INDONESIAN JOURNAL ON GEOSCIENCE
Geological Agency
Ministry of Energy and Mineral Resources

Journal homepage: http://ijog.geologi.esdm.go.id
ISSN 2355-9314, e-ISSN 2355-9306

Geomorphological Structure of Landform Characteristics As A Reference for Development Recommendations in Active Volcanic and Faulting Areas, A Case Study in Kerinci Region, Jambi Province, Indonesia

Hari Wiki Utama[1] and Rahmi Mulyasari[2]

[1]Geological Engineering Department, Jambi University, Jambi, Indonesia
[2]Geophysics Engineering Department, Lampung University, Lampung, Indonesia

Corresponding author: h.wikiutama@unja.ac.id
Manuscript received: December, 15, 2018; revised: May, 03, 2023;
approved: January, 22, 2024; available online: April, 16, 2024

Abstract - Kerinci Regency is located on the western to the southwestern part of the capital city of Jambi Province, Indonesia. It has interesting geomorphological sites consisting of the physiography of the Barisan Mountain Zone associated with the Sumatran Fault System known as a volcanic-tectonic complex. Geomorphology has an important role in providing information of the landscape in an area. This paper aims to determine the geomorphological characteristics of the area which can provide information regarding disaster mitigation, the direction of land-use innovation, and infrastructure development strategies. This research uses analyses of morphographic, morphometric, morphogenetic, morphoconservation, and morphochronological aspects. Analysis of satellite images and topographic contours is a method used to determine the characteristics of drainage patterns and geological mapping. A significant result of this research is a geomorphological map of Kerinci that divides the area into several geomorphological units, namely volcanic-denudational, karst, structural, volcanic-structural, structural-denudational, and fluvial morphologies. Based on the geomorphological map, the area has a very high potential hazard consisting of volcanic structural landforms, which are Tanco Isolated Hill (TIH), Kerinci Fault Escarpment Undulation (KFEU), Kerinci Fault Escarpment Volcanic Undulation (KFEVU), structural landforms (Alang Structural Valley (ASV), Kumun Fault Hills (KFH), and Pengasih Fault Undulation (PGFU)). This map can be used to design the Standard Operating Procedures (SOP) for regional development in Kerinci.

Keywords: geomorphology, development strategies, Kerinci, land use

How to cite this article:
Utama, H.W. and Mulyasari, R., 2024. Geomorphological Structure of Landform Characteristics As A Reference for Development Recommendations in Active Volcanic and Faulting Areas, A Case Study in Kerinci Region, Jambi Province, Indonesia. *Indonesian Journal on Geoscience*, 11 (1), p.123-139. DOI: 10.17014/ ijog.11.1.123-139

Introduction

Background

Kerinci is one of areas located on the magmatic arc and Sumatra Fault System of Barisan Range (Burton and Hall, 2014; Metcalfe, 2017; 1984; Natawidjaja, 2017; Triyoso *et al.*, 2020; Triyoso *et al.*, 2022). This area streches from the western to the southwestern parts of Jambi City, the capital of Jambi Province (Figure 1). Its irreversible geomorphologic location is made up of the Sumatra Fault System and the Barisan Range physiography. Additionally, this region is referred to as a volcanic-tectonic complex (Hutchison, 2014; Lange *et al.*, 2018; Crow *et al.*, 2019). That condition has the impacts on the morphological landforms of Kerinci, which triggers several disasters. Therefore, the study on

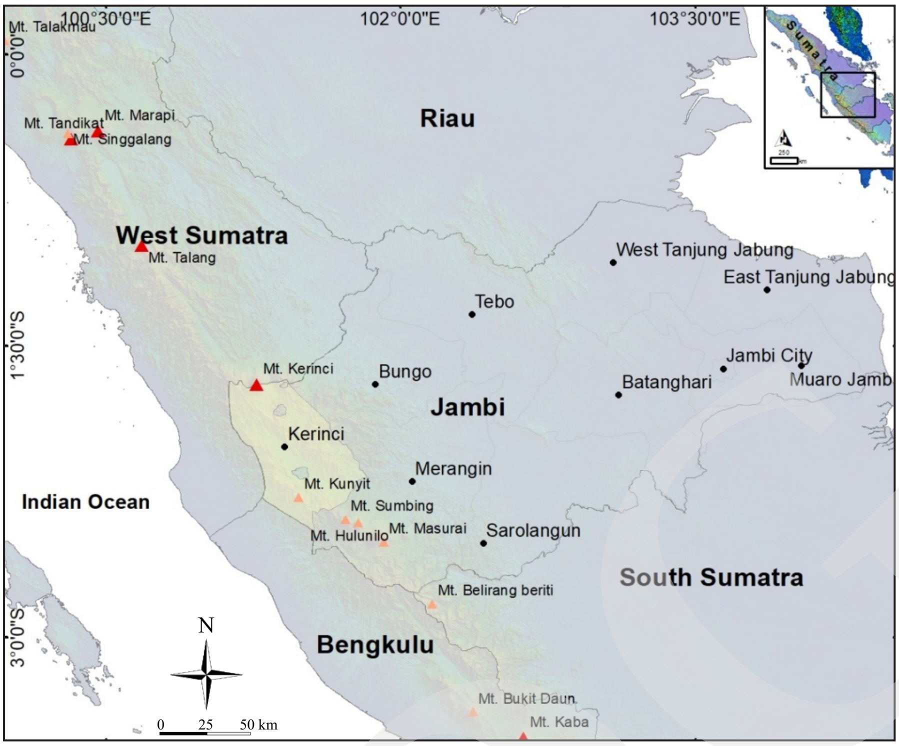

Figure 1. Schematic map showing Kerinci Regency as part of Barisan Range associated to structural valley and volcanic complex with NW−SE trending hills.

geomorphological condition in the area is necessary for innovative land-use and infrastructure development strategies. Geomorphological studies have an important role to provide information and overview on the existing landscape of an area on a map (Meitzen, 2017; Utama *et al.*, 2023).

A geomorphological map can be considered as graphical inventories of a landscape depicting landforms and surface as well as subsurface materials. This map can act as a preliminary tool for land management, geomorphological, and geological risk managements (Alcántara-Ayala, 2002; Bailey *et al.*, 2010; Kale *et al.*, 2014), as well as provides baseline data for other applied sectors of environmental research (Otto and Smith, 2013; Meitzen, 2017; Bradley *et al.*, 2018; Amine *et al*. 2019).

The purpose of this study is to analyze the geomorphological characteristics of this area that could provide information on the disaster mitigation, innovative land-use, and infrastructure development strategies, especially in active volcanic and faulting areas with a case study in the Kerinci region. The geomorphologic aspects was analyzed using satellite imagery and topographic contour analysis.

Geological Setting

Sumatra Island resulted from the subduction of Indian Ocean Plate boundary beneath Eurasian Continent Plate in the Cenozoic Period is thought to have a clockwise rotation until Paleogene and counterclockwise rotation in Neogene (Hall, 2013 and 2014; Otofuji *et al.*, 2017; Advokaat *et al.*, 2018). This subduction made the changing position of Sumatra Island, with the orientation of west-east to northwest-southeast (Zahirovic *et al.*, 2014). The deformation changes in Sumatra Island occurring in Oligo-Miocene Period (Hutchison, 2010; Hutchison, 2014) caused the movement of Sumatra Fault became active.

