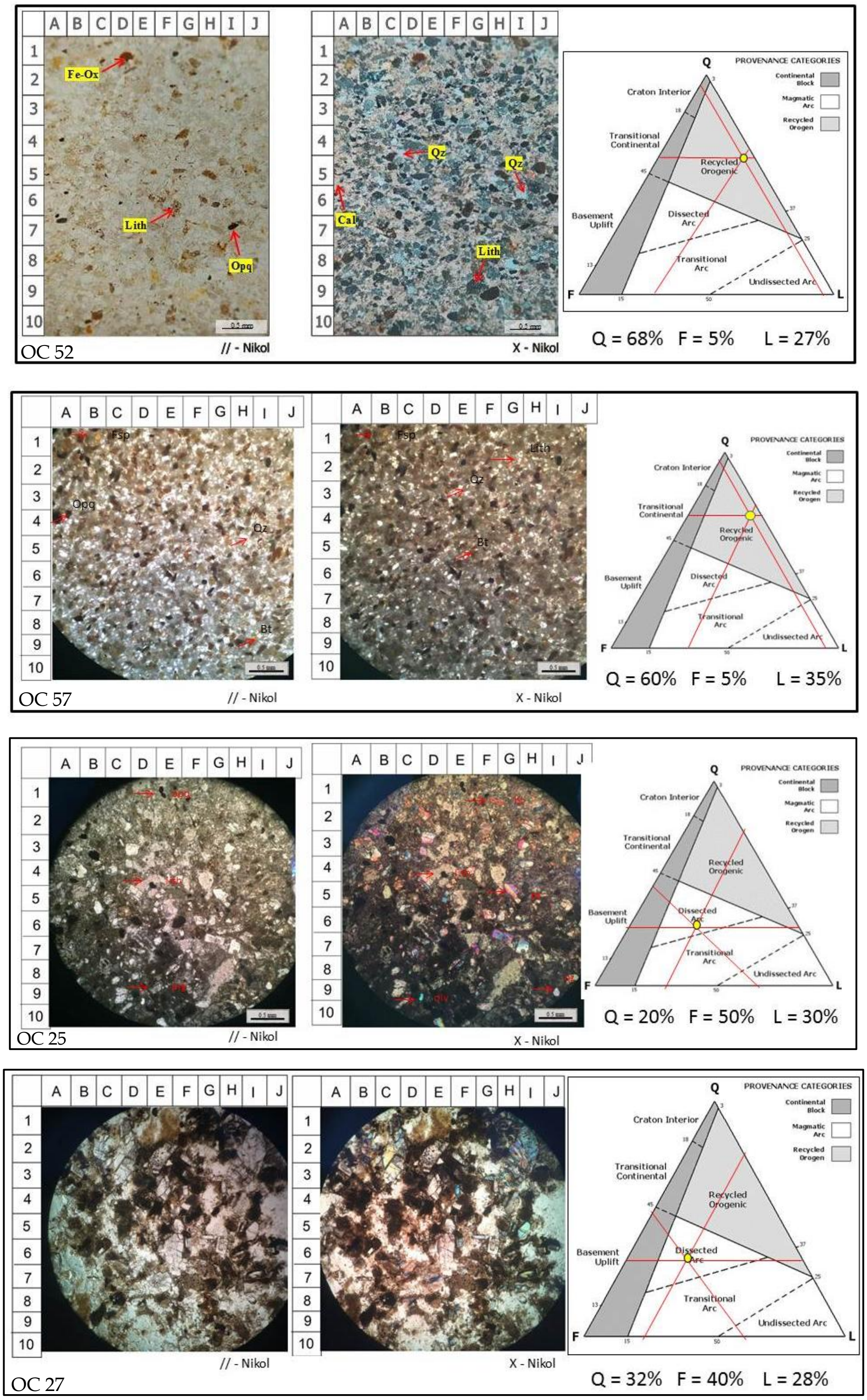


Figure 6. Thin section appearance of carbonate sandstone codes OC 52, OC 57, OC25, and OC27 at the research location

DOI : http://dx.doi.org/10.12962/j25023659.v12i3.9194
Received: 03-02-2026 Reviewed: 04-04-2026 Accepted: 30-07-2026 Available Online: 22-08-2026

Table 2. Point counting results of sandstone samples in the research area (Q=Quartz, F=Feldspar, L=Lithic Fragment, Lv=Lithic vulcanic, Ls=Lithic Sediment, M=Matrix

Rock Sampels	Q	L			F	M	QFL Provenance Field
		Ls	Lv	Total			
OC52	68%	20%	7%	27%	7%	25%	Recycled Orogenic
OC57	60%	20%	15%	35%	5%	25%	Recycled Orogenic
OC25	20%	0	30%	30%	50%	16%	Dissected Arc
OC27	32%	0	28%	28%	40%	19%	Dissected Arc

Based on the interpretation of sandstone samples on petrographic analysis and QFL diagram plotting, it can be concluded that the tectonic setting of the Seureula Formation Sandstone in the research area is in the tectonic setting of the Recycled Orogen sub-zone of the Foreland Uplift and the Magmatic Arc sub-zone of the Dissected Arc (Figure 7).

