

Landslide geomorphology evaluation and geology structure analysis at Riau-West Sumatra highway in km 89-94

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Abstract. The research area is in the location hit by landslide frequently. Located in Riau-West Sumatra Highway in Km 89-94, Pangkalan Sub District, Lima Puluh Kota District, West Sumatra Province. The research objective to analyse the geomorphological conditions, which is relevance an increased vulnerability to landslides in the study area. The method used consist of geomorphology analysis using morphometric, morphography and morphogenetic parameters. The results of the analysis concluded that the geomorphology of the reserach area is classified into two: High Hills Steep Structural Geomorphology Unit (S2) dominates in all regions and Slightly Steep Hills Denudational Geomorphology Units (D3) is located in the Northeast, the percentages of distribution are 83%, and 17% respectively. Drainage pattern classified to parallel system. Lithology constituent consisting of claystone, siltstone, sandstone, and andesite. Structural geology analysis of joint show trend pattern to the Northwest – Southeast.

1 Introduction

The research area is located on the Riau - West Sumatra Highway, Tanjung Balik area. The research area is located at 89-94 Km Highway, Pangkalan Koto Baru Subdistrict, Limapuluh Kota District, West Sumatera Province, regarding administratively. The coordinates are between 00002'00" and 00000'20" S and 100041'40"-100041'00" E. Topographic characterization of Lima Puluh Kota District varies consist of flat, undulating and hilly with height elevation between 110 meters and 2,261 meters from above of sea level [1-3], shows in Fig 1. As a result of the influence of natural barriers, especially the topography and morphology of the area in the the Barisan Hill, which effects to the slope of a fairly high land, hydrological conditions with high intensity rainfall and chemistry-physics of soil quality, then the area of Lima Puluh Kota District is very susceptible to the movement of the soil [4-9]. The geological structure in the form of a fault results in the vulnerability of this region from the dangers of ground motion [10, 11]. Research objective is to analyze the geomorphological conditions, which has the relevance of the increased vulnerability to landslides in the research area [9, 12-14].

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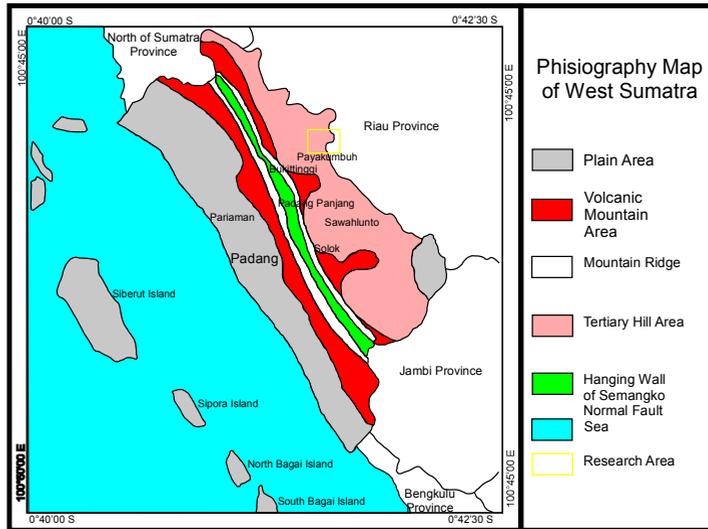


Fig 1. Physiographic map of West Sumatra which shows the research area marked with yellow boxes.

1.1 Regional geology

The stratigraphy of the research area consists of 3 formations based on regional geology. The oldest rocks in the research area are the Brani Formation (Tob) and the Andesite-Basalt Volcano (Ta), then followed by the Koto Alam Volcano Formation (QTve) [5, 15, 16].

The Brani formation is composed of polymeric brownish colored conglomerates with gravel to glacial fragments and a clay sand matrix. The conglomerate fragment consists of various lithologies, namely andesite, limestone, slate, and granite. The Brani Formation is deposited on Pre-Tertiary rocks in an inconsistent manner and related to each other by the Sangkarewang Formation. The Brani Formation rocks are estimated to be Paleocene to Eocene age.