Physiography

The Sumatra Island is divided into six physiographic zones: Barisan Range Zone, Low Hills, Wavy Plain Zone, Tigapuluh Mountains Zone, Outer Arc Zone, and Sunda Shelf Zone

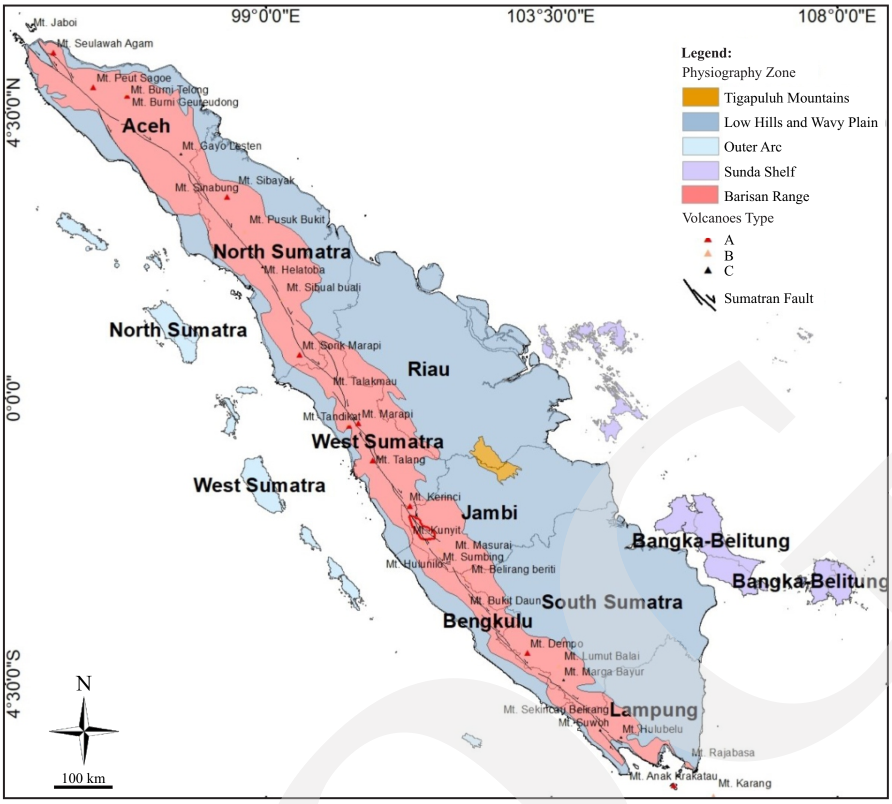

Figure 2. Physiographic map of Sumatra is divided into five zones, consisting of Barisan Range associated with Sumatra Fault System, Low Hills, Wavy Plain, Outer Arc, Tigapuluh Mountains, and Sunda Shelf (after Bemmelen, 1949; Utama *et al*., 2023). Kerinci Regency is part of Barisan Range associated with Sumatra Fault System, Inter-mountain basin, and Quaternary Volcanic Complex.

(Bemmelen, 1949; Zahirovic, 2016; Nabella *et al*., 2019; Utama *et al*., 2023). Kerinci Regency is part of Barisan Range Zone associated with Sumatran Fault System Physiography (Figure 2) which can be divided into the Quaternary Volcanic Zone, Basin Intra Mountain Zone, and Barisan Mountain.

The Barisan Range Zone is a physiographic zone consisting of Barisan Hill Zone, Sumatran Fault, Quaternary Volcano Zone, and Intramountain Basin Zone (Bemmelen 1949). The Barisan series, which is part of the bedrock of West Sumatra Terrane and the mixing zone in the west with Woyla Arc, have the consequences for its physiography that formed series of hills associated with active fault systems, Quaternary volcanoes, and also intra-mountain sedimentary basins.

Tectonic Setting

The regional tectonic setting of Sumatra Island has several phases, with active tectonics began in Paleocene-Eocene Period. Magmatisme activity started in Oligo-Miocene along the Sumatra Fault System (SFS). Pliocene tectonic activity produced crushed basalt as an indication of tectonic traces, accompanied by an active Quaternary volcanic activity (Kusnama *et al*., 1992; Rosidi *et al*., 1996).

There are nineteen segments of Sumatra Fault System (Natawidjaja, 2017; Natawidjaja, 2018). Based on the division of fault segment, the researched area is included into the Siulak segment (Figure 3). This segment is suspected to control the formation of Kerinci geomorphology, indicating the relationship between Siulak Fault segment with the existence of active volcano, volcano-tectonic lake, hotspring, and other geomorphological forms (Muraoka *et al*., 2010; Metcalfe, 2013 and 2017). Kerinci region has a unique geomorphology, because it relates to active volcanic and faulting areas (Figure 3).

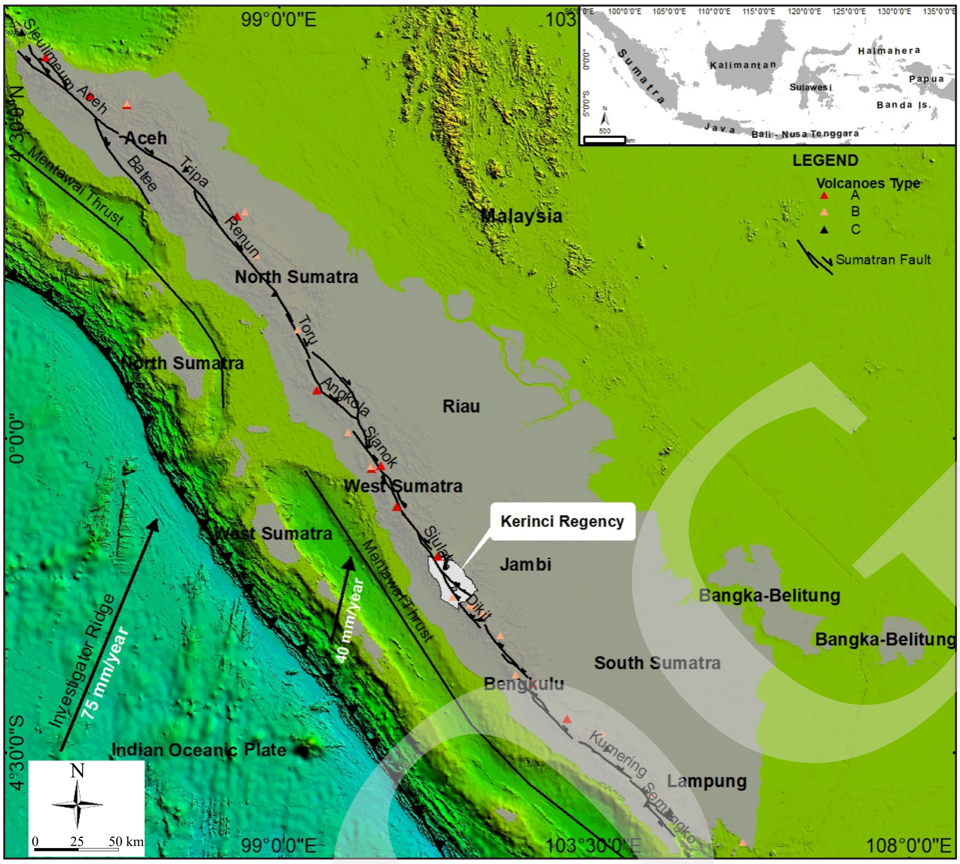

Figure 3. Map of tectonic setting of Sumatra. Approximately nineteen active fault segments as a consequence of active subduction on Sumatra West Coast of Indian Oceanic Plate to Sundaland Plate. This map was modified from Barber (2000); Barber and Crow (2003; 2009); Barber *et al*. (2005); Metcalfe (2000; 2009; 2010; 2011; 2013); Natawidjaja (2017); Ariani and Utama (2022). Kerinci Regency is assosiated to Siulak Fault segment.

Stratigraphy

On the basis of field geological observation including rock description on stratigraphic formation, geological structure identification, rock sampling integrated to regional geological maps of Sungaipenuh and Ketahun Sheet (Kusnama *et al*., 1992) and Painan sheet (Rosidi *et al*., 1996), the stratigraphy of Kerinci Regency is generally composed of Jurassic-Quaternary age, with the variety of basement rock from Asai, Siulak, Siguntur, and Peneta Formations, granitoid intrusion, and also Quaternary volcanic products (Figures 4 and 5).

