Vol. 6, No. 2, July 2024: 54-62

Jambura Geoscience Review

p-ISSN 2623-0682 | e-ISSN 2656-0380

Department of Earth Science and Technology, Universitas Negeri Gorontalo

Geology Structural Analysis of the Tanjung Betung II Region, Bengkulu: Recognized through Geological Mapping and Lineament Analysis

Devi Puspita Sari[1], Edy Sutriyono[1]

[1] *Geological Engineering, Sriwijaya University, Palembang, South Sumatra, Indonesia*

ARTICLE INFO

Article history:
Received: 23 December 2023
Accepted: 10 June 2024
Published: 29 July 2024

Keywords:
Bengkulu Basin; Faulting; Folding; Neogene Graben System; Lineament

Corresponding author:
Devi Puspita Sari
Email: psdepik@gmail.com

ABSTRACT

The research area is located in the Tanjung Betung II area, North Kaur, Bengkulu. This research was conducted to determine the geological structure and its relationship with the graben system in the Bengkulu basin by identifying and measuring structural components recorded in rock units. In interpreting deformation mechanisms, this research utilizes surface data obtained from geological structure mapping and lineament analysis based on Digital Elevation Model (DEM) images. Field observations on outcrops have identified five types of structures that have a general northwest-southeast trend, hereinafter referred to as the Manau IX fault, Bunian fault, Tanjung Kurung fault, Aek Kule syncline and Padang Manis fault. This structure may be associated with a graben system that formed in the late phase of basin evolution in the Neogene. Importantly, the structures recorded in the outcrop sequence may be the result of tectonic deformation that occurred during the Late Neogene, coinciding with the start of the Barisan orogeny.

How to cite: Sari, DP. (2024). Geology Structural Analysis of the Tanjung Betung II Region, Bengkulu: Recognized through Geological Mapping and Lineament Analysis. *Jambura Geoscience Review, 6* (2), 54-62. https://doi.org/10.37905/jgeosrev.v6i2.23721

1. INTRODUCTION

The research area is administratively located in the Tanjung Betung II region, North Kaur District, Kaur Regency, Bengkulu Province, approximately between 4°27'30.2" S - 103°14'14.5" E and 4°32'33.4" S - 103°18'04.5" E. The region is tectonically situated within the Paleogene Bengkulu basin, which is considered as the fore-arc basin (Yulihanto et al., 1995). The initial subsidence of the basin is commonly attributed to rifting that formed graben system in Paleogene or Paleocene-Eocene time. The rifting episode proceeded up to Neogene, as a consequence of this event the graben became wider to the WNW direction which is also affected by the control of the Sumatran Fault System (SFS) and the Mentawai Fault System (MFS). The early sedimentation within the basin took place in terrestrial and transition environments, following the transgressive event that resulted in rock units constituted the Hulusimpang Formation in the Oligocene-Early Miocene. The deposition of sediment materials during transgression proceeded up to the Early-Middle Miocene and produced the Seblat unit. This event ceased in the Middle-Late Miocene and followed by the onset of regression, which resulted in consecutively from lower to upper stratigraphic levels the Middle-Late Miocene Lemau Formation, the Late Miocene-Pliocene Simpangaur Formation, and the Pliocene-Pleistocene Bintunan Formation. Within the region studied there appeared two the outcropping units, including the Lemau Formation, and the Simpangaur Formation.