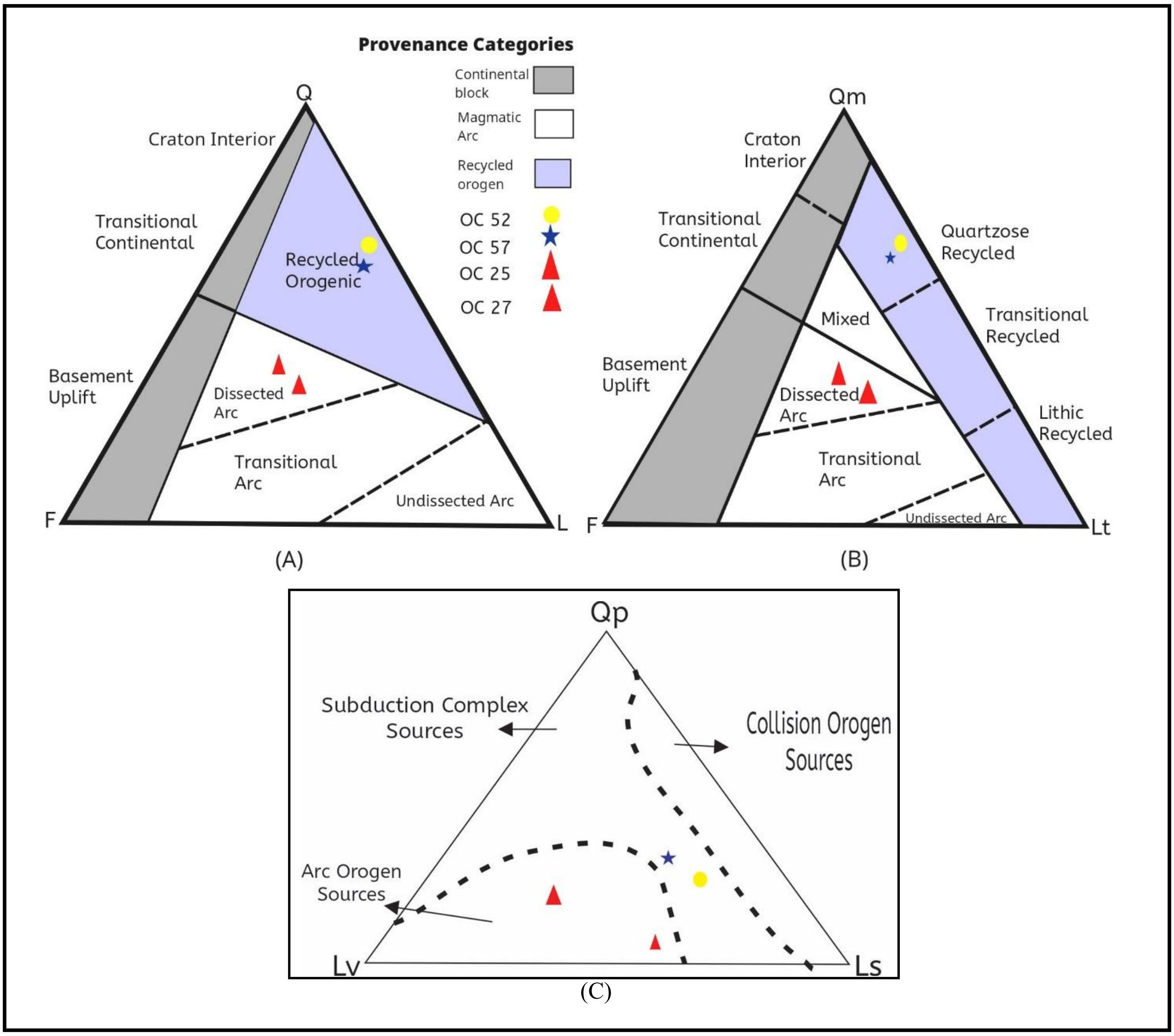


Figure 7. Results of plotting the Q-F-L (A), Qm-F-Lt (B), and Qp-Lv-Ls (C) diagrams of the Seureula Formation sandstone in the research area (Dickinson & Suczek, 1979)

