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THE STRATIGRAPHY AND GEOLOGICAL STRUCTURE IN KOTAAGUNG TIMUR DISTRICT, TANGGAMUS, LAMPUNG

STRATIGRAFI DAN STRUKTUR GEOLOGI KABUPATEN KOTAAGUNG TIMUR, TANGGAMUS, LAMPUNG

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Abstract. Kotaagung Timur region, Tanggamus Regency, Lampung, is the focus area of this research. In general, the area has a unique and complex geological setting such as the variety of volcanic rocks, granite, and the Sumatran Fault System that through this area. Geological research aims to obtain geology dynamics about stratigraphy and geology structure in the research area. Two analyses have been done to achieve these goals, i.e., field observation, petrography analysis, and structural geology analysis. The stratigraphy units of the study area are composed of volcanic rocks, plutonic rocks, and surface deposits and can be divided into eleven lithostratigraphic units. The stratigraphy of the research area can be grouped into 5 groups, i.e., the Mount Gisting volcanic group, the granitoid pluton group, the Cawang Haro Mountains volcanic group, the Mount Tanggamus volcanic group, and the alluvial deposit. Geological structures are well developed, and the research area is cut by ten faults, such as dextral strike-slip faults, sinistral strike-slip faults, and reverse faults. Based on these things, the geological history of the study area started in the Late Oligocene with three episodes of volcanism. The first episode was Mount Gisting's volcanism during the Late Oligocene-Early Miocene, followed by the granitoid intrusion. The volcanic products of the Cawang Haro Mountains in the Middle Miocene mark the second episode. The last volcanic episode occurred in the Holocene, it came from Mount Tanggamus's volcanism. The development of the structural geology happened before the previous volcanism episode.

Abstrak. *Wilayah Kotaagung Timur, Kabupaten Tanggamus, Lampung, menjadi fokus penelitian ini. Secara umum, wilayah ini memiliki tatanan geologi yang unik dan kompleks seperti keragaman batuan gunung api, granit, dan Sistem Sesar Sumatera yang melintasi wilayah ini. Penelitian* *geologi bertujuan untuk memperoleh dinamika geologi tentang stratigrafi dan struktur geologi di wilayah penelitian. Untuk mencapai tujuan tersebut, dilakukan dua analisis, yaitu pengamatan lapangan, analisis petrografi, dan analisis geologi struktur. Satuan stratigrafi wilayah penelitian tersusun atas batuan gunung api, batuan plutonik, dan endapan permukaan, serta dapat dibagi menjadi sebelas satuan litostratigrafi. Stratigrafi wilayah penelitian dapat dikelompokkan menjadi 5 kelompok, yaitu kelompok gunung api Gunung Gisting, kelompok pluton granitoid, kelompok gunung api Pegunungan Cawang Haro, kelompok gunung api Gunung Tanggamus, dan endapan aluvial. Struktur geologi berkembang dengan baik, dan daerah penelitian dipotong oleh sepuluh patahan, seperti patahan geser dekstral, patahan geser sinistral, dan patahan naik. Berdasarkan hal-hal tersebut, sejarah geologi daerah penelitian dimulai pada Oligosen Akhir dengan tiga episode vulkanisme. Episode pertama adalah vulkanisme Gunung Gisting pada Oligosen Akhir-Miosen Awal, diikuti oleh intrusi granitoid. Episode kedua ditandai oleh produk vulkanik Pegunungan Cawang Haro pada Miosen Tengah. Episode vulkanisme terakhir terjadi pada Holosen, berasal dari vulkanisme Gunung Tanggamus. Perkembangan geologi struktur terjadi sebelum episode vulkanisme sebelumnya.*

1. INTRODUCTION

Lampung Province is the southernmost region of Sumatra Island. This province is predominantly composed of volcanic and plutonic rocks associated with subduction since the Mesozoic era (Amin et al., 1993; Barber et al., 2005; Mangga et al., 1993; Mccourt et al., 1996). Lampung Province is also traversed by the Sumatra Fault System, particularly in Tanggamus Regency, which is crossed by the Semangko Fault (Natawidjaja, 2018; Sieh & Natawidjaja, 2000).

Kotaagung Timur Sub-district is located north of Semangko Bay and south of Mount Tanggamus. In this area, three volcanic rock formations of varying ages and Early Miocene intrusive rocks are exposed (Amin et al., 1993). This geological diversity presents a unique characteristic of the Kotaagung Timur region. Furthermore, the development of the Sumatra Fault System adds complexity to the geological information of the Kotaagung Timur area. Based on this uniqueness and geological complexity, the objective of this study is to understand the geological dynamics related to the stratigraphic relationships and the presence of structures that have developed in the research area. This research is expected to yield new and more detailed geological information.

2. LITERATURE REVIEW

In the southern part of Sumatra Island, the active segments of the SFS are the Semangko Segment and the Sunda Segment. The northern boundary of the Semangko Segment is defined by the Suoh step-over valley (Aribowo et al., 2017), and this segment branches into two main faults: the Eastern Semangko Fault and the Western Semangko Fault (Natawidjaja, 2018). The northern boundary of the Eastern Semangko Fault connects with the Kumering Segment, and the southern part of this fault gradually closes around Kotaagung but continues to form a graben structure in the Sunda Strait. The absence of seismic activity in the eastern part of Semangko Bay indicates that the Eastern Semangko Fault has been inactive during the Quaternary (Natawidjaja, 2018). In the works of Susilohadi et al. (2009) and Mukti (2018), this fault is also referred to as the Kotaagung Fault (**Figure 1**).

The Semangko Fault exhibits a significant dip-slip component, resulting in the formation of a depression around Kotaagung (Barber et al., 2005). This depression extends into the Sunda Strait, subsequently forming the Eastern Semangko Graben and the Western Semangko Graben (Mukti, 2018; Natawidjaja, 2018; Susilohadi et al., 2009).

Based on Amin et al. (1993), the stratigraphy of the research area, from oldest to youngest, consists of the Hulusimpang Formation, Granitic Intrusive Rocks, and Bal Formation. The regional stratigraphic sequence is illustrated in **Figure 2**. The Hulusimpang Formation extensively covers the research area and is estimated to date from the Late Oligocene to the Early Miocene (Amin et al., 1994; Bellon et al., 2004). The Hulusimpang Formation comprises volcanic breccia, andesitic-basaltic lava, and andesitic-basaltic tuff that have undergone weak (<25%) to moderate (25%-75%) hydrothermal alteration, characterized by propylitic alteration with minor argillic alteration, forming quartz veins, and containing sulphide minerals (Amin et al., 1994; Setiawan et al., 2005). The Hulusimpang Formation found around Tanggamus exhibits a tholeiitic magma affinity and was formed in an island arc tectonic setting (Zulkarnain, 2011).