Andesite-basalt volcanic rock unit (Ta) consists of lava flows, breccias, agglomerates, and hypabyssal rocks.

Koto Alam volcano formation (Qtve) consist of medium to base lava, agglomerates and lava.

1.2 Structural geology

Strike-slip Semangko fault generates a weak zone, which allows a magma exit on volcanic activity and produces a range of Barisan Mountains, shows in Fig. 2. This means that the position of Semangko Fault is right on the line of the Mountain Volcanic-Arc, which is found some Wrench Fault in the mountains. In the back-arc basin area is influenced by tensional with the direction of force perpendicular to the subduction zone. This tensional regime is caused by the presence of heat flow below the surface. The compression results in Wrench dextral trends are parallel to the plate boundary and strongly influences the conventional regime in the back-arc basin and to release structure, which aligned parallel to the plate boundaries [3, 17]. Cross section intersects Sumatra Island in West-East direction is shown in Fig 3.

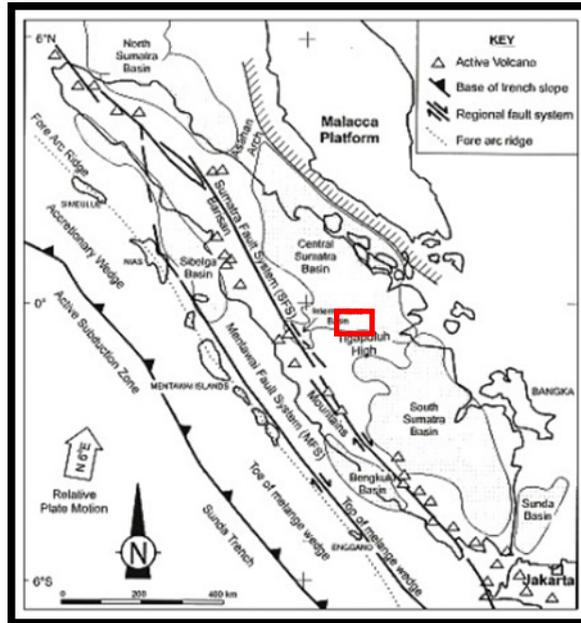


Fig. 2. Regional tectonic framework of the research area is marked in a red colored box.

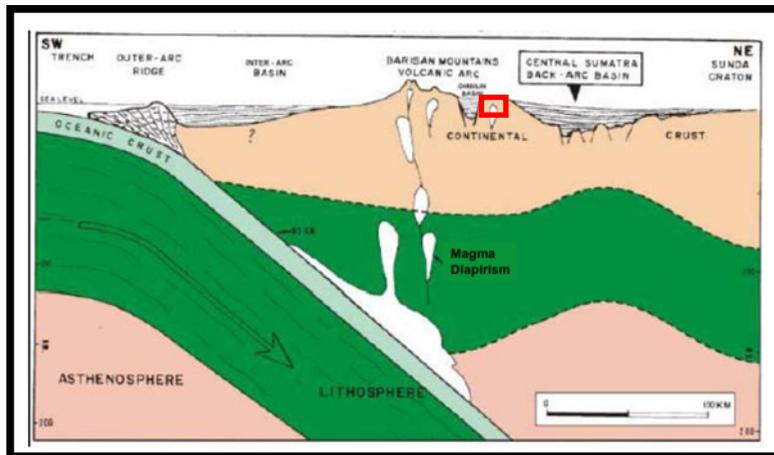


Fig. 3. Cross-section of Sumatra Island in West-East direction, the red box shows the research area.

2. Methodology

The geomorphology is defined as a study that describes the shape of land and process and the relationship. The landform and the process in the arrangement of spatial. The formation of the landscape is the result of the geomorphological process caused by the endogenic and exogenic forces. The landscape had varied shapes and classified based on certain factors such as process, phase, the type of lithology as well as the influence of geological or tectonic structures that work [18]. The classification of landscapes are shown in Table 1 and Table 2 into geomorphological units based on several factors through five approaches are: Morphography is an aspect that describes the morphology of an area such as terrain,

hills or mountains. Morphometry is the value of an area geomorphology aspect, such as slope, elevation, slope length, and roughness relief can be seen in Table 3.