DOI : http://dx.doi.org/10.12962/j25023659.v12i3.9194

Received: 03-02-2026 Reviewed: 04-04-2026 Accepted: 30-07-2026 Available Online: 22-08-2026

The provenance of the Seureula Formation sandstone in the QFL plot diagram is interpreted to recycled orogen sub-zone foreland uplift (Figure 8) which is a rock originating from the recycled orogen-foreland uplift and caused by tectonic processes or the destruction of older rocks.

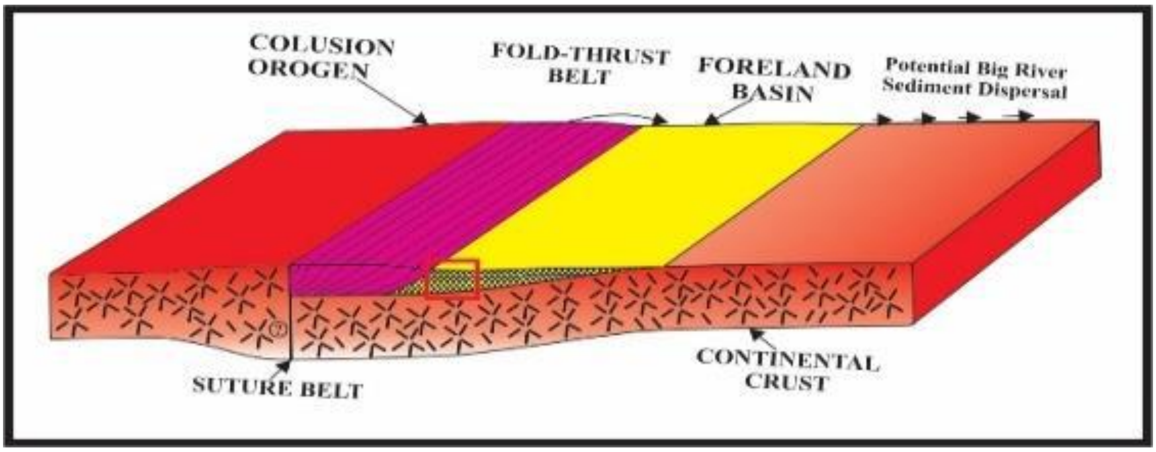


Figure 8. Recycled Orgen Provenance Model for Foreland Uplift sub-zone.

Origin of Rocks

Based on the plotting results on the Basu diagram [17] and Tortosa [25], it can be concluded that the quartz minerals in the sandstone samples come from acidic igneous rocks in the form of granite that has undergone a low-rank metamorphic process (Figure 9). The main characteristic of plutonic igneous rocks lies in the quartz found in a single form [26]. Only two rock samples (OC52 and OC57) allowed for the interpretation of quartz provenance study. In the meanwhile, data restrictions prevented rock samples with codes OC25 and OC27 from meeting the requirements for analysis.

Table 3. Percentage of minerals Qmu, Qmnu, Qp 2-3 crystals, and Qp >3 crystals in Seureula Formation sandstones.

Rock Samples	Quartz (Q)			
	Qm Undo	Qm Non Undo	Qp (2-3 crystal)	Qp (>3 crystal)
OC52	67%	20%	0	13%
OC57	56%	30%	0	14%