The intrusive rocks with a granitic composition are estimated to be around 18.7-20.1 million years old, corresponding to the Early Miocene (Amin et al., 1994). These intrusive rocks are classified as I-type granite with volcanic arc granite (VAG) characteristics and are associated with subduction processes (Mccourt et al., 1996). These granitic intrusive rocks are considered products of continuous subduction since the Early Mesozoic, although plutonism occurred episodically. The granitic intrusive rocks are distributed only around the Semangko Fault and intrude into the Hulusimpang Formation (Amin et al., 1994; Mccourt et al., 1996). Despite their alignment with the fault zone, this intrusion event occurred prior to the formation of the Semangko Fault (Barber et al., 2005).

The Bal Formation is a group of volcanic rocks consisting of volcanic breccia and tuff with a dacitic composition, accompanied by intercalations of sandstone. According to Amin et al. (1994), the Bal Formation is estimated to have been deposited in a terrestrial environment during the Middle Miocene. The dacitic tuff is unconformably overlaid on the Hulusimpang Formation (Barber et al., 2005).

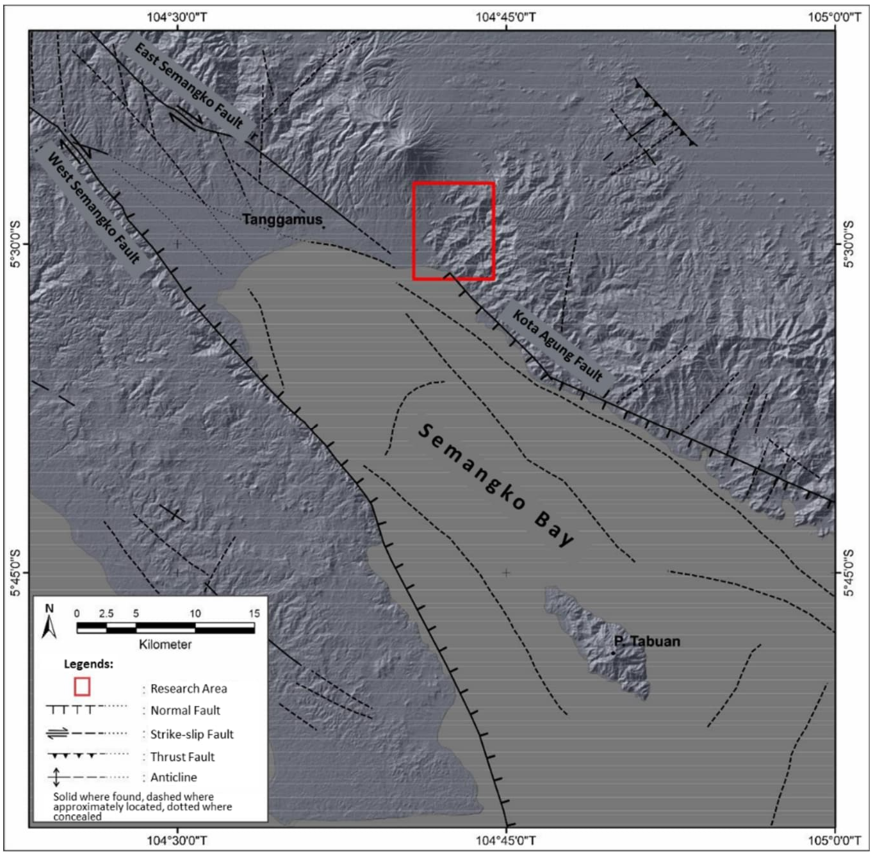

Figure 1. The geological structure distribution map around Semangko Bay (modified from Mukti, 2018; Natawidjaja, 2018; Susilohadi et al., 2009; Amin et al., 1993) indicates the location of the research area, which is symbolized by a red box.

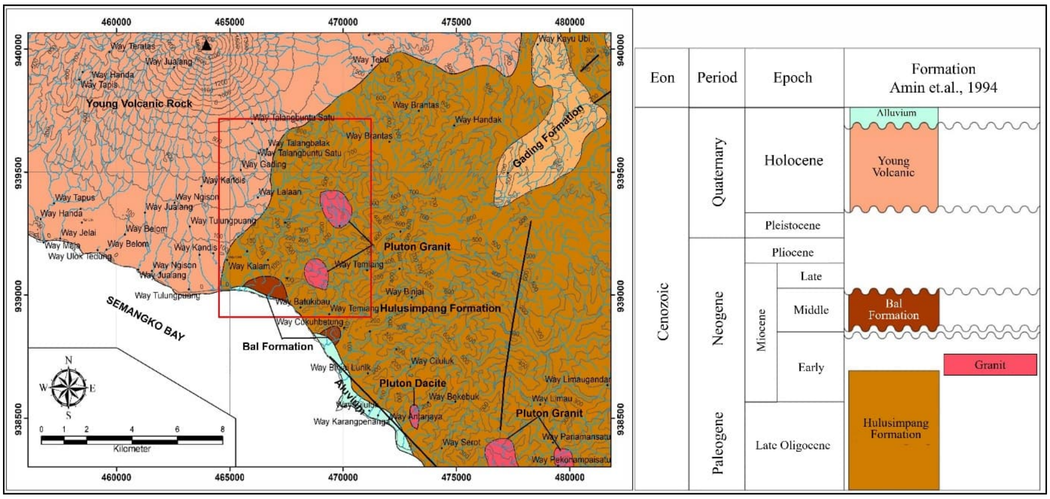

Figure 2. The regional geological map and stratigraphic column surrounding the research area (modified from Amin et al., 1993) indicate the research area's location, symbolized by a red box.

3. METHODS

This study used field mapping, petrographic analysis, and geological structural analysis. Geological mapping was carried out in the Kotaagung Timur area, located approximately 85 km from Bandar Lampung City, covering an area of 49 km². This activity aimed to collect field data, including lithological characteristics, stratigraphic relationships, and the manifestation of geological structures in the research area. The petrographic analysis utilized 23 thin-section samples to identify mineralogy, texture, and structure. The classification of pyroclastic rocks was based on Schmid (1981), while igneous rocks were named according to the IUGS classification by Le Bas & Streckeisen (1991), followed by the dominant mineral type in the lithology. Petrographic analysis was conducted using a polarizing microscope in the Petrology Laboratory at the Institute of Technology Sumatra. This analysis aimed to describe lithological names and determine the genesis of rock formation.

4. RESULTS AND DISCUSSION

4.1 Stratigraphy

The tertiary stratigraphy of the research area is divided into 7 lithostratigraphic units, which can be grouped into three categories: the Gunung Gisting Volcanic Rock Group, Granitoid Pluton, and Cawang Haro Mountain Volcanic Rock Group (**Figure 3**).