Table 1. Landscape unit classification based on high.

Relief unit	Angle Slope (%)	High (m)
Flat or nearly flat	0-2	< 5
Corrugated/sloping ramps	3-7	5-50
Wavy	8-13	51-75
Hilly wavy	14-20	76-200
Hilly sharp steep	21-55	200-500
Mountains sharp cuts	55-140	500-1000
Very steep	Mountains >140	>1000

Table 2. Classification of landscape unit.

Landform	Symbol	Color
Structure formation	S	Purple
Origin of volcano formation	V	Red
Denudation formation	D	Coklat
Sea origin formation	M	Biru Tua
River origin/fluvial formation	F	Green
Wind formation	A	Yellow
Karst formation	K	Orange
Glacial origin formation	G	Blue bright

Table 3. Classification structural landform.

Geomorphological process	Landform	Code	Structural landform
Endogenic	Structural	S17	Structural valley
Exogenic	Denudational	D1	Eroded hills

Passive morphostructure is the aspect that observes the lithology type and rock structure associated with the erosion process, such as Cuesta, hogback and dome. Active morphostructure is the aspect that examines the activity of endogenic processes such as vulcanism, fractures, and creases, such as volcanoes, anticline mountains, fault slopes. Morphodynamics is aspects that describe exogenic processes associated with wind, water or ice motion, such as sand dune, fluvial plain, sedimentation or desert [19, 20].

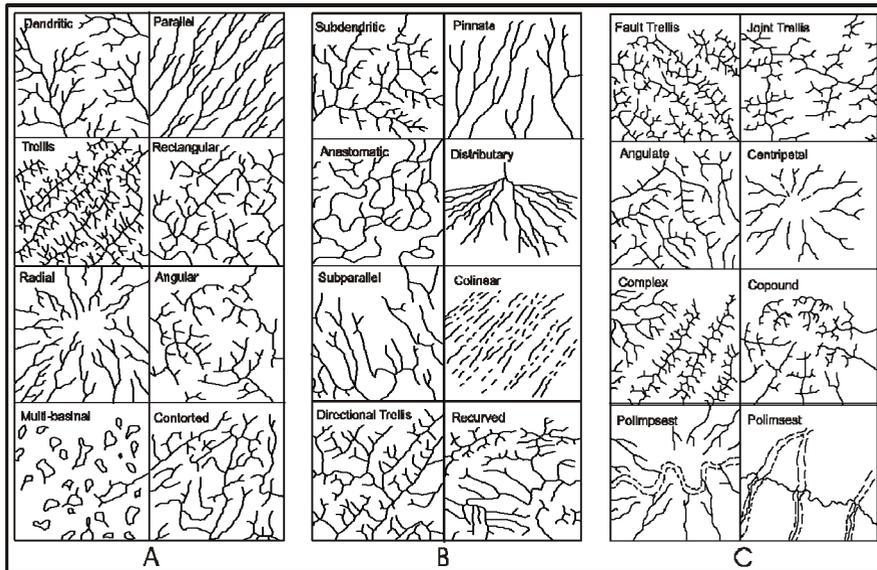


Fig. 4. Base patterns of river flowing and river flow modification patterns [15, 18].

Table 4. River patterns and their characteristics [19, 20].