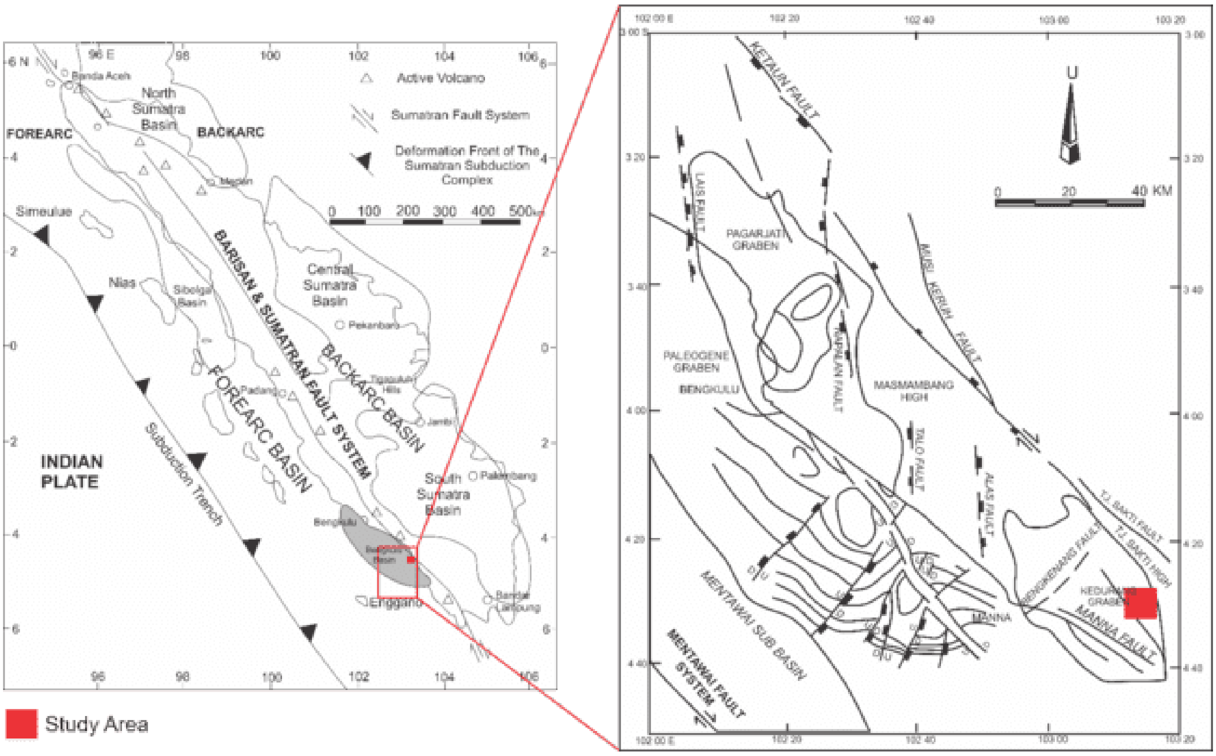

Figure 1. Map showing the tectonic setting of Sumatra (left); also shown study area located in the Bengkulu basin (right) (modified from Barber, 2005; Yulihanto et al., 1995).

The Middle-Late Lemau unit consists of sandstone, calcareous sandstone, limestone, dacitic breccia and claystone with the intercalated thin coal seam. Lemau Formation was deposited in shallow marine environments and lagoons (Heryanto & Suyoko, 2007). The overlying Late Miocene-Pliocene Simpangaur sequence is composed of lithologies such as tuffaceous sandstone, tuffaceous claystone, fossiliferous sandstone containing predominantly macro-Mollusca, and conglomerate. Heryanto et al. (2007) suggest that the sedimentary rocks constituted the Simpangaur sections were deposited in marine to transition environment during a transgressive phase. Importantly, the sequence has been deformed tectonically, and the recorded tectonic structures are exposed in the present study area. This research has observed the outcropping structural features to evaluate the development of deformation occurred within the Bengkulu basin. According to Pulunggono (1992), tectonic deformation occurring within the Bengkulu basin was principally associated with the movement of the NW-SE trending Sumatran Fault System (SFS) and the NW-SE striking Mentawai Fault System (MFS). Figure 1 shows the location of the recent study area in the Bengkulu basin.

2. METHOD

This study focuses on evaluating the geological structure exposed at the Tanjung Betung II region and the surrounding area. The present work employes two basic approaches, the mapping of surface geology and the analysis of Digital Elevation Model (DEM) imagery. The surface data obtained from observation and measurement on structural elements were compiled with the DEM analysis, especially the interpretation of landscape lineaments. Lineament is used to see general trends of lineaments and is adjusted to measurement on geological structures. The measurement and documentation of structural components were conducted by following the technique described by McClay (1987). Analysis of the structural data employed the computer-aided software such as Stereonet V10 (Allmendinger et al., 2012; Cardozo and Allmendinger, 2013) or Visible Geology available at https://app.visiblegeology.com/profile.html, Dips program accessible from https://www.geoengineer.org/software/dips, and Wintensor 5.1 available at https://damiendelvaux.be/Tensor/WinTensor/win-tensor.html.