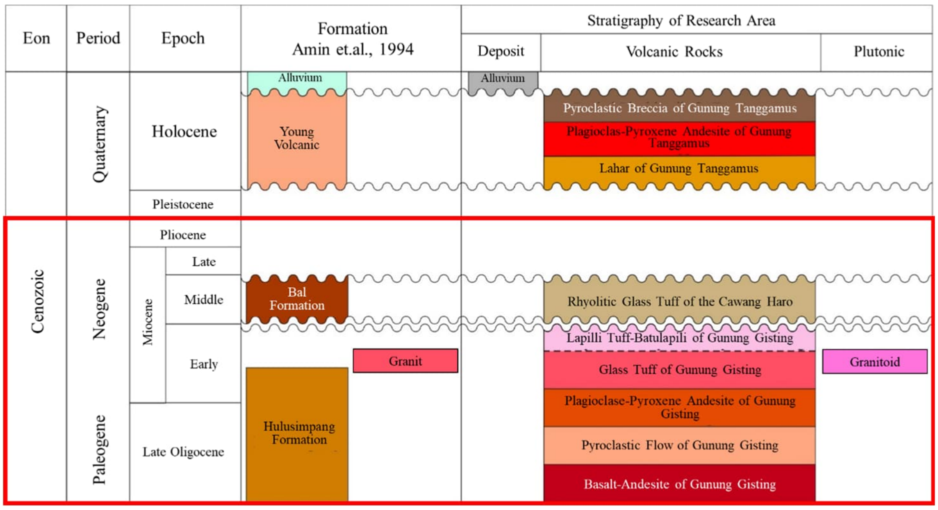

Figure 3. Stratigraphy column in the research area. Stratigraphy in the research area is in the red square.

4.1.1. Mount Gisting Volcanic Rock Group

This rock group comprises five units: the Basal-Andesite Unit of Gunung Gisting, the Pyroclastic Flow Unit of Gunung Gisting, the Plagioclase-Pyroxene Andesite Unit of Gunung Gisting, the Glass Tuff Unit of Gunung Gisting, and the Lapilli Tuff-Batulapili Unit of Gunung Gisting. These units are correlated with the Hulusimpang Formation, which dates from the Late Oligocene to the Early Miocene (Amin et al., 1993), and have undergone hydrothermal alteration. Most of these units are found in a fresh state.

The Basalt-Andesite Unit of Gunung Gisting is composed of igneous rocks ranging from basaltic to andesitic lava and is the oldest unit in the research area (**Figure 4a**). The andesite exhibits vesicular, amygdaloidal, and trachytic structures and is composed of plagioclase, chlorite, tremolite, epidote, opaque minerals, zeolite, secondary quartz, and secondary muscovite. Petrographic observations of andesite samples indicate that the pyroxene and plagioclase have been altered by muscovite, tremolite, epidote, secondary quartz, calcite, and chlorite (**Figure 5a**). The basalt exhibits intergranular, intersertal, vesicular and amygdaloidal structures filled with chlorite and secondary quartz while the main minerals are plagioclase, calcite, chlorite, epidote, opaque minerals, and secondary quartz (**Figure 5b**). Olivine phenocrysts have been replaced by calcite, while the groundmass (plagioclase, volcanic glass, and pyroxene) has been altered by calcite, chlorite, and epidote.

The Pyroclastic Flow Unit of Gunung Gisting is deposited conformably above the Basalt-Andesite Unit of Gunung Gisting (**Figure 4b**) and consists of pyroclastic flow deposits, such as crystal tuff, welded tuff, pyroclastic breccia, and lahar breccia. The pyroclastic breccia exhibits a megascopic appearance with a grayish-brown color, grain sizes ranging from ash to blocks, angular to sub-angular fragments, matrix-supported, very poor sorting, and fragments composed of andesite, basalt, and tuff. Petrographic examination of the matrix of the pyroclastic breccia reveals glass tuff (Schmid, 1981) composed of secondary quartz, lithic fragments, plagioclase, chlorite, illite, quartz, opaque minerals, and epidote (**Figure 5c**).

The Plagioclase-Pyroxene Andesite Unit of Gunung Gisting is composed of andesitic lava and conformably overlies the Pyroclastic Flow Unit of Gunung Gisting (**Figure 4d**). The andesite lithology exhibits amygdaloidal and trachytic structures. The mineral composition of this lithology includes plagioclase, glass, chlorite, opaque minerals, pyroxene, calcite, and illite. The plagioclase groundmass and volcanic glass have been partially altered by chlorite.

The Glass Tuff Unit of Gunung Gisting is deposited above the Plagioclase-Pyroxene Andesite Unit and exhibits flow structures. The altered glass tuff lithology is composed of lithic fragments, secondary quartz, smectite, illite, zeolite, and opaque minerals. In addition to lithic fragments, the primary composition of this lithology consists of volcanic glass, even though the volcanic glass has been completely replaced by smectite, illite, and secondary quartz (**Figure 5d**).

The Lapilli Tuff Unit of Gunung Gisting is composed of interbedded lapilli tuff, lapilli, and tuff. The lapilli tuff has grain sizes from ash to lapilli and vesicular structures (**Figure 4c**). The batulapili consists of lapilli-sized grains, vesicular structures, and accretionary lapilli texture. Petrographic observations reveal the presence of volcanic glass, pyroxene, lithic fragments, quartz, hornblende, and plagioclase (**Figure 5f**) without secondary minerals. This lithology is assumed to be a product of pyroclastic fall deposits of Gunung Gisting in the Early Miocene, after the intrusion of the Granitoid Unit.