The Quaternary volcanic products consist of basalt, andesite, rhyolitic lava, and pyroclastic rocks like-breccia, and tuff by product of Kerinci, Tujuh, Kunyit, and Raya Mountains. The sedimentary rocks with volcanic sediments consist of tuffaceous breccias, conglomerates, sandstones, tuffaceous claystone, and tuffaceous sandstone originating from Kumun, Hulusimpang, and Bandan Formations. Mesozoic formation comprises sedimentary and volcanic rocks of Siulak Formation such as silicified tuff, Siulak Limestone, Metamorphic Peneta Formation, Asai Metamorphics, and Siguntur Quartzite. The researched area also has granitoid intrusions such as Pliocene Sungaipenuh granite, Pliocene Sungaipenuh granodiorite, and basement granite of Jurassic age. The presence of Late Pliocene basalt is suggested to be a volcanic origin.

Geology of Kerinci

The geology of Kerinci is obtained from geological map data, remote sensing, and several geological surveys. Furthermore, the researched area has sixteen stratigraphy units (Figures 4 and 5). The age determination of the stratigraphy

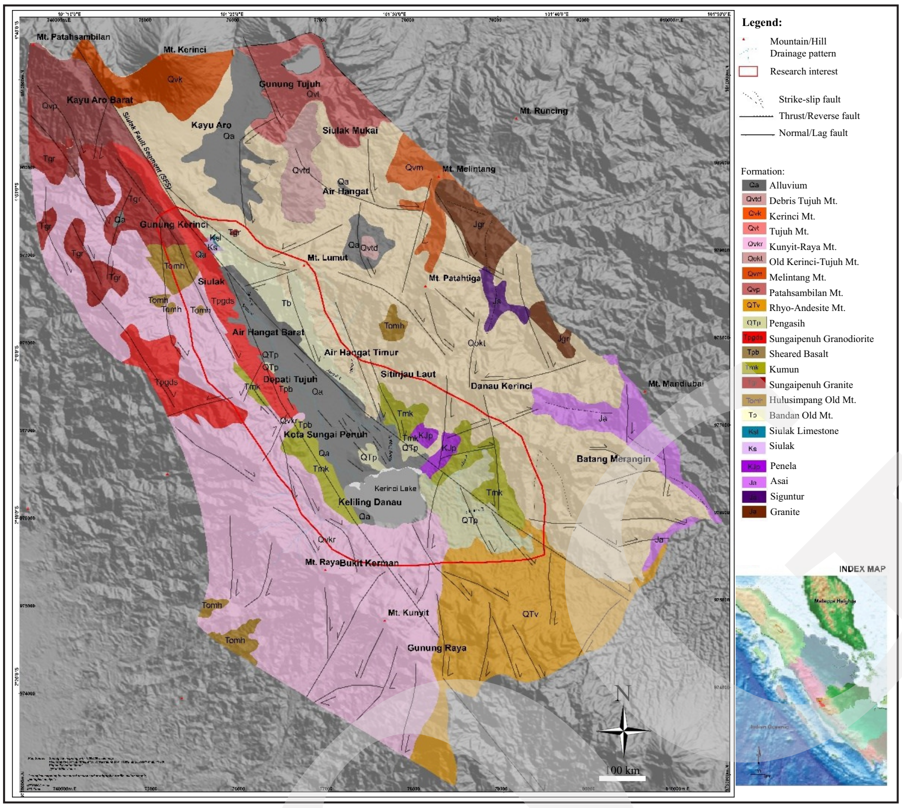

Figure 4. Geological map of Kerinci (after Kusnama *et al*., 1992; Rosidi *et al*., 1996). Structural geology is dominantly influenced by stratigraphy.

units is based on a previous research, and refers to regional geological maps. There is a change in formation boundary units from regional to local geological map because of the difference on the scales. Furthermore, the dynamic geological conditions of Kerinci are influenced by the existence of Siulak Fault segmentation.

MATERIALS AND METHODS

The data used in this research were Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM) data with a spatial resolution of 90 m and ASTER GDEM with spatial resolution of 30 m, which are available free of charge from USGS website (USGS, 2018), geological maps of Sungaipenuh Ketahun, and Painan Sheets with scale of 1:250.000, and data from the Geological Research and Development Centre (Kusnama *et al*., 1992; Rosidi *et al*., 1996). All the data were used to analyze and to specify geomorphological aspects. Digital topography has been used to classify the geomorphology (Makowski *et al*., 2017; Hunt *et al*., 2019; Bell *et al*., 2021).

The research was presented to find geomorphological aspects, namely morphology, morphogenesis, and morphochronology (Zuidam, 1985; Verstappen, 2000; Verstappen, 2010; Mulyasari *et al*., 2019). Data and geomorphological parameters were used to calculate and to compute geomorphic aspect using remote sensing method integrated with GIS (Geographic Information System) techniques.

The geomorphological map has been analyzed using some approaches for determining geomorphic units, namely identification, interpretation, and determination to classify the geomorphic unit. This geomorphic aspect has been used in morphology, morphogenesis, and morphochronology determinations. The three aspect above would be combined with morphoconservation aspect. Morphoconservation is the utility of a geomorphic unit, such as recommendation for developing an area.

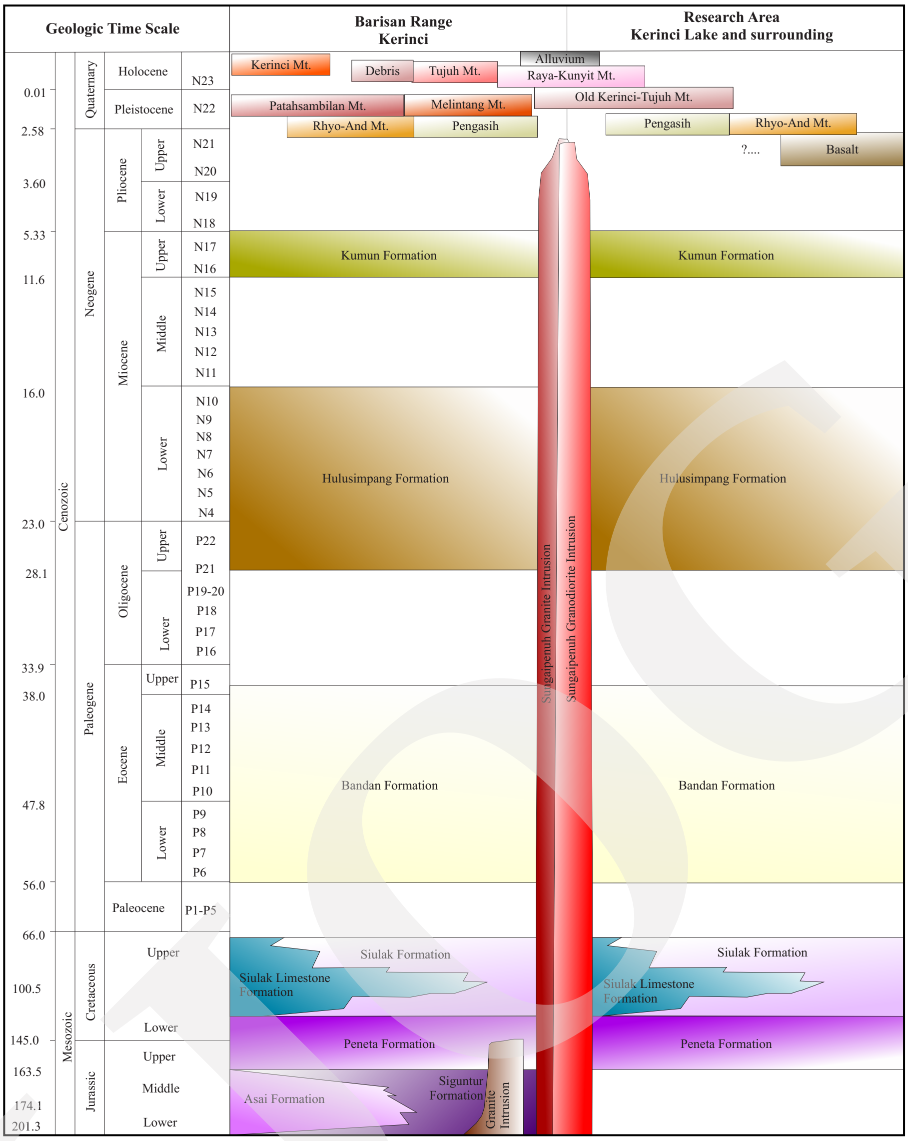

Figure 5. Stratigraphic column of the geology of Kerinci region.