The DEM imagery utilized in the recent study is the Nasional DEM (DEMNas). The imagery was gained from https://tanahair.indonesia.go.id/portal-web, which is under the management of the Geospatial Information Agency (GIA). The DEM imagery were carried out by looking at landscape lineament. The map was created using several data sources, such as the IFSAR data with ~5 m resolution, the TERRASAR-X with 5 m resampling resolution from the initial 5-10 m resolution, and the ALOS PALSAR with 11.25 m resolution by adding mass point data used in generating the Indonesian Landscape Map (Peta Rupa Bumi Indonesia). The DEMNas has a spatial resolution of 0.27-arcsecond by using the EGM2008 vertical datum. In interpreting the landscape lineament, the recent research has observed the topographic expression of the landforms displayed by the DEMNas imagery. The positive relief is interpreted as the high topography of hills or mountain, whereas the negative configuration is considered as valleys or river channels (Saleem, 2013; Meixner et al., 2018). In addition, the general trend of the lineament displayed by the DEMNas was analyzed using the Georose application program which can be accessed from https://www.cesdb.com/georose.html.

3. RESULTS AND DISCUSSION

Relying primarily on the DEMNas interpretation, a number of locality sites were identified for field observation, including the Manau IX river, the Bunian river, the Tanjung Kurung river, the Padang Manis river, and the Aek Kule river (Figure 2). At the selected location there appeared four brittle-typed deformation and one ductile-styled structuring. The brittle deformation resulted in the Manau IX normal fault, the Bunian strike-slip fault, the Tanjung Kurung normal fault, and the Padang Manis thrust fault, whereas the ductile tectonics produced a folding structure which formed the Aek Kule syncline. Interestingly, the outcropping structures tend to have the NW-SE trend, suggesting the early phase of structuring within the graben system in Neogen or Late Oligocene-Early Miocene. The geological structure in the research area has a NE-SW trend in accordance to the lineament (Figure 2). According to Yulihanto et al. (1995), the structural trend might have been controlled by the movement of the inferred basin boundaries with NW – SE orientation such as Ketahun fault, Tanjung Sakti fault and Manna fault. In addition, the deformation of rock succession was interpreted due mainly to the N-S extensional faulting at Lais, Napalan, and Alas areas.

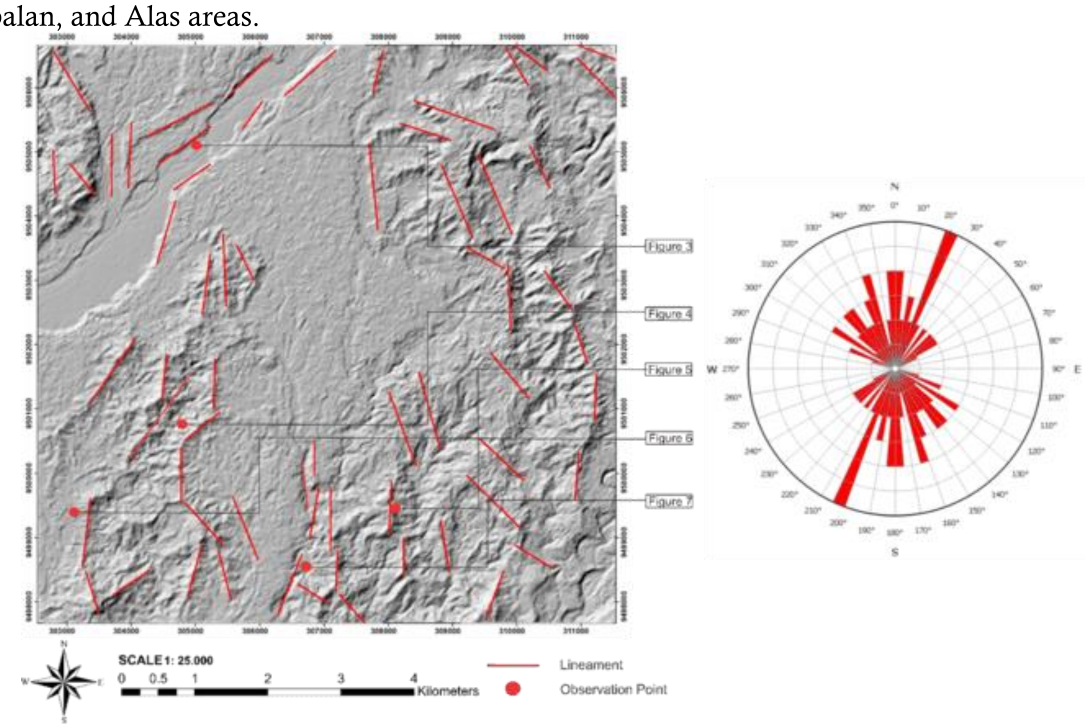

Figure 2. The grey generated DEM imagery showing the inferred lineament of landscape (left), and its trend shown in the rose diagram (right).