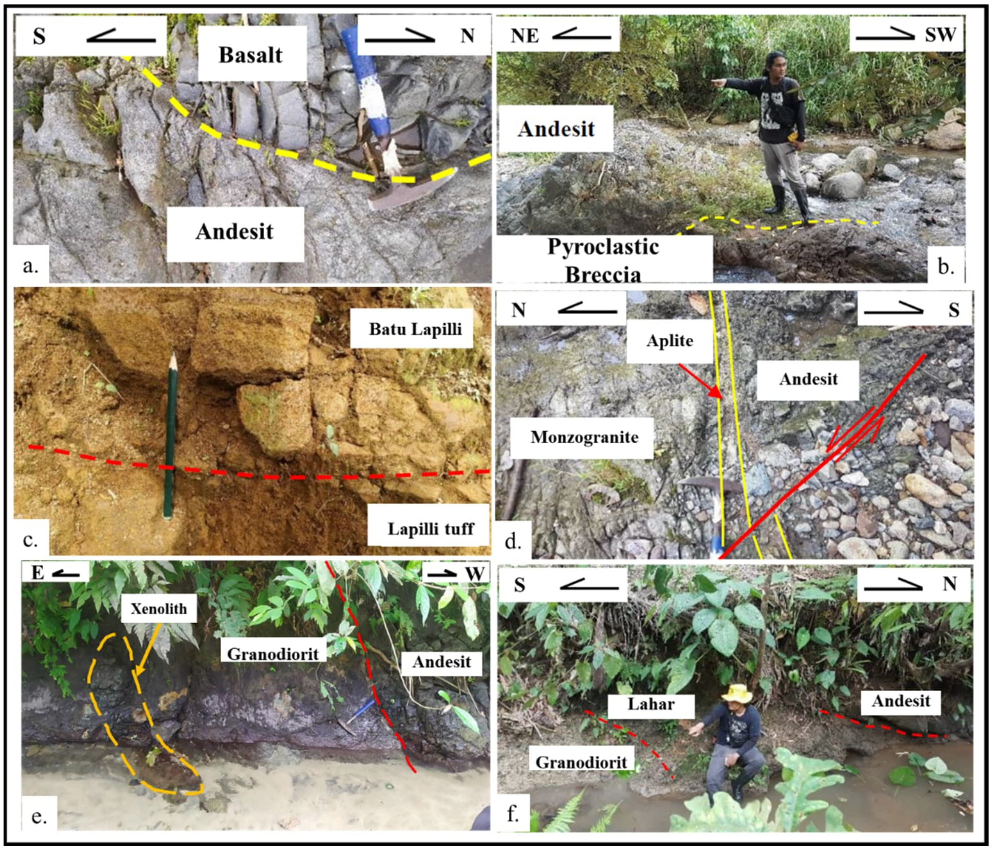

Figure 4. Outcrops of rocks in the research area: (a) The lithological contact between basalt and andesite in the Basalt-Andesite Unit of Gunung Gisting. (b) The contact between the Basalt-Andesite Unit of Gunung Gisting and the Pyroclastic Flow Unit of Gunung Gisting. (c) The Lapilli Tuff-Batulapili Unit of Gunung Gisting. (d) The contact between the Granitoid Unit and the Plagioclase-Pyroxene Andesite Unit of Gunung Gisting. (e) The intrusion of granodiorite into andesite. (f) The stratigraphic relationship of the Pyroclastic-Lahar Breccia Unit of Gunung Tanggamus with the Granitoid Unit and the Plagioclase-Pyroxene Andesite Unit of Gunung Tanggamus.

4.1.2. Granitoid Pluton

The Granitoid Pluton is composed of the Granitoid Unit, which exhibits monzogranite and granodiorite lithologies with a lens-shaped characteristic. It is correlated with granite that is approximately 18-20 million years old, corresponding to the Early Miocene (Amin et al., 1993; McCourt et al., 1996). The monzogranite features crystal sizes up to 4 mm and contains andesitic xenoliths. In this outcrop, an intrusive contact between the Granitoid Unit and the Plagioclase-Pyroxene Andesite Unit of Gunung Gisting is observed (**Figure 4e**).

Additionally, there are aplite veins or discontinuous fractures in the surrounding rock (**Figure 4d**). This indicates that tectonic activity in the research area was already active prior to the formation of the Granitoid Unit. This tectonic activity is estimated to have been active at least during the Early Miocene or before the formation of the Sumatra Fault System in the Middle Miocene (McCarthy & Elders, 1997).

Petrographic analysis results indicate that this unit has undergone hydrothermal alteration, characterized by the presence of alteration minerals such as plagioclase, quartz, K-feldspar, hornblende, chlorite, illite, actinolite, opaque minerals, and epidote (**Figure 5e**). The hydrothermal alteration is marked by potassic-propylitic alteration and propylitic alteration. The potassic alteration in the research area is characterized by secondary biotite, secondary K-feldspar, and tremolite, while the propylitic alteration is characterized by chlorite and epidote minerals (Corbett et al., 1997).