The image of SRTM DEM-ASTER GDEM was used as the basic data to analyze and to interpret the geomorphological aspects. Several stages of analysis were carried out to achieve the objectives of this study. First, analyzing the hillshade with four irradiation directions was to find out the development of lineaments and the presence of faults. Second, determining manual lineaments and delineating structural geology was to determine structural geological aspects. Third, overlaying the regional geology and SRTM data was to find out the local geological map. This map interpretation was carried out to identify the type of lithology, rock resistance, drainage patterns, geological structures, weathering, and erosion as reflected by the slope and the elevation. Fourth, based on the local geological map, the geomorphic units were used to determine the morphological-morphochronological aspects. In addition, this research was supported by checking several locations for deciding and ascertaining data.

Result and Discussion

Geomorphic features were meticulously analyzed using a combination of satellite imagery, topographic contour assessment, and cutting-edge

Geographic Information System (GIS) techniques. These integrated approaches facilitated a comprehensive understanding of the landscape intricacies. The analytical process involved several progressive stages, encompassing the examination of morphology, morphometry, morphogenesis, and morphochronology aspects. In addition to the geomorphological analysis, a thorough investigation of the geological framework was undertaken. This involved scrutinizing the lithology units, formation characteristics, tectonic phenomena, and neotectonic interpretations. These geological investigations served as crucial data crosschecks, ensuring the accuracy of the findings.

The innovative aspect of this research lies in the perfect combination amongst the advanced remote sensing techniques, GIS technology, and geological interpretations. This integrated methodology enabled an understanding of the complex interactions amongst the landforms, geology, and tectonics in Kerinci. To verify the results, additional geological investigations were conducted, including lithology unit-formation, tectonics, and neotectonic interpretation. The result of the research is focused on the geomorphology aspect to be used for recommendations in developing the area.

Drainage Pattern

Drainage patterns in Kerinci Regency can be divided into radial, centrifugal radial, rectangular, dendritic, subdendritic, and parallel. The differences in drainage pattern reflect the diversity of lithology of the rock formations and also the degree of the rock resistance. Thus, drainage pattern is an important factor in dividing geomorphic units (Figure 6).

The researched area has a dendritic drainage pattern on the alluvial plain controlled by the geological structure that in some parts transformed the pattern into subdendritic. The slopes in the Kerinci depression known as Sungaipenuh

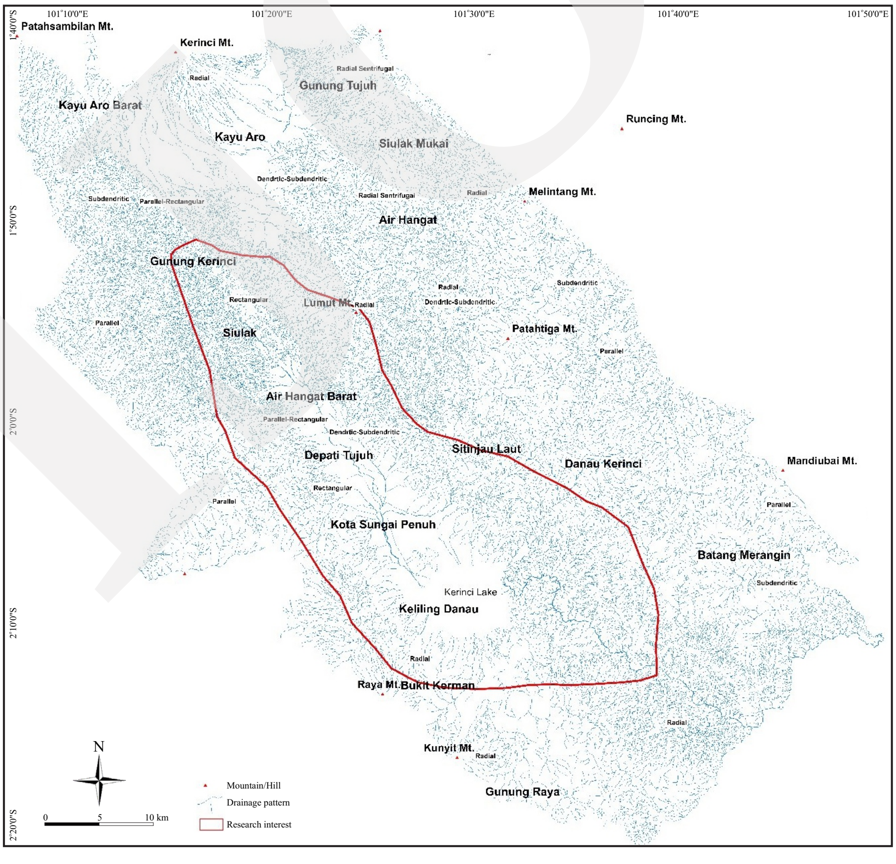

Figure 6. Drainage pattern on the Kerinci Regency. The researched area is in polygon red colour. Researched areas can be divided into radial, centrifugal radial, rectangular, dendritic, subdendritic, and parallel patterns.

depression show the centripetal radial drainage pattern, the characteristics of Kerinci, Kunyit, Raya Mountain, Lumut, Patahtiga, Patahsembilan, Melintang Mountains, and Tujuh Mountain Caldera. This drainage pattern is identical with volcanic landforms and structural volcanic landforms.

The outside area was characterized by parallel drainage pattern indicated by hills and undulations, showing intermittent or secondary stream perpendicular pattern to the primary drainage. The drainage pattern occupies a ridge area in the western and eastern parts of Lake Kerinci which is composed of metamorphic, meta-sedimentary, and meta-igneous rocks.

The outer area has a rectangular drainage pattern associated with the fracture zone such as Siulak Fault system and joints. The determination of drainage patterns was conducted to comprehend the landform characteristics. The rectangular drainage pattern is along the Sumatran Fault System of Siulak segment, both within the researched and outside areas, with fault orientations of north-northwestern and south-southeastern.

Geomorphic Features

The geomorphic identification of Lake Kerinci and its surrounding area was conducted using ASTER GDEM-SRTM DEM image with 30-90 m resolution/pixel. The resolution of the image helps precisely distinguish amongst geomorphic features. This data has been overlaid with geological map, and integrated with geological units and geomorphic features.

Geomorphic Interpretation

The interpretation of the researched area was conducted by determining dominantly geomorphic process which generally controlled the landform and landscape. The interpretation included endogenic processes (lithology, resistance, structural geology, solubility (morphogenesis), and exogenic processes, *i.e*. weathering, erosion (morphogenesis), landform or morphography, slope, elevation (morphology), degree of deformation and morphostratigraphy (morphochronology). Based on this approach, the Lake Kerinci process is dominantly controlled by volcanic and structural processes (fractional of fluviatil, denudational, and karst processes).

Determination of Geomorphic Unit

Based on the explanation of geomorphic unit for identification and interpretation stage, the researched area was determined based on the approaches affirmed, which was divided into six landforms, namely volcanic-denudational, karst, structural, volcanic-structural, structural-denudational, and fluvial landforms (Figure 7). These landform determination were also bent on morphochronological aspects (Table 1). The geomorphic unit determination is also supported by surface mapping of several landscapes and outcrop locations.

Volcanic Denudational Landform

This landform has been the product of volcanic process associated with Barisan Range having lithologic resistance, such as the ductile deformation in Siulak Formation with tuffaceous shale of Mesozoic Epoch which were the secondary factor controlled the landform processes. It has a combination factor of Cretaceous-Quaternary volcanism with several stratigraphy unit that have weathered, eroded, and resedimented. This landform is composed of Siulak Volcanic Denudational Hill (SVDH) and Volcanic Denudational Undulation (VDU).