3.1. Manau IX Fault

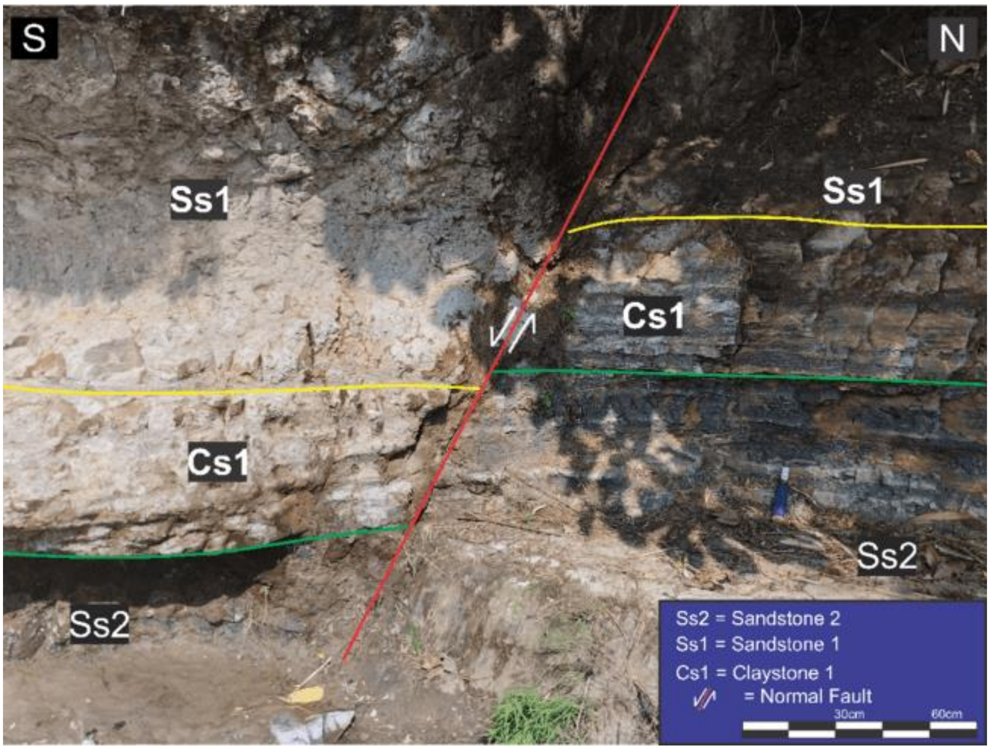

Figure 3. The outcropping rock units showing a normal fault striking NE-SW (N55˚E) and dipping SE (63˚).

In this particular spot there are two rock units, the Lemau's sandstone Ss2 and the Simpangaur's tuffaceous claystone Cs1 and sandstone Ss1 (Figure 3). Lithological characteristics of the faulted successions are briefly described that the sandstone Ss2 is light to dark grey in color, medium-fine sized grains, very well sorted, and non-carbonate, suggesting the non-marine depositional environment, whereas the overlying tuffaceous claystone is gray to brown in color, and shows a massive bed, and the top section is fossiliferous sandstone Ss1 bedding containing predominantly Mollusca, light to brownish dark grey in color, very fine sand grains, and well rounded.

It has been observed that the sequences have been faulted to the NE-SW direction or striking N55˚E and dipping ~63˚. The netslip of faulting is about 63˚, N135˚E, and pitch ~20˚, hence the structure is classified as horizontal dip-slip faulting (Fossen, 2010). Structural analysis using a stereographic model reveals that the main stress ($\sigma 1$) was 72˚, N338˚E and the minimum stress ($\sigma 3$) 18˚, N141˚E. In addition, it is interpreted that the tensional faulting may occur in relation to the movement of the Ketahun fault and the Manna faults around the region in the Miocene.

3.2. Bunian Fault

The Bunian Fault appears to deform the claystone and tuffaceous sandstone of the Simpangaur Formation (Figure 4). Lithology of the unit consists of claystone at the lower level (Cs), which is gray to brown, massive, and non-carbonate, and tuffaceous sandstone at the top section (Ss) that is light to dark grey, medium – fine sand grain, very well sorted, bedding structure and non-carbonate. The rock unit in this particular site has been faulted to the NE-SW direction or N100˚E with a dip of ~89˚. The netslip of faulting is about 89˚, N 124˚ E and pitch ~15˚, hence the structure is classified as a vertical strike slip fault (Fossen, 2010). Structural analysis using a stereographic model reveals that the main stress ($\sigma 1$) is 22˚, N283˚E and the minimum stress ($\sigma 3$) is 50˚, N043˚E. In addition, it is interpreted that the shearing deformation may occur in relation to the movement of the Sumatran fault and the Mentawai fault around the region in the Miocene.