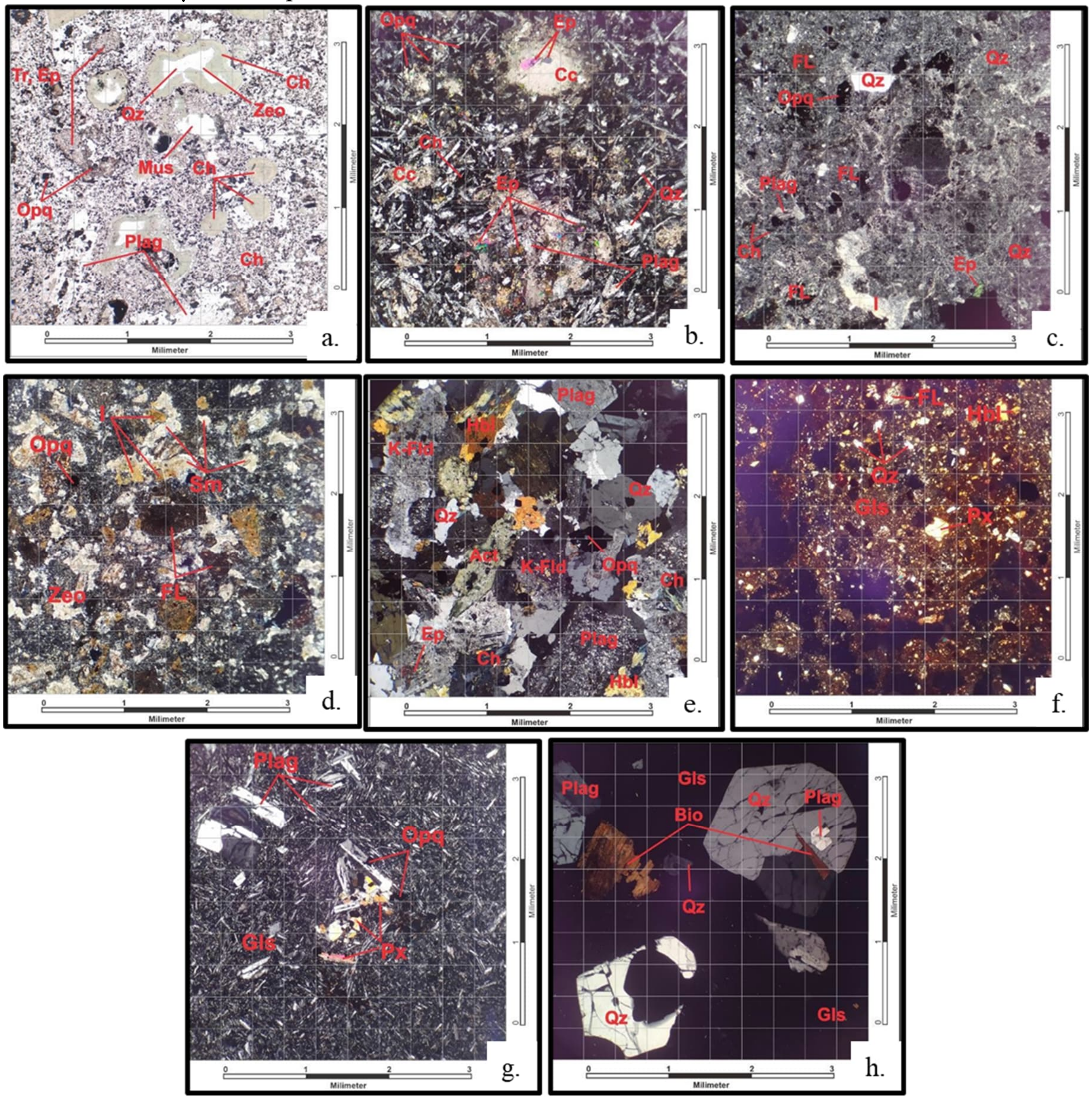

Figure 5. Petrographic samples from each unit present in the research area: (a) Petrography of andesite and (b) petrography of basalt in the Basalt-Andesite Unit of Gunung Gisting. (c) Petrography of the matrix of the pyroclastic breccia in the Pyroclastic Flow Unit of Gunung Gisting. (d) Petrography of glass tuff in the Glass Tuff Unit of Gunung Gisting. (e) Petrography of monzogranite in the Granitoid Unit. (f) Petrography of batulapili in the Lapilli Tuff-Batulapili Unit of Gunung Gisting. (g) Petrography of andesite in the Plagioclase-Pyroxene Andesite Unit of Gunung Tanggamus. (h) Petrography of glass tuff in the Rhyolitic Glass Tuff Unit of the Cawang Haro Mountains. Tr: tremolite, Ep: epidote, Qz: quartz, Ch: chlorite, Zeo: zeolite, Mus: muscovite, Opq: opaque, Cc: calcite, FL: lithic fragment, I: illite, Sm: smectite, K-Fld: K-feldspar, Act: actinolite, Hb: hornblende, Gls: volcanic glass, Px: pyroxene, Bio: biotite.

4.1.3. Volcanic Rocks of The Cawang Haro Mountain

The volcanic products of the Cawang Haro Mountains consist of rhyolitic glass tuff with lapilli-sized grains with pumice fragments, which are part of the Rhyolitic Glass Tuff Unit of the Cawang Haro Mountains. This unit is located within the Bukit Barisan Selatan National Park and was deposited through pyroclastic flow mechanisms, correlating with the Bal Formation, which dates to the Middle Miocene (Amin et al., 1993). Petrographic examination reveals distinctive textures, including vitrophyric, fiamme, and embayment textures in quartz minerals. This lithology is composed of volcanic glass, plagioclase, quartz, and biotite (**Figure 5h**).

4.2. Geology Structure

The geological structures developed in the research area can be classified into three types based on their movement: Strike-Slip Faults, Oblique Slip Faults, and Thrust Faults.

4.2.1. Strike-Slip Fault

The strike-slip faults include three main fault features: the Kotaagung Fault, the Sukabanjar Strike-Slip Fault, and the Way Pihabung Strike-Slip Fault. The Kotaagung Fault extends along the eastern side of Semangko Bay, oriented northwest-southeast (Susilohadi et al., 2009), and is a branch of the Semangko Segment (Natawidjaja, 2018). This fault is defined as the primary structure in the research area and has been identified through satellite imagery analysis by examining linear features and the morphology of the escarpment. Barber & Crow (2005) state that the lateral movement of this fault is dextral with a significant dip-slip component and activated during the Middle Miocene (McCarthy & Elders, 1997).

The Sukabanjar Strike-Slip Fault (**Figure 6c**) is a part of Kotaagung Fault Zona. It associated with these shear fractures is a strike-slip fault (Anderson, 1951) with lateral movement and intersects Tertiary-aged units.

The Way Pihabung Strike-Slip Fault (**Figure 6d-e**) is identified on the fault plane, with a strike and dip of N150°E/86°SW and a pitch of 20°. According to Rickard (1972), this type of fault is classified as a Normal Right Slip Fault as a complementary structure to the Kotaagung (Wilcox et al., 1973).

4.2.2. Oblique Slip Fault

The oblique-slip faults are characterized by the presence of three types of faults: the Way Lalaan Strike-Slip Fault, the Way Temiang Oblique Slip Fault, and the Way Pihabung Oblique Slip Fault. The Way Lalaan Strike-Slip Fault is identified by the presence of a fault plane with a strike and dip of N278°E/70°NE and a pitch of 4° (**Figure 6b**). According to Rickard (1972), this type of fault is categorized as a left slip fault. Based on the interpretations of Moody and Hill (1956), the Way Lalaan Strike-Slip Fault is interpreted as a third-order fault. This fault is identified as cutting through the Plagioclase-Pyroxene Andesite Unit of Gunung Gisting and has been filled with secondary minerals. It is estimated to have been active from the late Oligocene to early Miocene.

The Way Temiang Oblique Slip Fault is identified on the fault plane, with data indicating a strike and dip of N48°E/52°SE and a pitch of 26°. According to Rickard (1972), this type of fault is categorized as a Reverse Left Slip Fault and interpreted as an antithetic fault accompanying the Kotaagung Fault (Wilcox et al., 1973).

The Way Pihabung Oblique Slip Fault is inferred based on the analysis of paired shear fractures, with the fault strike determined from the linearity of the northeast-southwest trending valley at the shear fracture measurement site. Based on dynamic analysis, this fault is classified as a strike-slip fault, exhibiting lateral sinistral movement, and is considered an antithetic fault to the Kotaagung Fault (Wilcox et al., 1973).

4.2.3. Thrust Fault

The Pahabung Thrust Fault is identified on the fault plane exposed at the Pahabung Bawah outcrop (**Figure 6a**) with a strike and dip of N210°E/64°NW, and a pitch of 86°. According to Rickard (1972), this type of fault is categorized as a reverse slip fault. Based on the interpretations of (Moody & Hill, 1956), the Pahabung Thrust Fault is interpreted as a second order thrust fault. This fault is identified as cutting through the Basal-Andesite Unit of Gunung Gisting and is filled with secondary minerals. It is estimated to have been active from the late Oligocene to early Miocene.