Structural Landform

SFS of Siulak Fault was the primary controlling factor, having an important role in the morphology of Peneta Fault Undulation (PFU), Peneta Fault Valley (PFV), Siulak Deras Fault Hills (SDVH), Alang Structural Valley (ASV), Kumun Fault Valley (KFV), Pengasih Fault Valley (PGFV), Pengasih Fault Undulation (PGFU), and Kerinci Fault Escarpment Undulation (KFEU). This landform consists of tuffaceous shale, silicified and sheared basalt, sandstone, conglomerate, and breccia. Silicified-sheared basalt indicated the track/fossil of Neogene tectonics.

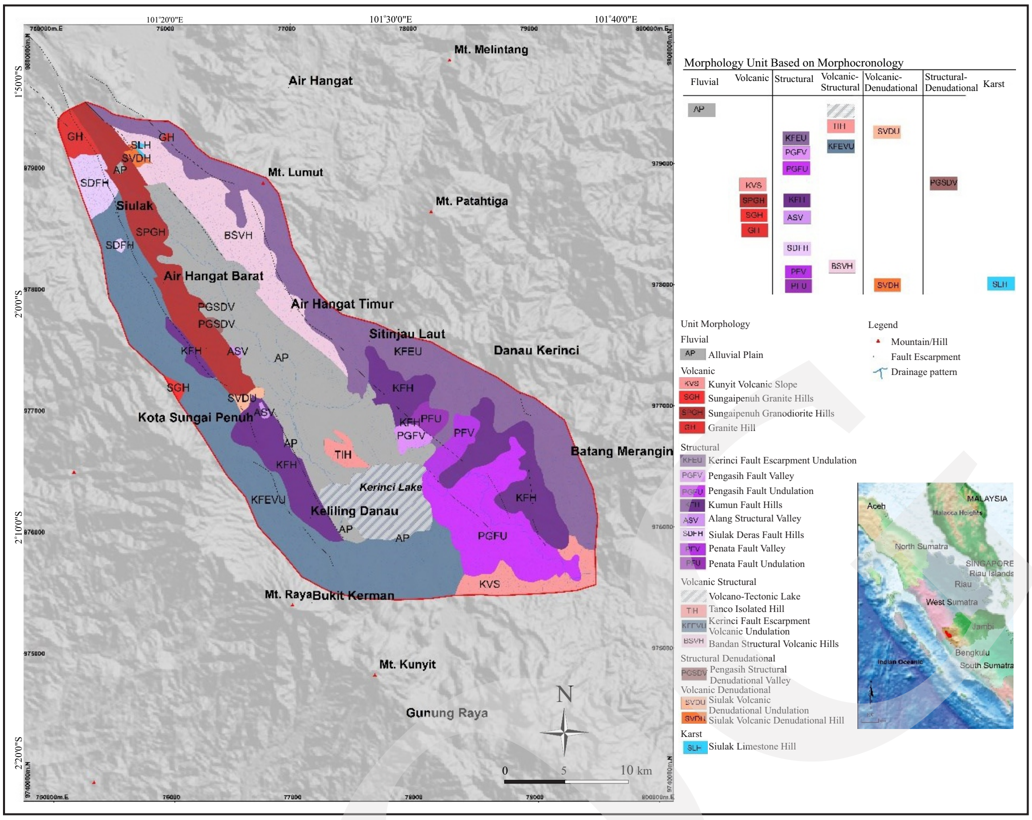

Figure 7. Geomorphology map of Kerinci. Overlay map of stratigraphy formation, structural geology, and the considered geomorphology characteristics, envelop of morphology, morphogenesis, and morphochronology. Red polygon is the interesting researched area.

<u>Karst Landform</u>

The researched area has the small (fractional) karst landform characterized by Cretaceous metasedimentary limestone. The influencing geological processes are active tectonics that have existed since Cretaceous to Quaternary. Basically, the karst area have multibasinal drainage pattern, while the researched area does not have such system, because in general karst in Sumatra had been deformed by the Sumatran Fault. The example of this landform is only in Siulak Limestone Hill (SLH).

<u>Volcanic Structural Landform</u>

Volcanic structural landform is a combination of volcanism in Paleogene-Quaternary controlled by SFS (Sumatra Fault System). The SFS was active in Middle Neogene, where several stratigraphy units have been weathering with low to medium degree. This landform generally comprises volcanic breccia and andesitic tuff which is very attractive with Lake Kerinci tectonic volcano and Tanco Isolated Hill (TIH). The geomorphic orientation is southeastern - northwestern which are similar to SFS, especially Siulak Fault which has a dextral fault that could be pull apart. While lithologically, it is made up of tuff and volcanic breccia. In addition, this landform includes Kerinci Fault Escarpment Undulation (KFEU) and Bandan Structural Volcanic Hills (BSVH). The fault escarpment is active tectonics showing the northeastern-southwestern side of the Lake Kerinci.

<u>Volcanic Landform</u>

More than half of a researched area is composed of volcanic products controlled by SFS. Magmatism in the Kerinci Regency began with the granitoid intrusion in Jurassic, then granodiorite intrusion in Pliocene. Furthermore, it was followed by another magmatism forming Kunyit Volcano that produced tuff and pumiceous claystone. This volcano has been active to have

Table 1. Geomorphic Units of The Researched Area (oldest to youngest)

No	Morphology	Landform origin Id	Morphogenesis	Potential hazard degree	Morpho-chronology
1	AP (Alluvial Plain)	Fluvial	Plain, alluvial, flat relatively, active fault system	High	Holocene
2	LAKE (Lake)	Volcanic Structural	Lake, meteoric-volcanic water, volcano-tectonic	-	Holocene
3	TIH (Tanco Isolated Hill)	Volcanic Structural	Hill, isolated, tuff, volcanism, active Siulak fault, angle-steep slope	Very high	Pleistocene
4	SVDU (Siulak Volcanic Denudational Undulation)	Volcanic Denudational	Undulate, volcanic breccia, tuff, step slope, volcanism, low resistance, weathering, eroded	Moderate	Pleistocene
5	KFEU (Kerinci Dault Escarpment Undulation)	Structural	Undulate, breccia, fault system, low-middle resistance	Very High	Pleistocene
6	KFEVU (Kerinci Fault Escarpment Volcanic Undulation)	Volcanic Structural	Undulate, volcanic breccia, andesitic tuff, volcanism, fault system, middle resistance	Very high	Pleistocene
7	PGFV (Pengasih Fault Valley)	Structural	Valley, sandstone, structural, high resistance	Moderate	Pleistocene
8	PGFU (Pengasih Fault Undulation)	Structural	Undulate, angle of slope, claystone, siltstone, structural, high resistance	Very high	Pleistocene
9	PGSDV (Pengasih Structural Denudational Valley)	Structural Denudational	Valley, siltstone, sandstone, micro fault, low resistance, weathering, eroded	High	Pleistocene
10	KVL (Kunyit Volcanic Slope)	Volcanic	Hill, pumiceous claystone, volcanism, angle slope, middle resistance	Low	Pleistocene
11	KFH (Kumun Fault Hills)	Structural	Hill, sandstone, conglomerate, breccia, active fault SFS, angle slope, deformation	Very high	Pliocene
12	ASV (Alang Structural Valley)	Structural	Valley, tectonic-fault, basalt silicified-sheared, deformation	Very high	Pliocene
13	SPGH (Sungaipenuh Granodiorite Hills)	Volcanic	Hill, granodiorite, high resistance, magmatism	Low	Pliocene
14	SGH (Sungaipenuh Granite Hills)	Volcanic	Hill, granodiorite, high resistance, magmatism	Low	Pliocene
15	GH (Granite Hill)	Volcanic	Hill, granite, high resistance, magmatism	Low	Miocene
16	SDFH (Siulak Deras Fault Hills)	Structural	Hills, steep slope, lava, breccia, ignimbrite, fault	Moderate	Oligo-Miocene
17	BSVH Bandan Structural Volcanic Hill)	Volcanic Structural	Hill, angle-steep slope, volcanism-tectonic fault, volcanic breccia, tuff	High	Eocene
18	SLH (Siulak Limestone Hill)	Karst	Hill, angle slope, soluble, limestone	Moderate	Cretaceous
19	PFV (Peneta Fault Valley)	Structural	Valley, tuffaceous shale, minor fault system	High	Cretaceous
20	PFU (Peneta Fault Undulation)	Structural	Undulate, angle slope, fault, tuffaceous shale, minor fault system	High	Cretaceous
21	SVDH (Siulak Volcanic Denudational Hill)	Volcanic Denudational	Hills, angle slope, tuffaceous shale, low resistance, eroded, weathering	Moderate	Cretaceous

granite-granodiorite magmatism. This landform is half of Barisan Range, of which more than half part is Quaternary active volcano. Granite Hill (GH), Seblat Granodiorite Hill (SGH), and Sungaipenuh Granodiorite Hill (SPGH) are plutonic rocks, while Kunyit Volcanic Slope (KVL) is volcanic rocks and volcanic-sedimentary rocks.