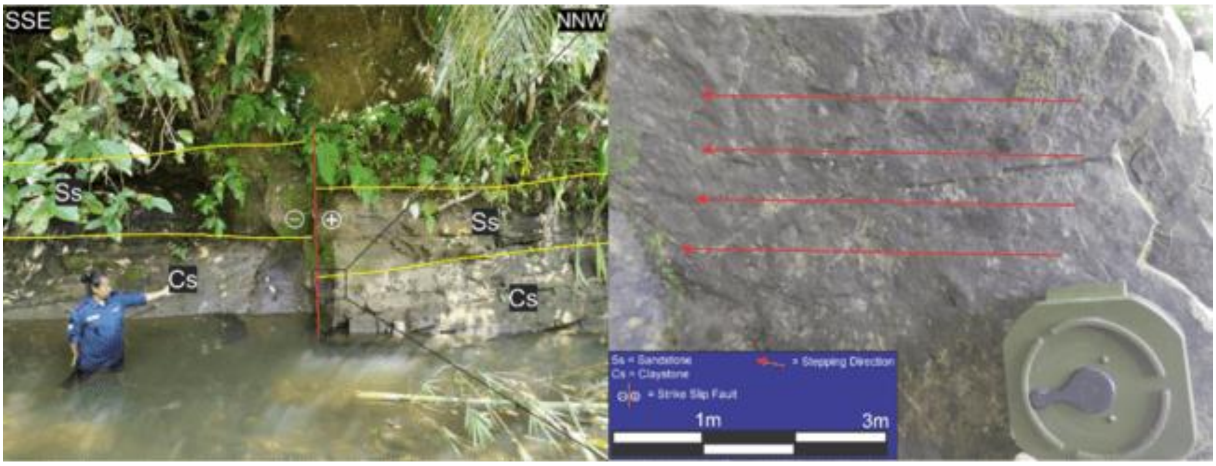

Figure 4. The outcropping rock units showing a strike slip fault striking NW-SE at N100˚E and dipping 89˚ to the SW direction.

3.3. Tanjung Kurung Fault

In this location there is an exposure of the rock unit from the Simpangaur Formation (Figure 5). The lithology of the unit is composed of intercalated sandstone and claystone. The lower sandstone bed (Ss1) contains predominantly Mollusca is light to dark grey color, very fine sand and rounded, the overlying claystone is gray to brown, and massive, whereas the upper sandstone layer (Ss2) contains predominantly Mollusca with light to dark grey color, very fine sand grain size, and well rounded. The intercalated rock section has been displaced due likely to faulting.

The fault trends NE-SW at N212˚E and dips ~69˚. The measured structural components show netslip ~64˚, N265˚E, and pitch ~75˚. These data suggest that the structure may be categorized as vertical dip-slip fault (Fossen, 2010), or normal-slip fault (Richard, 1972). Additionally, the stereographic model used for analysis reveals the main stress (σ1) is 63˚, N147˚E and the minimum stress is (σ3) 24˚, N299˚E. It is also interpreted that the tensional faulting may occur in association with the movement of Ketahun fault and the Manna fault around the region in the Miocene.

Figure 5. The outcropping rock units showing a normal fault striking NE-SW (N212˚E) and dipping NW (69˚).