Around the Way Pihabung River, three fault planes are exposed, consisting of a brecciation plane and two fault planes, with the orientations of N306°E/80°NE, N300°E/32°NE (with an offset of aplite veins), and N295°E/72°NE, which exhibits striations with a pitch of 70°. The direction of movement for the faults referred to as a Left Reverse Slip Fault (Rickard, 1972) and is interpreted as accompanying structures to the Kotaagung Fault (Wilcox et al., 1973).

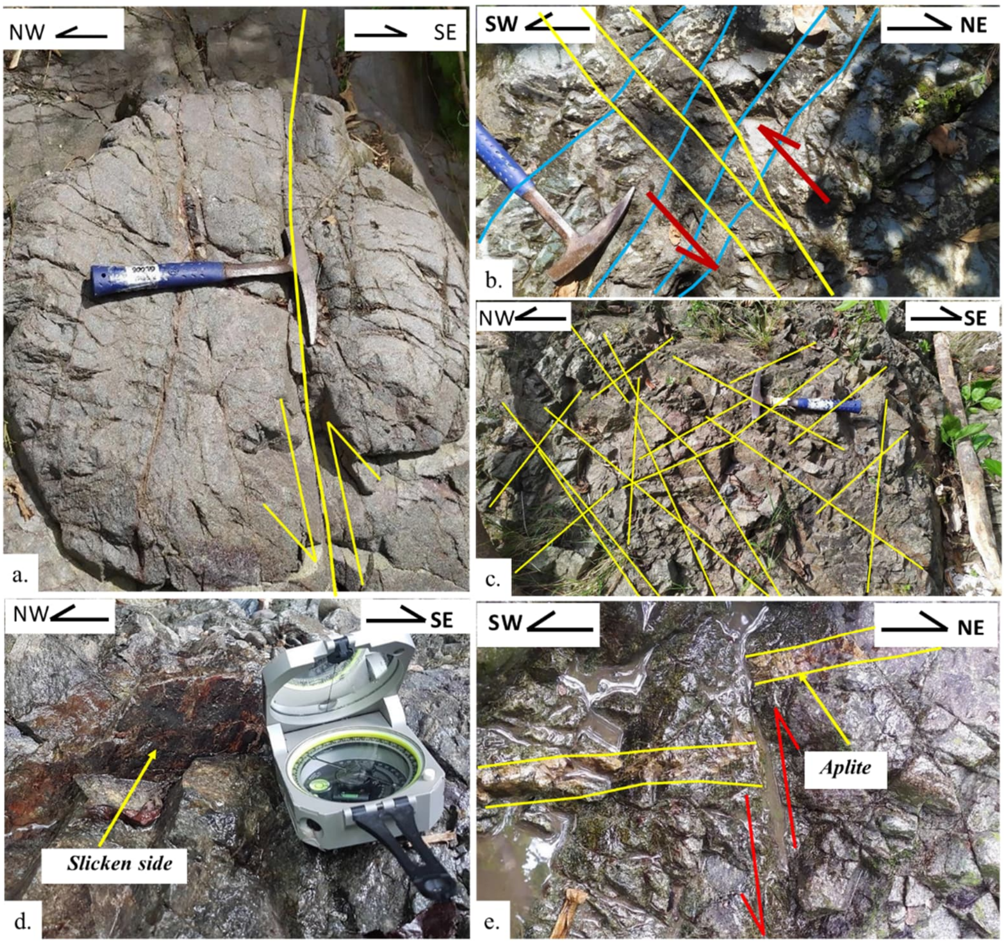

Figure 6. Outcrops of faults in the research area: (a) The fault plane of the Pahabung Thrust Fault. (b) The fault plane of the Way Lalaan Strike-Slip Fault. (c) Shear fractures found at the Kampung Baru location. (d) The appearance of slickensides, fault plane, and aplite on the Way Pihabung Thrust Fault. (e) Additional features of the Way Pihabung Thrust Fault, including slickensides and the fault plane.

4.3. Geology of Kotaagung Timur

4.3.1. Late Oligocene to Early Miocene

The effusive eruption products of Gunung Gisting, represented by the Basal-Andesite Unit of Gunung Gisting, initiate the geological history of the research area and the tectonic activity that forms the Pahabung Thrust Fault (**Figure 7a**). Subsequently, the magma chamber of Gunung Gisting undergoes crystal fractionation, resulting in a more felsic magma composition, which leads to a more explosive eruption style for Gunung Gisting.

The products of these explosive eruptions then deposit the Pyroclastic Flow Unit of

Gunung Gisting conformably over the Basal-Andesite Unit of Gunung Gisting. The eruptions culminate in the collapse of the summit of Gunung Gisting, forming a caldera morphology (**Figure 7b**).

Continuing subduction subsequently supplies mafic magma to the magma chamber of Gunung Gisting. This results in magma mixing processes, making the magma chamber of Gunung Gisting andesitic in nature, forming the Plagioclase-Pyroxene Andesite Unit of Gunung Gisting. After the formation of this unit, active tectonics give rise to the Way Lalaan Strike-Slip Fault. Subsequently, the magma chamber becomes more felsic as crystal fractionation processes occur again. This results in increased explosive volcanic activity from Gunung Gisting, leading to the deposition of the Glass Tuff Unit of Gunung Gisting (**Figure 7c**).

4.3.2. Miocene to Middle Miocene

The ongoing subduction activity in Sumatra Island results in the supply of granitic magma (Mccourt et al., 1996). This granitic magma intrudes into older units through pre-existing fractures (**Figure 7d**). The formation of this unit is also accompanied by hydrothermal solution activity, which causes the alteration of the older units.

Following the mineralization process, Gunung Gisting becomes active again, marked by explosive eruption products in the form of the Lapilli Tuff-Batulapili Unit. These eruptions occur under saturated conditions and are characterized by the accretionary lapilli texture commonly found in the Lapilli Tuff-Batulapili Unit.

Volcanism in the research area has shifted to the southwest, likely located in the Cawang Haro Mountains (Amin et al., 1993). This volcanism is associated with the formation of volcanic products represented by the Bal Formation, characterized by acidic magma (Amin et al., 1993; Barber et al., 2005). This volcanism deposits the Rhyolitic Glass Tuff Unit of the Cawang Haro Mountains in the research area. The rhyolitic nature of this unit is believed to be related to the supply of granitic magma similar to that of the Granitoid Unit (**Figure 7e**).