Structural Denudational Landform

This landform has been formed by the product of tectonic process associated with the Sumatran Fault System. However, this landform has lithologic resistance, such as on the ductile deformation in Siulak Formation with sedimentary rocks, volcanic rocks, and metasediment of Mesozoic Epoch. This landform was specifically controlled by Siulak Fault segment, and only comprises Pengasih Structural Denudational Valley (PGSDV). The degree of weathering deformation is another factor that has been forming this landform.

Fluvial Landform

Fluvial is the recent geologic settings, sedimentary processes, unlithification, and sedi-

Figure 8. Overview of Kerinci situation; a). Landscape of Lake Kerinci where the land is used for padi field; b). Potential landslide is associated with Sumatran Fault System of Siulak segment, which is the background of beautiful landscape of Tanco isolated hill and Lake Kerinci.

Figure 9. Landscape of Kerinci with a) volcanic complex and b) Active fault system of Sumatra Fault.

mentary material. Generally, this landform has a characteristic of plain slope, such as alluvial plain (AP). Fossil of minor geology structure is believed to have been covered below the alluvial lithology, so it is difficult to find the fault line on the surface. Nevertheless, this minor fault structure can possibly cause the reactivity that trigger Siulak segment changing the morphology.

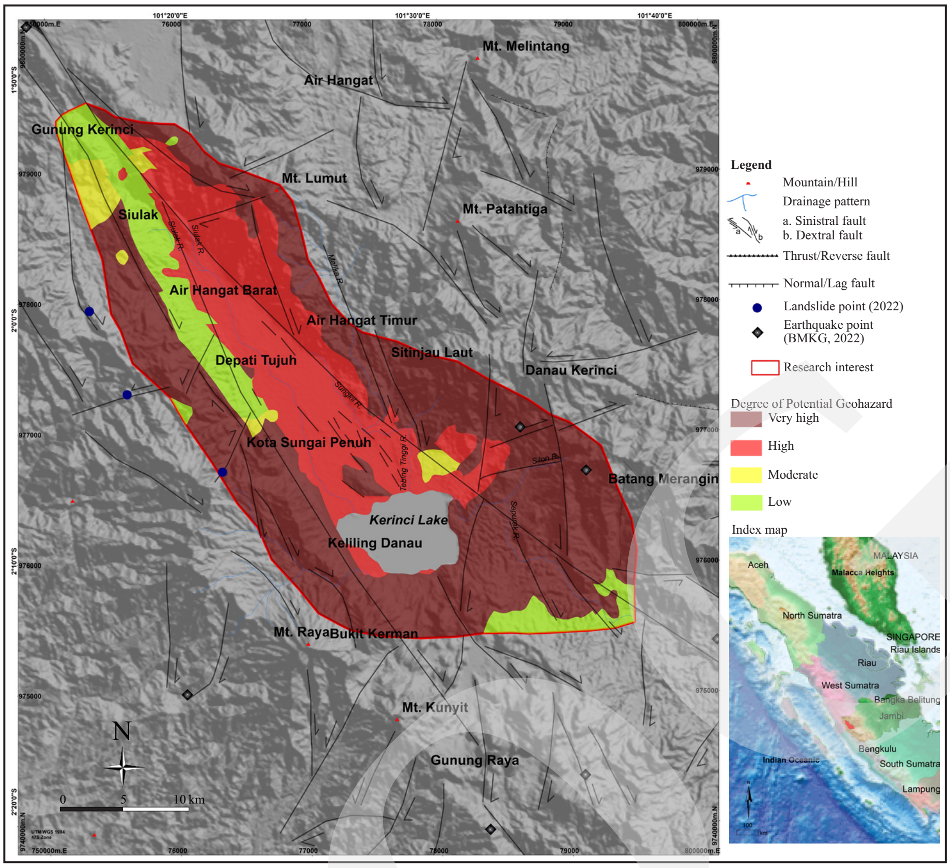

Figure 10. Geohazard potential zone of the researched area. Degree of potential zone indicates the role of active structural and volcanic system of landform. The point of the earthquake was obtained from BMKG (2022) and from the eathrquake data of the last five years. Geological structure based on previous researches from regional geological maps by Kusnama *et al*. (1992) and Rosidi *et al*. (1996); geological interpretation, and measurements at several locations in the field.

Land Use and Infrastructure Development Strategies

The study of geomorphology for a standard operating procedure is the focus of this research. Based on the considerable study, the geomorphology map and geological map have made the potential zonation, with the result that could be used as the recommendation for the standard operational procedure in developing the area. Acording to the previous explanation, the researched area was divided into four zonations based on the geomorphic units (Figure 10).

Geomorphic features were meticulously analyzed using a combination of satellite imagery, topographic contour assessment, and cutting-edge Geographic Information System (GIS) techniques. These integrated approaches facilitated a comprehensive understanding of the landscape intricacies. The analytical process involved several progressive stages, encompassing the examination of morphology, morphometry, morphogenesis, and morphochronology aspects. In addition to the geomorphological analysis, a thorough investigation of the geological framework was undertaken. This involved scrutinizing lithology units, formation characteristics, tectonic phenomena, and neotectonic interpretations. These geological investigations served as crucial data crosschecks, ensuring the accuracy of the findings.

The innovative aspect of this research lies in the advanced remote sensing techniques, GIS technology, and geological interpretations. This integrated methodology enabled an understanding of the complex interactions amongst landforms, geology, and tectonics in Kerinci areas. In order to verify the results, additional geological investigations were conducted, including lithology unit formation, tectonics, and neotectonic interpretation. The result of the research is focused on the geomorphology aspect to use for recommendations in developing the area.

The principle of making the zonation is based on the morphology and morphogenesis (lithology, structural geology, weathering, erosion) which are very high, high, medium, and low (Table 1). In addition, the aspect of lithology and structural geology is very important, especially active structural SFS, because the researched area is located near the dense residence, government buildings, public transportation, roads, bridges, and irrigation.

Very High Potential

Very high potential is classified as very high risk if an area will be developed. The lithology of this potential comprises sandstone, volcanic breccia, tuff, and silicified basalt. The existence of SFS Siulak segment is the primary cause that triggers the mass movement. SFS is an active fault, so the government needs to considerably handle the study of hydrogeology and engineering geology. The characteristics of very high potential comprise volcanic structural landform, which are Tanco Isolated Hill (TIH), Kerinci Fault Escarpment Undulation (KFEU), Kerinci Fault Escarpment Volcanic Undulation (KFEVU), and structural landforms (Alang Structural Valley (ASV), Kumun Fault Hills (KFH), and Pengasih Fault Undulation (PGFU)).

High Potential

In the fluvial landform, alluvial plain (AP) was included as the high potential category. Although the lithology is sedimentary material, however the existence of minor fault of SFS concealed alluvial deposits. By any chance, reactivated fault SFS can trigger the mass movement and risky for the development of the area. The considerable study of hidro-geotech can localize the specified area. This classification included structural denudational, which is Pengasih Structural Denudational Valley (PGSDV). The volcanic structural landform is Bandan Structural Volcanic Hill (BSVH). Structural landform comprises Peneta Fault Undulation (PFU) and Peneta Fault Valley (PFV). The lithology comprises tuffaceous shale, sandstone, and siltstone.