3.4. Padang Manis Fault

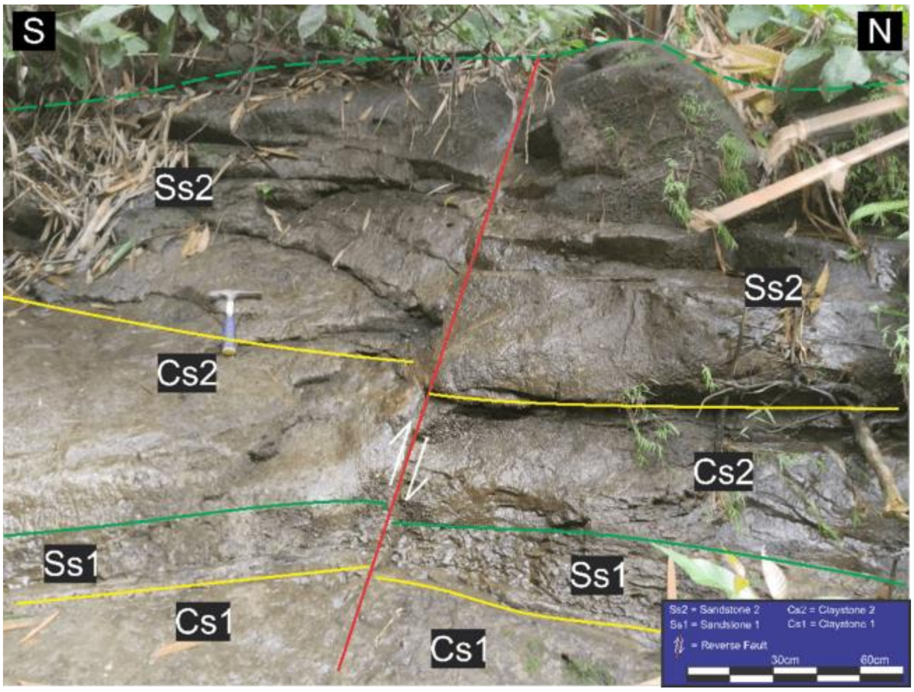

Figure 6. The outcropping rock units showing a reverse fault striking NW-SE (N229˚E) and dipping NW (70˚).

Within the Padang Manis river there is an outcrop of intercalated sandstone and claystone (Figure 6). In this site, the lower claystone (Cs1) is gray to brown color and massive structure, the overlying sandstone (Ss1) is light to dark grey color, very fine sand, well rounded, and non-carbonate, the upper claystone (Cs2) is gray to brown color, massive structure, non-carbonate, and the uppermost sandstone (Ss2) is light to dark grey color, very fine sand, well rounded, bedding structure and non-carbonate. The rock section has been displaced due to faulting.

Field observation on the outcrop suggests that the sequence has been faulted to the NE-SW direction or N229˚E with a dip of ~70˚. The netslip of faulting is about 70˚, N135˚E and pitch ~44˚, hence the structure is classified as vertical oblique slip fault (Fossen, 2010). Structural analysis using stereographic model reveals that the main stress ($\sigma 1$) is 24˚, N318˚E and the minimum stress is ($\sigma 3$) 66˚, N142˚E. In addition, it is interpreted that the compression faulting may occur in relation to the movement of Ketahun fault and the Manna fault around the region in the Miocene.

3.5. Aek Kule Syncline

The Aek Kule outcrop displayed a folding feature, suggesting a compressional-typed structure. Field observation and measurement on the exposure showed that the WNW limb strikes to N235˚E and dips 22˚ to ESE, and the ESE limb trikes to N58˚E and dips 19˚ to WNW. This suggests that the outcrop shows a synclinal structure (Figure 7). The syncline is formed by tuffaceous sandstone and tuffaceous claystone of Simpangaur Formation. Petrological characteristics of the folded successions are briefly described that the lower sandstone (Ss2) is white to grey, medium – fine sand, very well sorted, grain supported fabric, lamination structure and non-carbonate, the overlying claystone (Cs2) is gray to brown, massive structure and non-carbonate, the upper sandstone (Ss1) is white to grey, medium – fine sand, very well sorted, grain supported fabric, lamination structure and non-carbonate, the uppermost claystone (Cs1) is light to gray to brown color, massive structure and non-carbonate. The measured interlimb angle is about 137˚ or gentle, and the fold axis inclines about 86˚ or upright. Thus, the Aek Kule folding feature is classified as a gentle-upright syncline (Fluety, 1964).

Figure 7. Aek Kule folding feature showing a gentle-upright syncline.

Figure 8 displays a structural map constructed based on field data collected by DEM interpretation. The map depicts two generally trending structural landforms, with NE-SW extensional forces represented mainly by thrust faults, and NW-SE compressional forces including folds, strike-slip and reverse faults. In addition, NE-SW extensional forces occurred due to the influence of the movement of the Ketahun fault and Manna fault in the Miocene era. However, the NW-SE compression structure shows that the resulting structure is influenced by structural control in the direction of the Sumatran fault and the Mentawai fault. In this case, the Bengkulu basin entered into 2 different processes where in the Paleogene it produced a NE-SW oriented rifting phase, which was then overwritten by oblique slip movement with a NW-SE orientation (Hall et al, 1993). The Late Neogene orogeny is considered the last tectonic event responsible for the inversion of the Bengkulu basin from tensional faults (Yulihanto et al, 1995).