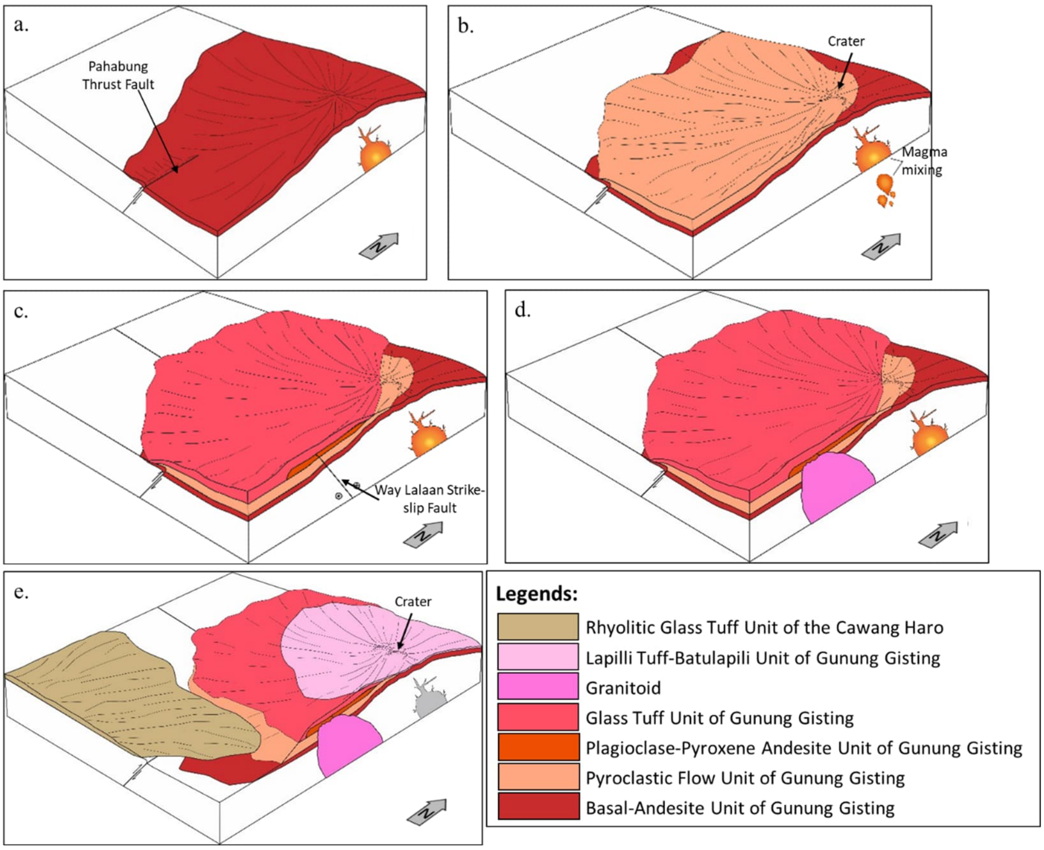

Figure 7. The block diagram illustrates the geological history of the research area from the Late Oligocene to the Middle Miocene: (a) Formation of the Basal-Andesite Unit of Gunung Gisting and the development of the Pahabung Thrust Fault. (b) Deposition of the Pyroclastic Flow Unit of Gunung Gisting and the formation of a caldera. (c) Formation of the Way Lalaan Strike-Slip Fault and deposition of the Glass Tuff Unit of Gunung Gisting. (d) The Granitoid Unit intruded on all units from Gunung Gisting. (e) Deposition of the Lapilli Tuff-Batulapili Unit, followed by the formation of caldera morphology and the development of the Rhyolitic Glass Tuff Unit of the Cawang Haro Mountains.

4.3.3. Middle Miocene to Pleistocene

After the deposition of the Rhyolitic Glass Tuff Unit of the Cawang Haro Mountains, no volcanic activity has been recorded in the research area. The Sumatra Fault System is believed to have first formed during this period, specifically in the Middle Miocene (McCarthy & Elders, 1997). The Sumatra Fault System that influences the geological structure in the research area is the Kotaagung Fault, which is part of the Semangko Segment (Mukti, 2018; Natawidjaja, 2018; Susilohadi et al., 2009).

The Semangko Segment subsequently developed into the Semangko Pull-apart Basin (Mukti, 2018; Susilohadi et al., 2009), resulting in the formation of the Kotaagung Fault and activating secondary faults that serve as accompanying structures, including thrust faults, synthetic strike-slip faults, and antithetic strike-slip faults in the research area (**Figure 8a**).

The Way Pihabung Thrust Fault, along with ongoing exogenic processes, is responsible for the exposure of the Granitoid Unit in the research area. The Granitoid Unit has been exposed at least since the Pleistocene or before the formation of the volcanic products of Gunung Tanggamus. This is marked by a nonconformity relationship between the Granitoid Unit and the volcanic products of Gunung Tanggamus. The Sumatra Fault System subsequently became the primary control on the geomorphology of the research area, characterized by a series of elongated hill morphology with linear patterns similar to those of the Sumatra Fault System (**Figure 8b**).

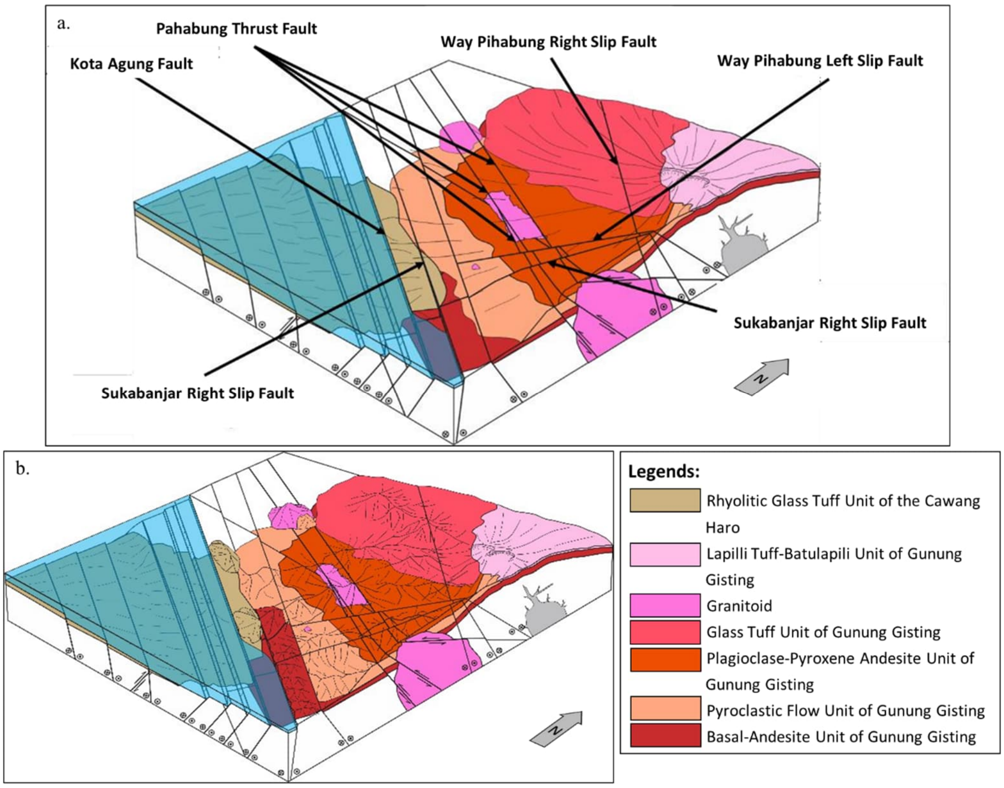

Figure 8. The block diagram illustrates the geological history of the research area from the Late Oligocene to the Middle Miocene: (a) Geological structure in the research area. (b) The recent morphology is controlled by the erosion and weathering.