Moderate Potential

This landform is occupied by Siulak Volcanic Denudational Hills (SVDH) and Volcanic Denudational Undulation (VDU). Karst landform is Siulak Limestone Hill (SLHM), while structural landforms are Siulak Deras Fault Hill (SDFH) and Pengasih Fault Valley (PGFV). The research ed area is composed of andesitic lava, volcanic breccia, sandstone, claystone, and limestone. This classification is useful for area development having the lithological characterisctics of resistant, weathered, ductile - brittle deformation.

Low Potential

Low potential occupied the volcanic landform which is Kunyit Volcanic Slope (KVL), Sungaipenuh Granodiorite Hill (SPGH), Seblat Granite Hill (SGH), and Granite Hill (GH). The characteristics of the lithology are crystalline rocks, high resistance, and not influenced by active fault. Therefore, this area is very recommended for developing government buildings, public transportation, and residencial area.

Conclusions

Geological aspects of the stratigraphy that make up rock formations and geological structures are important factors in making geomorphological classifications. The results obtained are geomorphological maps based on the analyses of morphological, morphogenetics, morphochronology, and morphoconservation aspects. The researched area are divided into several geomorphological units, namely volcanic-denudational, karst, structural, volcanic-structural, structural-denundational, and fluvial morphologies. In addition, with these criteria, the local government can design the region based on geomorphological features towards innovative land-use and strategic infrastructure development in active volcanic and faulting areas such as the Kerinci region. Thus, the local government should produce Standard Operating Procedures to be used as recommendations for future regional development. Geohazard potential obtained from geological data, geomorphology, and additional elements from earthquake points is an important reference for regional development strategies in innovative and sustainable development.

Acknowledgments

In arranging this research, the authors thank Hazizah Devila, the research assistant who has helped. Thanks are also conveyed to a lot of people who have provided motivation, advices, and support to the researchers.

References

Advokaat, E.L., Bongers, M.L.M., Rudyawan, A., Fadel, M.K.B., Langereis, C.G., and Hinsbergen, D.J.J. van, 2018. Early Cretaceous origin of the Woyla Arc (Sumatra, Indonesia) on the Australian Plate. *Earth and Planetery Science Letters,* 498, p. 348-361. DOI: 10.1016/j.epsl.2018.07.001

Alcántara-Ayala, I., 2002. Geomorphology, natural hazards, vulnerability and prevention of natural disasters in developing countries, *Geomorphology,* 47, p. 107-124. DOI: 10.1016/S0169-555X(02)00083-1

Amine, A., Hassani, I.E.E.A.E., Remmal, T., Kamel, F.E., Wyk de vries, B. Van, and Boivin, P., 2019. Geomorphological Classification and Landforms Inventory of the Middle-Atlas Volcanic Province (Morocco), Scientific Value and Educational Potential. *Quaestiones Geographicae,* 38 (1), p. 107-129. DOI: 10.2478/quageo-2019-0010

Ariani, R.P. and Utama, H.W., 2022. *Petrogenesis and Geological Structure of Tantan Granitoid in Sungai Manau District, Merangin* Regency, Jambi Province. *Eksplorium,* 43, p.79-88. DOI: 10.55981/eksplorium.2022.6415

Barber, A.J., 2000. The origin of the Woyla Terranes in Sumatra and the Late Mesozoic evolution of the Sundaland margin. *Journal of Asian Earth Sciences.* 18, p.713-738. DOI: 10.1016/S1367-9120(00)00024-9

Barber, A.J., Crow, M J., and Milsom, J.S., 2005. Geology, Resources and Tectonics Evolution. *Geological Society Memoir, London*, 290 pp. DOI: 10.1017/S0016756806212974

Barber, A.J. and Crow, M.J., 2003. Evaluation of Plate Tectonic models for the development of Sumatra. *Gondwana Research,* 20, p.1-28. DOI: 10.1016/S1342-937X(05)70642-0

Barber, A.J., and Crow, M.J., 2009. Structure of Sumatra and its implications for the tectonic assembly of Southeast Asia and the destruction of Paleotethys. *Island Arc,* 18, p.3-20. DOI: 10.1111/j.1440-1738.2008.00631.x

Bailey, G.N., Reynolds, S.R., and King, G.C.P., 2010. Landscapes of human evolution: models and methods of tectonic geomorphology and the reconstruction of hominin landscapes. *Journal of Human Evolution*, p.1-24. DOI: 10.1016/j.jhevol.2010.01.004

Bell, R., Fort, M., Götz, J., Bernsteiner, H., Andermann, C., Etzlstorfer, J., Posch, E., Gurung, N., and Gurung, S., 2021. Major geomorphic events and natural hazards during monsoonal precipitation 2018 in the Kali Gandaki Valley, Nepal Himalaya. *Geomorphology,* 372. DOI: 10.1016/j.geomorph.2020.107451.

Bemmelen, R.W., 1949. *The Geology of Indonesia Volume 1A*, Government Printing Office, The Hague, Netherlands, 732pp.

Bradley, K.E., Feng, L., Hill, E.M., Natawidjaja, D.H., and Sieh, K., 2017. Implications of the diffuse deformation of the Indian Ocean lithosphere for slip partitioning of oblique plate convergence in Sumatra. *Journal of Geophysical Research Solid Earth,* 122, p.572-591. DOI: 10.1002/2016JB013549

Burton, P.W. and Hall, T.R., 2014. Segmentation of the Sumatran fault. *Geophysical Research Letters,* 41, p.4149-4158. DOI: 10.1002/2014GL060242

Crow, M.J., Van Waveren, I.M., and Hasibuan, F., 2019. The geochemistry, tectonic and paleogeographic setting of The Karing Volcanic Complex and the Dusunbaru pluton, an early Permian volcanic-plutonic centre in Sumatra, Indonesia. *Journal of Asian Earth Sciences,* 169, p.257-283. DOI: 10.1016/j.jseaes.2018.08.003

Hall, R., 2013. The palaeogeography of Sundaland and Wallacea since the Late Jurassic. *Journal of Limnology,* 72, p.1-17. DOI: 10.4081/jlimnol.2013.s2.e1.

Hall, R., 2014. Indonesia Tectonics: Subduction, Extention, Provenance, and More. *Indonesian Petroleum Association, Proceedings, 38th Annual Exhibition and Convention, Jakarta,* Indonesia IPA, 14 G, p.360.

Hunt J.A., Pyle D.M., and Mather T.A., 2019. The geomorphology, structure, and lava flow dynamics of Peralkaline Rift Volcanoes from high-resolution digital elevation models. *Geochemistry, Geophysics, Geosystems,* 20 (3), p.1508-1539. DOI: 10.1029/2018GC008085

Hutchison, C.S., 2010. Oroclines and paleomagnetism in Borneo and South-East Asia, *Tectonophysics,* 496, p.53-67. DOI: 10.1016/j.tecto.2010.10.008

Hutchison, C.S., 2014. Tectonic evolution of Southeast Asia. *Bulletin of the Geological Society of Malaysia*, 60, p. 1-18.

Kale, V.S., Sengupta, S., Achyuthan, H., and Jaiswal, M.K., 2014. Tectonic controls upon Kaveri River drainage, cratonic Peninsular India: Inferences from longitudinal profiles, morphotectonic indices, hanging valleys and fluvial records. *Geomorphology,* 227, p.152-165. DOI: 10.1016/j.geomorph.2013.07.027

Kusnama, Pardede, R., Mangga, S.A., and Sidarto, 1992. *Geological Map of Indonesia Quadrangle: Sungai Penuh and Ketahun Scale 1: 250.000*. Geological Research and Development Centre, Bandung.

Lange, D., Tilmann, F., Henstock, T., Rietbrock, A., Natawidjaja, D., and Kopp, H., 2018. Structure of the central Sumatran subduction zone revealed by local earthquake travel-time tomography using an amphibious network. *Solid Earth,* 9, p.1035-1049. DOI: 10.5194/se-9-1035-2018

Makowski, C., Finkl, C.W., and Vollmer, H.M., 2017. Geoform and landform classification of continental shelves using geospatially integrated IKONOS satellite imagery. *Journal of Coastal Research,* 33 (1), p.1-22. DOI: 10.2112/JCOASTRES-D-16A-00003.1

Meitzen, K.M., 2017. Applied Geomorphology. International Encyclopedia of Geography: People, the Earth. *Environment and Technology*, p.1-7. DOI:10.1002/9781118786352.wbieg0144.