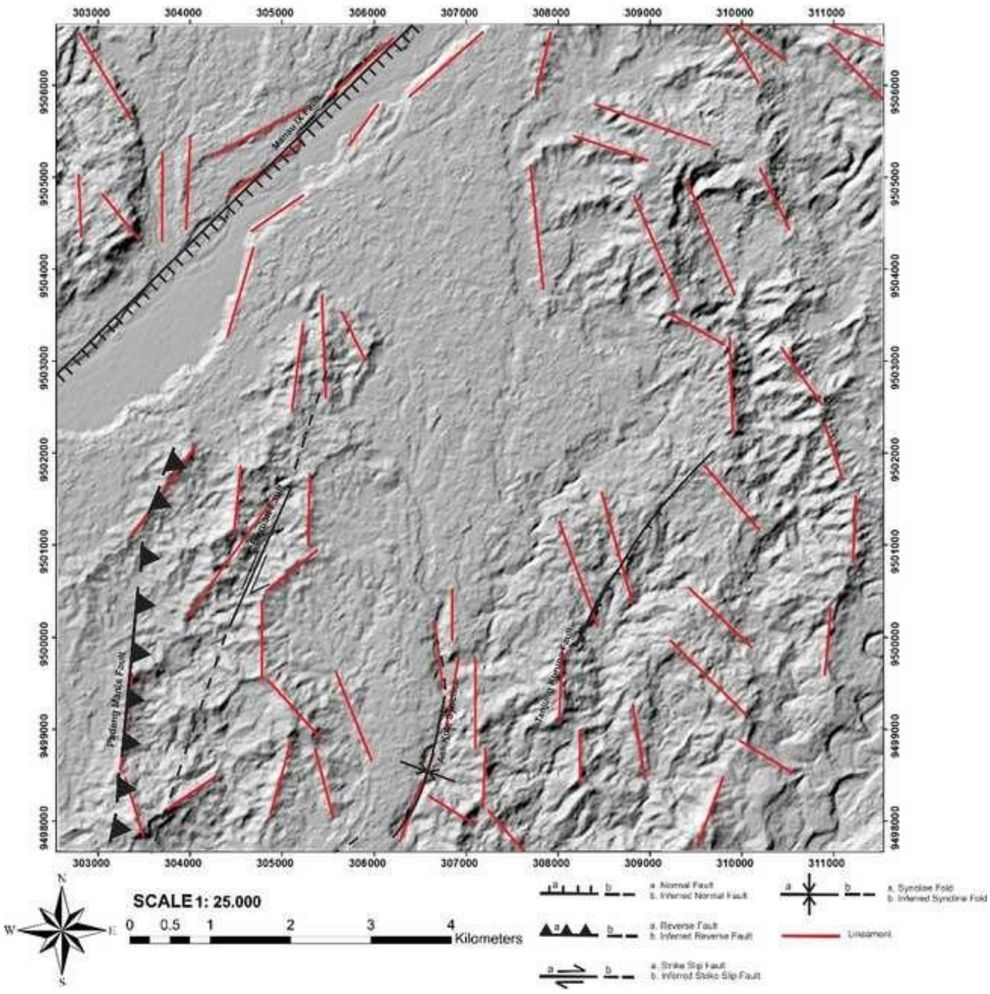

Figure 8. The map displaying trends generated from intergration of field data and DEM interpretation.

4. CONCLUSIONS

Based on the lineament analysis of the DEM map and surface geological mapping in the Tanjung Betung II region, it can be concluded that the research area shows tectonic structures with a general orientation of NW-SE. These include brittle and ductile-typed deformation, such as the Manau IX fault, Bunian fault, Tanjung Kurung fault, Aek Kule syncline, and Padang Manis fault. The tectonic deformation of the rock succession may take place during the episode of graben formation in Neogene, likely associated with the movement of Sumatran Fault System and Mentawai Fault System which are both striking to the NW-SE direction. The period of structuring occurred in accordance with the onset of Barisan Orogeny in Late Neogene. This study has many potential applications in industries that are closely related to geological structures, such as geothermal and even regarding the risk of earthquakes that also occur in the research area which can be further developed by analyzing tectonic movements and also validating and accurate DEM data.