5. CONCLUSION

Based on the analyses conducted, the conclusions of this study are as follows the stratigraphy of the research area is divided into 3 groups with 7 units. The geological structures in the research area are 3 types. The research area has generally experienced two episodes of volcanism and one episode of granitic intrusion. The first episode of volcanism dates to the Late Oligocene to the Early Miocene, the second episode to the Middle Miocene, and the episode of granitic intrusion occurred during the Early Miocene.

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REFERENCES

Amin, T. C., Sidarto, Santosa, S., & Gunawan, W. (1993). *Geological Map of the Kotaagunf Quadrangle, Sumatera*.

Amin, T. C., Sidarto, Santosa, S., & Gunawan, W. (1994). *Geology of the Kotaagung Quadrangle, Sumatera*.

Aribowo, S., Muslim, D., Winantris, Natawidjaja, D. H., & Daryono, M. R. (2017). Sub-Segmentasi Sesar Pada Segmen Kumering Antara Danau Ranau Hingga Lembah Suoh, Lampung Barat. *Jurnal Lingkungan Dan Bencana Geologi*, *8*, 31–46. http://jlbg.geologi.esdm.go.id/index.php/jlbg

Barber, A. J., & Crow, M. J. (2005). Structure and structural history. In A.J. Barber, M.J. Crow, & J.S. Milsom (Eds.), *Sumatra: Geology, Resources, and Tectonic Evolution* (pp. 175–233). The Geological Society. http://mem.lyellcollection.org/

Barber, A. J., Crow, M. J., & Milsom, J. S. (2005). Tectonic Evolution. In *Sumatra: Geology,* *Resources and Tectonic Evolution* (Vol. 31, pp. 234–259). www.geolsoc.org.uk.

Bellon, H., Maury, R. C., Soeria-atmadja, R., Cotten, J., & Polvé, M. (2004). long magmatic activity in Sumatra (Indonesia), from Paleocene to Present. In *Bull. Soc. géol. Fr* (Issue 1).

Corbett, G. J., Leach Greg Corbett, T. M., & Leach Terry Leach, T. (1997). *Southwest Pacific Rim Gold-Copper Systems: Structure, Alteration, and Mineralization*.

Fossen, H. (2016). *Structural Geology*. Cambridge University Press.

Le Bas, M. J., & Streckeisen, A. L. (1991). The IUGS systematics of igneous rocks. *Journal of the Geological Society*, *148*(5), 825–833. https://doi.org/10.1144/gsjgs.148.5.0825

Mangga, S. A., Amirudin, Suwarti, T., Gafoer, S., & Sidarto. (1993). *Peta Geologi Lembar Tanjung Karang, Sumatera*.

McCarthy, A. J., & Elders, C. F. (1997). Cenozoic deformation in Sumatra: oblique subduction and the development of the Sumatran Fault System. In A. J. Fraser, S. J. Matthews, & R. W. Murphy (Eds.), *Petroleum Geology of Southeast Asia* (pp. 335–363). Geological Society. http://sp.lyellcollection.org/

Mccourt, W. J., Crow, M. J., Cobbing, E. J., & Amin, T. C. (1996). Mesozoic and Cenozoic plutonic evolution of SE Asia: evidence from Sumatra, Indonesia. In R. Hall & D. Blundell (Eds.), *Tectonic Evolution of Southeast Asia* (pp. 321–335). Geological Society. http://sp.lyellcollection.org/

Moody, J. D., & Hill, M. J. (1956). Wrench-Fault Tectonics. *Bulletin of The Geological Society of America*, *67*, 1207–1246.

Mukti, M. M. (2018). Structural Configuration and Depositional History of The Semangko Pull-Apart Basin in The Southeastern Segment of Sumatra Fault Zone. *Riset Geologi Dan Pertambangan*, *28*(1), 115. https://doi.org/10.14203/risetgeotam2018.v28.954

Natawidjaja, D. H. (2018). Updating active fault maps and sliprates along the Sumatran Fault Zone, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *118*(1). https://doi.org/10.1088/1755-1315/118/1/012001

Rickard, M. J. (1972). Fault classification: Discussion. *Bulletin of the Geological Society of America*, *83*(8), 2545–2546. https://doi.org/10.1130/0016-7606(1972)83[2545:FCD]2.0.CO;2

Schmid, R. (1981). Descriptive nomenclature and classification of pyroclastic deposits and fragments - Recommendations of the IUGS Subcommission on the Systematics of Igneous Rocks. *Geologische Rundschau*, *70*(2), 794–799. https://doi.org/10.1007/BF01822152/METRICS

Setiawan, I., Zulkarnain, I., Indarto, S., Sudarsono, dan, & Indarto dan Sudarsono, S. (2005). Alterasi dan Mineralisasi di Sayap Barat Pegunungan. In *Pertambangan Jilid* (Vol. 15, Issue 1).

Sieh, K., & Natawidjaja, D. (2000). Neotectonics of the Sumatran fault, Indonesia. *Journal of Geophysical Research: Solid Earth*, *105*(B12), 28295–28326. https://doi.org/10.1029/2000jb900120

Susilohadi, S., Gaedicke, C., & Djajadihardja, Y. (2009). Structures and sedimentary deposition in the Sunda Strait, Indonesia. *Tectonophysics*, *467*(1–4), 55–71. https://doi.org/10.1016/J.TECTO.2008.12.015

Wilcox, R. E. , Harding, T. P. , & Seely, D. R. (1973). Basic Wrench Tectonics. *AAPG Bulletin*, *57*(1), 74–96. http://archives.datapages.com/data/bulletns/1971-73/data/pg/0057/0001/0050/0074.htm

Zulkarnain, I. (2011). Geochemical Evidence of Island-Arc Origin for Sumatra Island; A New Perspective based on Volcanic Rocks in Lampung Province, Indonesia. *Jurnal Geologi Indonesia*, *6*(Desember), 213–225.