River patterns	Characteristics
Dendritic	Flat sedimentary rock layers or crystalline rock association, that are non-uniform and resistant. Regionally, the flow area has a slope, the type of drainage pattern forms a branch spread like a shade tree.
Parallel	Generally shows areas of moderate to steep slopes and can be found also in areas of elongated hills. There is often a transition pattern between dendritic patterns with parallel patterns. The elongated hills form with parallel drain patterns reflecting the hills are influenced by folding.
Trellis	Sedimentary sediments dipped, volcanic rocks or low-grade metasediment with clear weathering differences. The type of drainage pattern usually faces on the side along the subsequent stream.
Rectangular	faults that have a slope angle, do not have a refractive layer of rock and often show an uninterrupted flow pattern.
Radial	Volcanic area, intrusion (dome) and the remnants of erosion. Radial drainage patterns in volcanic areas are referred to as multi radial drainage patterns. Note: the radial drainage pattern has two systems: the centrifugal system (spreading out from the center), means that the area is domed or conical, while the centripetal system (spreading toward the center) means that the area is a hollow.
Annular	Structure of dome / cone, basin and possibly <u>stocks</u>
Multibasinal	Deposition in the form of dunes result of landslide with difference of grinding or bedrock smoothing, is area of movement of soil, volcanism, solubility and melting of snow (<u>permafrost</u>)

There are some aspects of the approach in geological mapping like the shape of the slope, the pattern of the ridge and patterns of drainage. The drainage pattern is classified into a basic drainage pattern and a flow pattern of modification. The basic streaming pattern is a characteristic drainage pattern that can be distinguished from other drain patterns than the modification flow pattern (Fig. 4) [18, 21]. Drainage pattern changed from the basic pattern, but the general pattern remains dependent on the underlying pattern. The characteristics of the basic drainage pattern and its modification are in Table 4 [22, 23].

This lithology is used as a controller in determining limit - geological units. Lithology may affect the morphology of rivers and topology networks that facilitate weathering and rock resistance to erosion. Petrography is an analysis of the composition of rocks using a microscope to determine the name of rocks more accurately to determine the deposition environment based on the percentage of rock composition. In petrographic observations, we must be able to decide on the amount of composition volumetrically to determine precisely the name and texture of the rock [24-26].

The basis used for the naming/classification of rocks is based on the composition of mineral constituents of rock and based on the texture of rocks. Both criteria are not only useful for the description (naming) of rocks but also for the origin of rock events. Calculation of the percentage of mineral sedimentary rock composition can be seen in Fig. 2 and Fig. 3. Method of Rock Naming: Calculates the percentage of the presence of a major mineral, where the amount of $Q + A + P + RF$ should be 100%. Q = Quartz, A = Alkali feldspar, P = Plagioclase, RF = Rock Fragment, shows in Fig. 5. If the number of primary mineral percentages is not 100%, then the main mineral count is recalculated to 100%. Plot the percentage price of the main mineral into the diagram to get the name of the rock [25, 27, 28].

QAPF classification for plutonic and volcanic rocks which is based on the mineral capital proportions of Quartz (Q), Alkali Feldspar (A) and Plagioclase (P) or plagioclase (P) and feldspathoids (F), shows in Fig. 6. Rocks with mafic content $> 90\%$ have their classification. If the mineral mode cannot be determined as the case for volcanic rocks, then a chemical classification of total alkalis versus silica (TAS) is used [29, 30].

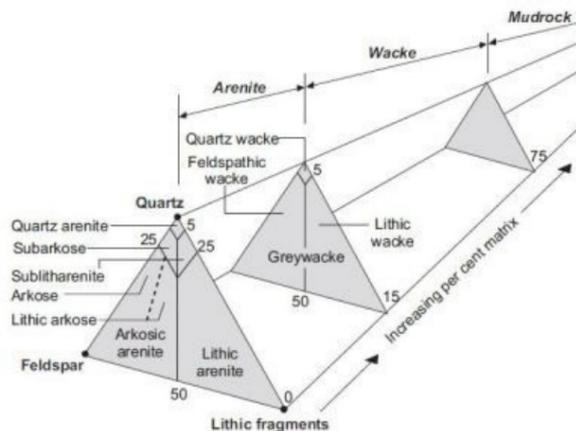


Fig. 5. Classification of sandstone [31].