5. REFERENCES

Allmendinger, R.W. (2012). Manual Fault Fold Forward v.6, Geological Society of America Abstracts with Programs. 1-19.

Alviyanda et al. (2023). Studi Batuan Asal (Provenance) Batupasir Formasi Simpangaur Daerah Way Krui, Lampung. Journal of Science and Applicative Technology vol. 7 (1), 2023, pp. 26-34. doi: https://doi.org/10.35472/jsat.v7i1.1086.

Amin, Gafoer, S., T.C., Kusnama, dan Rustandi, E. (1993). Peta Geologi Lembar Manna dan Enggano, Sumatra, Skala 1:250.000. Bandung : Pusat Penelitian dan Pengembangan Geologi.

Barber, A.J., and Crow, M.J. (2003). An Evaluation of Plate Tectonic Models for the Development of Sumatra Gondwana Research.

Cardozo, N., Bawa-Bhalla, K., Zehnder, A.T., and Allmendinger, R.W. (2003). Model Mekanis Lipatan Perambatan Sesar dan Perbandingan dengan Model Kinematik Trishear. Jurnal Geologi Struktural, 25 (1): 118.

Fluety, M.J. (1964). The Description of Folds. In Proceedings of the PGA, 75, 461-492. Proceedings of the Geologist' Association.

Fossen, H. (2010). Structural Geology. New York: Cambridge University Press.

Harding, T.P. (1973). Newport-Inglewood Trend, California Contoh Deformasi Gaya Wrench, Amerika. Buletin Asosiasi Ahli Geologi Perminyakan, Vol. 57, no.1, 97- 116.

Heryanto, R. dan Suyoko. (2007). Karakteristik Batubara di Cekungan Bengkulu. Jurnal Geologi Indonesia, Vol. 2 No. 4. pp. 247-259. doi:10.17014/ijog.2.4.247-259

McClay, K. (1987). The Mapping of Geological Structures. London: Department of Geology Royal Holloway and Bedford New College, University of London, 161 pp.

Mentari, Sakilla Gia et al. (2023). Paleoenvironment of the Miocene Lemau Formation Based on the Palynology Analysis in Seluma, Bengkulu. Journal Jambura Geoscience Review Vol 5, No.1, January 2023: 33-41. doi: 10.34312/jgeosrev.v5i1.17150

Mukti, M.M., Singh S.C., Delighton, I., Hananto, N.D., Moeremans, R., and Permana, H. (2012). Structural Evolution of Back thrusting in The Mentawai Fault Zone, Offshore Sumatran Forearc. Geochem. Geophysics. Geosyst., 13, Q12006.

Pulonggono, A. dan Cameron, N.R. (1984). Sumatran microplates, their characteristics and their role in the evolution of the Central and South Sumatera basins. In Proceedings of the IPA, 1221 – 1443. Proceedings 13th Annual Convention, IPA.

Rickard, M. J. (1972). Fault Classification: Discussion. Geological Society Of America Bulletin, 83 (8), 2545–. doi:10.1130/0016-7606(1972)83[2545: Fcd]2.0. Co;2

Saleem, T. A. (2013). Analysis and Tectonic Implication of DEM-Derived Structural Lineaments, Sinai Peninsula, Egypt, International Journal of Geoscience.

Simandjuntak, T.O., and Barber, A.J. (1996). Contrasting Tectonic Styles in The Neogene Orogenic Belts of Indonesia. Geological Society Special Publication, 106, 185-201.

Tarigan, S. A., & Sutriyono, E. (2018). Geologi Dan Lingkungan Pengendapan Formasi Lemau Daerah Tanjungdalam Dan Sekitarnya, Bengkulu Utara (Skripsi, Universitas Sriwijaya). Diperoleh dari https://repository.unsri.ac.id/7718/

Trilaksana, M.J. (2017). Pola Struktur Geologi Dan Evolusi Tektonik Daerah Bengkulu, Lahat, Muara Enim dan Pagar Alam Cekungan Bengkulu Sumatera Selatan Berdasarkan Data Permukaan (Skripsi, Universitas Trisakti). Diperoleh dari http://repository.trisakti.ac.id

Yulihanto, B., Situmorang, B., Nurdjajadi, A., and Sain, B. (1995). Structural Analysis of The Onshore Bengkulu Forearc Basin And its Implication for Future Hydrocarbon Exploration Activity. In Proceedings of the IPA, 85-96. Proceedings 24th Annual Convention, IPA.