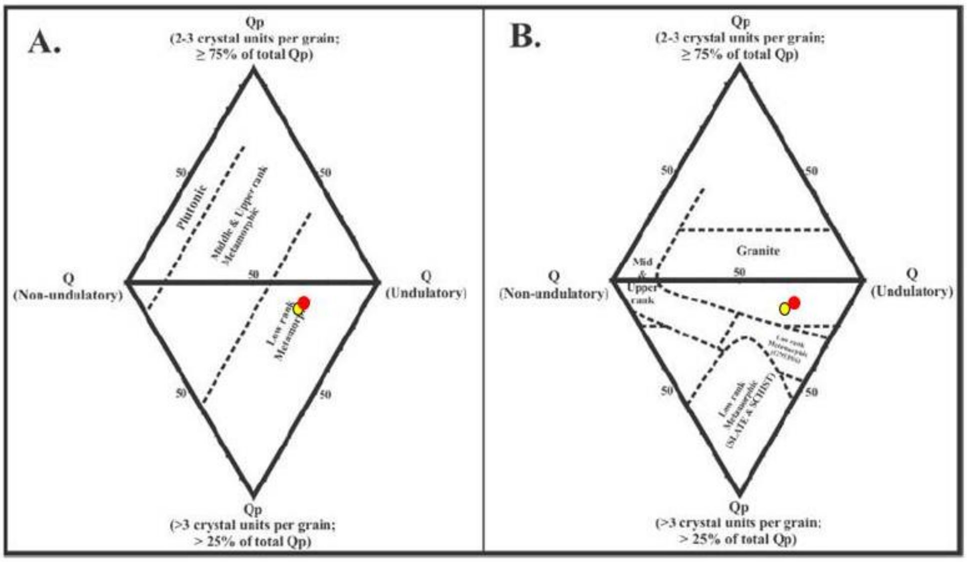


Figure 9. Plotting results of Seureula Formation sandstone samples in the research area.

DOI : http://dx.doi.org/10.12962/j25023659.v12i3.9194
Received: 03-02-2026 Reviewed: 04-04-2026 Accepted: 30-07-2026 Available Online: 22-08-2026

Based on the composition of quartz minerals that are quite dominant in the section, it is possible that the original rock is in the form of rocks and is influenced by the basement that was deposited first, seeing the results of the tectonic arrangement entering the recycled orogen type. Regionally, the Seurela Formation is situated within the North Sumatra Basin (NSB), a back-arc basin whose evolution was governed by the interaction between the Indo-Australian and Euraisan plates (Tambubolon et al., 2021). Futhermore, the Seurela Formation was likely influenced by magmatic and volcanic activity associated subsequent accumulation of sediments in the NSB, resulting in the formation of recycled-orogen type sandstones. Petrographic analysis indicates that the magmatic arc provenance originated form andesitic of the Tuan Unit (QTvtu) within the Geureundong volcanic center. Volcanic activity at this center produced andesite rocks that likely underwent weathering and erosion, supplying plagioclase and potentially other mafic minerals to the depositional basin.

CONCLUSION

The sandstone in the Seurela Formation interpreted from the tectonic settings of the recycled orogen and dissected arc with probable source rocks consisting of granitic igneous rocks (recycled orogen) and andesite igneous rocks (dissected arc).

REFERENCES

Abhijit Basu, Steven W. Young, Lee. (1975). Re-evaluation of the Use of Undulatory Extinction and Polycrystallinity in Detrital Quartz for Provenance Interpretation. *SEPM Journal of Sedimentary Research*, *Vol. 45*. https://doi.org/10.1306/212f6e6f-2b24-11d7-8648000102c1865d

Alfaiz, K., Imaduddin, Jibran, M. K., Assyifa, Y., Qauvani, Z. R., Fahira, S. J., Putra, R. R., Khaira, N., Futhra, S., & Zahran, A. (2021). Identification of The Shallow hydrocarbon Zone Using Tilt Derivative Gravity Data and The Wenner - Schlumberger Configuration Method in Rantau Pereulak Area, East Aceh, Aceh Province. *Join Convention Bandung*.

Baiyegunhi, C., Liu, K., & Gwavava, O. (2017). Diagenesis and reservoir properties of the permian ecca group sandstones and mudrocks in the Eastern Cape Province, South Africa. *Minerals*, *7*(6). https://doi.org/10.3390/min7060088

Bennett, J. D., Bridge, D. Mc., Cameron, N. R., Djunuddin, A., Ghazali, S. A., Jeffrey, D. H., Kartawa, W., Keats, W., Rock, N. M. S., Thompson, S. J., & Whandoyo, R. (1981). *The Geology of the Langsa Quadrangle (0420), Sumatra. Scale 1:250 000*. Bandung.

Boggs, Jr., S. (2009). Petrology of Sedimentary Rocks. In *Petrology of Sedimentary Rocks*. https://doi.org/10.1017/cbo9780511626487

Clure, J. (2005). Fuel resources: Oil and gas. *Geological Society Memoir*, *31*. https://doi.org/10.1144/GSL.MEM.2005.031.01.10

de Smet, M. E. M., & Barber, A. J. (2005). Tertiary stratigraphy. In *Geological Society Memoir* (Vol. 31). https://doi.org/10.1144/GSL.MEM.2005.031.01.07

Dickinson, W. R. (1983). Provenance of North American Phanerozoic sandstones in relation to tectonic settings. *Geological Society of America Bulletin*, *94*(2). https://doi.org/10.1130/0016-7606(1983)94<222:PONAPS>2.0.CO;2

Dickinson, W. R. (1985). Interpreting provenance relations from detrital modes of sandstones. *Provenance of Arenites. Proc. Cetraro, Cosenza, 1984*. https://doi.org/10.1007/978-94-017-2809-6_15

Dickinson, W. R. (1988). Provenance and sediment dispersal in relation to paleotectonics and paleogeography of sedimentary basins. In K. L. Kleinspehn & C. Paola (Eds.), *New Perspectives in Basin Analysis* (pp. 3–25). Springer.