3.1.2 Morphography

The research area is composed of landforms with elevation values ranging from 325-1156 m, with U-shaped and V-shaped basins, and one type of parallel drainage pattern. Based on landform in the research area is divided into two namely, hills and mountain. The kind of drainage pattern that dominates in the research area is parallel. Upstream rivers research area overlooks in the Southwest especially in areas with steep slopes with elevation values ranging from 700 to 900 m and flowing downstream of steep Northeast trending streams with elevation values ranging from 331-468 m. Some major rivers converge in the center of the research area and flow northward with elevation values of 325-412 m as shown in Fig 8.

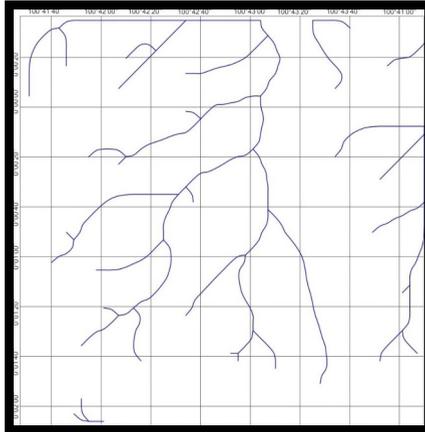


Fig. 8. The drainage pattern of the research area shows the parallel type.

The existing lithology in this flow pattern is dominated by the rocks and clay, with a grain size ranging from smooth to very smooth. The parallel flow pattern of the research area indicates a large fracture that cuts and shapes the land with a steep slope. The morphology of the steep slopes followed by the straight-shape flow streams, which have the direction of the slopes with the branches of the tiny river bit. Structure and lithology contained in this research area greatly influence the formation of this flow pattern.

3.1.3 Morphogenetic

The result of geomorphology map analysis and the field appearance, the morphogenetic of the research area is classified into two namely: the structural origin and the denudational origin. Determination of geomorphology unit is generated based on the result of geomorphology analysis through morphometry, morphography, and morphogenetic aspects. Based on the geomorphology aspect analysis, the research areas are classified into two geomorphological units, namely High hills steep structural geomorphological units, and roughly steep hill denudational geomorphological units.

The high steep hills structural geomorphological units (S2) has a topography steep mountain relief with a steep slope of 56-140% and a height of 688 m and a range of elevation values of 468-1156 m which has a very strong erosion rate. This unit of land is characterized by a very tight and elongated contour pattern, which has a steep incline to a very steep incline. The lithology units are clay and andesite, which are resistant to weathering and erosion. Based on the shape of the relief and slope, this unit is called the High steep hills structural geomorphological units as shown in Fig 9.

The slightly steep hills denudational geomorphology units (D3) has a topography with steep hills up to steep slopes with a slope of 21-55% and a height of 125 m and an elevation

range of 325-450 m. This unit is easily weathered and eroded. This unit of land is characterized by a tight and elongated contour pattern and has a rather steep slope. The lithology in this unit is clay and silt. Based on the shape of the relief and the slope of the slope, this unit is called the slightly steep hill denudational geomorphological units, shown in Fig. 10.



Fig. 9. Photo geology shows the High steep hills structural geomorphological units.



Fig. 10. Photo geology shows the Slightly steep hill denudational geomorphology units.

3.2 Lithology

Rock analysis is used several parameters to analyze lithology of rocks i.e, colors consisting of weathering color and fresh color, texture consisting of grain, grain shape, compactness, sorting, permeability, hardness, sedimentary structure, carbonate content, mineral composition, hardness, and contact. The following types of lithology are obtained in the research area are claystone, siltstone, sandstone, and andesite.

3.2.1. Claystone

Characteristics of claystone are greenish brown-green color, while fresh brown color, round grain shape, enclosed containers indicated by granular touch, well sorted was indicated by uniform grain size, permeability was indicated by its absorption quite quickly when it was dropped water, soft can be squeezed in the show from Fig. 11 (a).

3.2.2. Siltstone

The characteristics of stone in the research area are weathering products, judging from the lithologic state is not ideal and fresh. Siltstone in the research area showed colors are dark

brown as weathered and fresh brown as fresh, very fine grain size, good sorting, closed pack and permeability well indicated by rapid absorption when in water drops, soft can be squeezed as shown in Fig. 11 (b).