Metcalfe, I., 1984. Stratigraphy, palaeontology and palaeogeography of the Carboniferous of Southeast Asia. *Mémories de la Société Géologie de France,* 147, p.107-118.

Metcalfe, I., 2000. The Bentong-Raub Suture Zone. *Journal of Asian Earth Science,* 18, p.691-712. DOI: 10.1016/S1367-9120(00)00043-2

Metcalfe, I., 2009. Late Palaeozoic and Mesozoic tectonic and palaeogeographical evolution of SE Asia. *Geological Society, London, Special Publications,* 315, p.7-23. DOI: 10.1144/sp315.2

Metcalfe, I., 2010. Tectonic framework and Phanerozoic evolution of Sundaland. *Gondwana Research*. DOI: 10.1016/j.gr.2010.02.016

Metcalfe, I., 2011. Tectonic framework and Phanerozoic evolution of Sundaland. *Gondwana Research,* 19, p.3-21. DOI: 10.1016/j.gr.2010.02.016

Metcalfe, I., 2013. Tectonic evolution of the Malay Peninsula. *Journal of Asian Earth Sciences,* 76, p.195-213. DOI: 10.1016/j.jseaes.2012.12.011

Metcalfe, I., 2013. Gondwana dispersion and Asian accretion: Tectonic and palaeogeographic evolution of eastern Tethys. *Journal of Asian Earth Sciences,* 66, p.1-33. DOI: 10.1016/j.jseaes.2012.12.020

Metcalfe, I., 2017. Tectonic Evolutions of Sundaland. *Bulletin of the Geological Society of Malaysia,* 63, p.27-60. DOI: 10.7186/bgsm63201702

Mulyasari, R., Utama, H.W., and Haerudin, N., 2019. Geomorphology study on the Bandar Lampung Capital City for recommendation of development area. IOP Conference Series: Earth and Environmental Science 279, 012026. *The International Conference on Geoscience, Makassar, Indonesia,* 279, p.012026-1- 012026-13. DOI: 10.1088/1755-1315/279/1/012026

Muraoka, H., Takahashi, T., Sundhoro, H., Dwipa, S., Soeda, Y., Momita, M., and Shimada, K., 2010. Geothermal systems contrained by the Sumatran Fault and its pull-apart basin in Sumatra, Western Indonesia. *Proceedings of World Geothermal Congress*, p.2-4.

Nabella, F., Utama, H.W., and Said, Y.M., 2019. Geology and Genesis of the Tanco Isolated Hill on the Kerinci Lake, Jambi. IOP Conf. Series: Earth and Environmental Science 279, 012027. The *International Conference on Geoscience, Makassar, Indonesia,* 279, p.012027-1 - 012027-13. DOI: 10.1088/1755-1315/279/1/012027

Natawidjaja, D.H., 2018. Updating active fault maps and sliprates along the Sumatran Fault Zone. *Indonesia, Conference Series: Earth and Environmental Science,* 118, p.2-10. DOI: 10.1088/1755-1315/118/1/012001

Natawidjaja, D.H., 2017. Major Bifurcations, Slip Rates, and A Creeping Segment of Sumatran Fault Zone in Tarutung-Sarulla-Sipirok-Padangsidempuan, Central Sumatra, Indonesia. *Indonesian Journal on Geoscience,* 5, p.137-160. DOI: 10.17014/ijog.5.2.137-160

Otto, J. C. and Smith, M. J., 2013. *Geomorphological mapping, Geomorphological Techniques, Chap. 2*, Sec. 6.

Otofuji, Y., Moriyama, Y.T., Arita, M.P., Miyazaki, M., Tsumura, K., Yoshimura, Y., Shuib, M.K., Sone, M., Miki, M., Uno, K., Wada, Y., and Zaman, H., 2017. Tectonic evolution of the Malay Peninsula inferred from Jurassic to Cretaceous paleomagnetic results. *Journal of Asian Earth Sciences,* 134, p.130-149. DOI: 10.1016/j.jseaes.2016.10.007

Rosidi, H. M. D., Poetro, S. T., Pendowo, B., Gafoer, S,. and Suharsono, 1996. *Geological Map of Indonesia Quadrangle: Painan and Northeast Muarasiberut, Sumatra Scale 1: 250.000*. Geological Research and Development Centre, Bandung.

Said, Y.M. and Utama, H.W., 2023. Late Cretaceous Andesite Intrusion within Strike-slip Fault of Geological Field Features and Landscape, Jambi, Indonesia. *AIP Conference Proceedings, 2598, 020005. 4th International Conference on Earth Science, Mineral and Energy, Yogyakarta, Indonesia,* 2598, p.020005-1-020005-11. DOI: 10.1063/5.0126836

Triyoso, W., Suwondo, A., Yudistira, T., and Sahara, D.P., 2020. Seismic Hazard Function (SHF) study of coastal sources of Sumatra Island: SHF evaluation of Padang and Bengkulu cities. *Geoscience Letters,* 7, p.1-7. DOI: 10.1186/s40562-020-00151-x

Triyoso, W., Sahara, D.P., Sarsito, D.A., Natawidjaja, D.H., and Sukmono, S., 2022. Correlation Dimension in Sumatra Island Based on Active Fault, Earthquake Data, and Estimated Horizontal Crustal Strain to Evaluate Seismic Hazard Functions (SHF). *GeoHazards,* 3, p.227-241. DOI: 10.3390/geohazards3020012

United State Geological Survey (USGS), 2018. *Shuttle Radar Topography Mission (SRTM) 90 M*, http://earthexplorer.usgs.gov/ [7 Aug 2018].

United State Geological Survey (USGS), 2018. *ASTER GDEM 30 M*, http://earthexplorer.usgs.gov/ [7 Aug 2018].

Utama, H.W., Said, Y.M., and Siregar, A.D., 2023. Releasing Bend Structures of Dikit Fault Segment on Grao Sakti, Jambi: Its Related Strike-slip Fault Zone. *AIP Conference Proceedings, 2482, 080009. The 3rd International Conference on Engineering, Technology and Innovative Researches, Purbalingga, Indonesia*, p. 080009-1 - 080009-11. DOI: 10.1063/5.0112809

Utama, H.W., Said, Y.M., Siregar, A.D., Adhitya, B., and Mastur, A.K., 2023. Geochemical Data for Geothermal Exploration on Grao

Sakti, Jambi, Indonesia. *AIP Conference Proceedings, 2482, 080008. The 3rd International Conference on Engineering, Technology and Innovative Researches, Purbalingga, Indonesia*, p.080009-1-080009-8. DOI: 10.1063/5.0111332

Verstappen, H.Th., 2000. *Outline of the Geomorphology of Indonesian*. International Institute for Aerosace Survey and Earth Sciences, Hengelosestraat, Netherland, 200pp.

Verstappen, H.Th., 2010, Indonesian Landforms and Plate Tectonics. *Jurnal Geologi Indonesia,* 5 (3), 200 pp.

Zahirovic, S., Seton, M., and Muller, R. 2014. The Cretaceous and Cenozoic tectonic evolution of Southeast Asia. *Solid Earth,* 5, 227pp. DOI: 10.5194/se-5-227-2014

Zahirovic, S., Matthews, K.J., Flament, N., Müller, R.D., Hill, K.C., Setona, M., Gurnis, M., 2016, Tectonic evolution and deep mantle structure of the eastern Tethys since the latest Jurassic. *Earth Science Reviews,* 162, p.293-337. DOI: 10.1016/j.earscirev.2016.09.005

Zuidam, R.A., 1985. *Aerial photo Interpretation in terrain analysis and geomorphologic mapping*. Smiths publisher, Netherlands, 442pp.