Dickinson, W. R., & Suczek, C. A. (1979). Plate tectonics and sandstone compositions. *The American Association of Petroleum Geologists Bulletin*, *63*(12), 2164–2182.

Folk, R. L. (1974). *Petrology of Sedimentary Rocks*. Hemphill Publishing Company.

Larrea, M. L., Castro, S. M., & Bjerg, E. A. (2014). A software solution for point counting. Petrographic thin section analysis as a case study. *Arabian Journal of Geosciences*, *7*(8). https://doi.org/10.1007/s12517-013-1032-0

MacKenzie, W. S., Adams, A. E., & Brodie, K. H. (2017). Rocks And Minerals In Thin Section. In *Rocks and Minerals in Thin Section*.

DOI : http://dx.doi.org/10.12962/j25023659.v12i3.9194

Received: 03-02-2026 Reviewed: 04-04-2026 Accepted: 30-07-2026 Available Online: 22-08-2026

Morton, A. C., Humphreys, B., Dharmayanti, D. A., & Sundoro. (1994). Paleogeographic implications of the heavy mineral distribution in Miocene sandstones of the North Sumatra Basin. *Journal of Southeast Asian Earth Sciences*, *10*(3), 177–190.

Nelson, S. A. (2007). *Petrology Sandstone and Conglomerate*. Tulane University.

Nugraha, G. S., Sunardi, E., Haryanto, I., Adhiperdana, B. G., Fakhruddin, R., Fitriany, R., & Gunarsih, D. (2023). Facies analysis, biostratigraphy, and provenance of the late Neogene Seulimeum Formation, Northwest Aceh basin, Sumatra (Indonesia). *Heliyon*, *9*(9). https://doi.org/10.1016/j.heliyon.2023.e20032

Pettijohn, F. J. (1975). *Sedimentary rocks* (1st ed.). Harper & Row.

Pettijohn, F. J., Potter, P. E., & Siever, R. (1987). *Sand and Sandstone* (2nd ed.). Springer Science.

Ryacudu, R., Djaafar, R., & Gutomo, A. (1992). Wrench faulting and its implication for hydrocarbon accumulation in the Kuala Simpang area - North Sumatra Basin. *Proceedings 21st Annual Convention*, 93–116.

Sartika, D., Gunarsih, D., Ahmad, L., Muhni, A., Rahmatillah, L. F., & Adhari, M. R. (2023). PROVENANCE ANALYSIS OF THE RAMPONG FORMATION SANDSTONE IN THE KETUKAH AREA, GAYO LUES, ACEH. *Indonesian Physical Review*, *7*(1). https://doi.org/10.29303/ipr.v7i1.261

Syavitri, D., Setiawan, R., & Jambak, M. A. (2019). Biostratigraphic analysis based on planktic Foraminifera from well X in North Sumatra Basin. *Journal of Physics: Conference Series*, *1402*(3). https://doi.org/10.1088/1742-6596/1402/3/033067

Tampubolon, R. A., Ozza, T., Arifin, M. T., Hidayatillah, A. S., Prasetio, A., & Furqan, T. (2021). A review of regional geology of the North Sumatra Basin and its Paleogene petroleum system. *Berita Sedimentologi*, 23–31.

Tortosa, A., Palomares, M., & Arribas, J. (1991). Quartz grain types in Holocene deposits from the Spanish Central System: Some problems in provenance analysis. *Geological Society Special Publication*, *57*. https://doi.org/10.1144/GSL.SP.1991.057.01.05

Zhang, Z., & Wang, H. (2019). Comprehensive provenance analysis and its applications to eocene clastic rocks in the huimin depression, bohai bay basin, China. *Minerals*, *9*(9). https://doi.org/10.3390/min9090517

DOI : http://dx.doi.org/10.12962/j25023659.v12i3.9194

Received: 03-02-2026 Reviewed: 04-04-2026 Accepted: 30-07-2026 Available Online: 22-08-2026