(a)



(b)

Fig. 11. Photo geology shows (a) the landslide loose claystone on Station 3, the direction of the photo N 240°E, (b) the outcrop of a landslide of siltstone at station 6, the direction of the photo N 239°E.



(a)



(b)

Fig. 12. Photo geology shows (a) the sandstone outcrop showing a landslide at Station 1, the direction of the photo N 220 °E, (b) the andesite at Station 13 with a slope of 65°, N 151°E.

3.2.3. Sandstone

Sandstone outcrops characteristics are white, yellowish color and yellowish-gray color, excellent grain size, well sorted, open and compact packing, rounded with medium porosity as shown in Fig. 12 (a).

3.2.4 Andesite

Andesite outcrop conditions characteristics are dark gray as a weathered color and pale white as a fresh color, holocrystalline, aphanitic, subhedral, inequigranular, height and width are 11 meters and 7.5 meters respectively, shown in Fig. 12 (b).

3.3 Geological structure

The geological structures are observed in the research area are joints, which are examined at Station 13 in Andesite. The reconstruction data show the direction of the shear joint 1, shear joint 2, extension joint, release joint are N 180°E/36°, N 26°E/18°, N 120°E/57°, and N 222°E/73° respectively. Values of σ_1 , σ_2 , σ_3 are 32°, 16°, and 53° successively. The result of joint analysis show trend pattern to the Northwest-Southeast, stereo net plot analysis shown in Fig. 13.

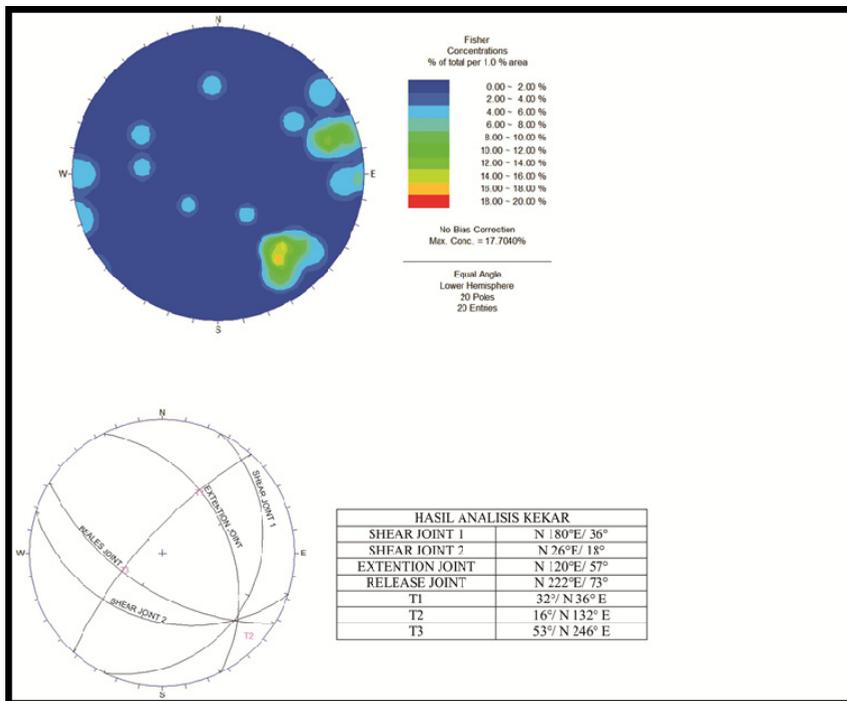


Fig. 13. Stereo net plot analysis show trend pattern of joints to the Northwest–Southeast.

4 Conclusions

The research area have two geomorphological units, namely: High Steep Hills Structural Geomorphological Units (S2) and Slightly Steep Hill Denudational Geomorphological Units (D3). River flow patterns in the study area are classified into Sub-Dendritic drainage patterns. The lithologies found in the research area are claystone, siltstone, sandstone, and andesite. The joint analysis show trend pattern to the Northwest-Southeast.

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