Quantitative Geomorphosite Analysis of Ranah Minang Silokek Geopark

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Abstract. The unique geological condition of Ranah Minang Silokek Geopark (RMSG) is the main reason for its designation as a geopark. RMSG, covering an area of 3131 km², has a long history of geological processes which begin from Carboniferous Period to Tertiary Period. The long geological history of RMSG is represented by fourteen geosites found in this area. Studies about the geodiversity of these fourteen geosites have been conducted by several researchers. However, the study about geopark eligibility in this area has not been conducted specifically. Thus, this research is aimed to determine the eligibility of RMSG as a geopark using a geomorphosite assessment method. In this research, the geomorphosite assessment will use five criteria values which consist of scientific and intrinsic values, educational values, economical values, conservation values, and added values. Those criteria will be applied in each geosites in the RMSG area and the results will be in the percentage format. Then, the geomorphosite value will be determined by the average value of the five criteria. Based on the assessment, a total of thirteen geosites have the value above 50%, while one geosite acquired below 50%. Despite gaining more than 50% value, most of the geosites have a low economic values parameter which is below 40%. Improvements of accessibility and amenities are necessary to be done in order to increase eligibility of RMSG as a sustainable geopark.

1. Introduction

In the tourism industry, geotourism is a relatively new concept which is referred to as nature-based tourism that concentrates on the geosystem [1]. Basic aspect of geotourism is geoheritage which consists of geosite and geomorphosite. Yet, the geomorphosite concept is more comprehensive and it includes cultural, aesthetic, and economic aspects [2]. Moreover, in geotourism, the visitors are probably not enjoying just one site, however; they will visit several geosites in the area of a geopark. Hence, the geomorphosite study will be much more important to satisfy visitors in terms of knowledge or geological history. However, the deep analysis of geomorphosite, especially quantification treatment is still a constraint. The analysis needs to be conducted as a basis of appropriate use and its management of its geoheritage [2].

This study was conducted in the Ranah Minang Silokek Geopark (RMSG) which has the same coverage with Sijunjung Regency (Figure 1). RMSG is an area which has a complete geological history from Carboniferous Period to Tertiary Period. In terms of geological condition, that area is part of Ombilin Basin which is known as intermountain basin and part of Mergui Microplate [3] in [4]. In the new version, there are fourteen quantified geosites that can represent the geopark throughout Sijunjung Regency. Whereas in the previous study in [5], Kubalikova method [2] was utilized to prior geomorphosites which are different with the most updated. Hopefully, both of them will make a well-defined scientific research in the RMSG.

The aim of this paper is to determine the eligibility of RMSG as a geopark using a quantitative method through the geomorphosite assessment method [2]. This is achieved by reviewing previous literature and fieldwork to each geosite of Ranah Minang Silokek Geopark (RMSG).

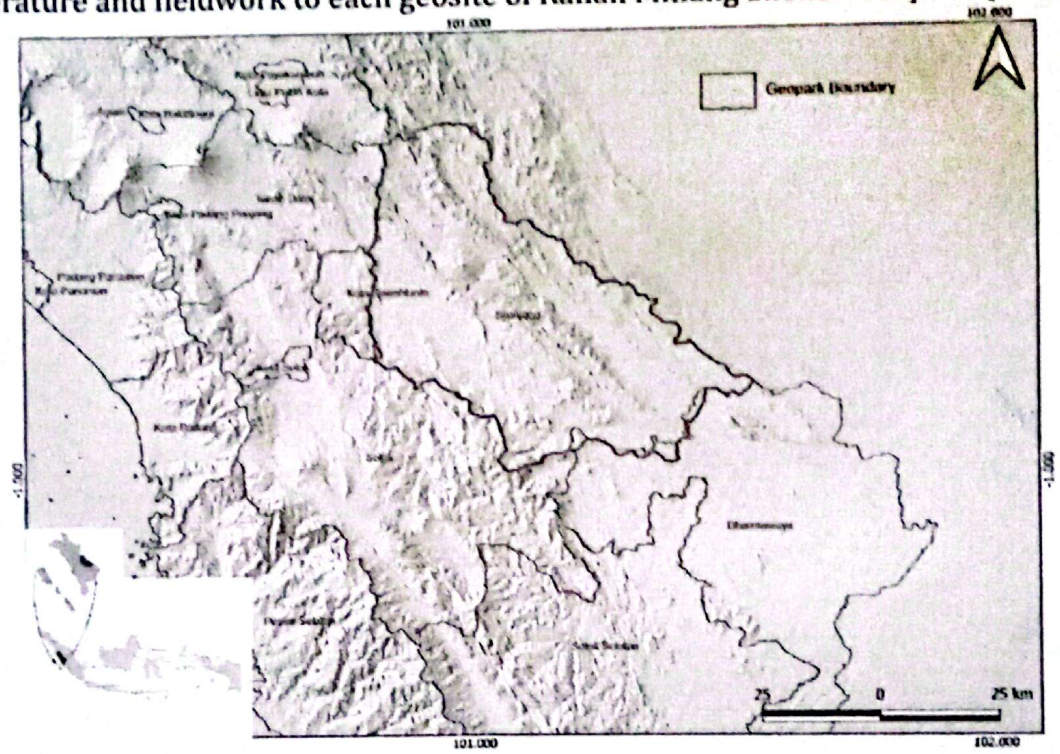

Figure 1. Ranah Minang Silokek Geopark (RMSG) has the same boundary with Sijunjung Regency which is covering area of 3131 km².

2. Geological Settings

The geological settings of RMSG can be divided into three sections which consist of tectonic, stratigraphy, and geological structures.

2.1 Tectonic

RMSG is an area located in the Barisan Mountain Range Zone and Ombilin Basin (Figure 2). The formation of Barisan Mountain is influenced by the subduction activity in Sumatra. In the Eocene–Early Oligocene Epoch, the subduction process triggers the uplifting which results in the formation of a mountain range known as Barisan Mountain [6]. Furthermore, the subduction process also causes partial melting of the upper mantle layer which triggers the formation of magma and magmatism [7]. Emerging magma to the surface will create volcanoes and this event is marked as the beginning of the Barisan Mountain volcanism.

Some sections of the RMSG area are part of the Ombilin Basin. Ombilin Basin is a pull apart basin which is formed due to the extensional regime that happened in Eocene–Oligocene Epoch.

This tectonic regime triggers the formation of the horst and graben system. Furthermore, this event is followed by the transgression event in Late Oligocene–Middle Miocene Epoch [8]. The transgression event causes an increase of sea level which makes the majority of the region in Sumatra submerged. Submerged graben is a perfect zone for the sedimentation, with the sediment source coming from Barisan Mountain Range. Thus, some of the sedimentary rocks such as sandstone, mudrock, and conglomerate can be found in Ombilin Basin, and also in some parts of the RMSG area.

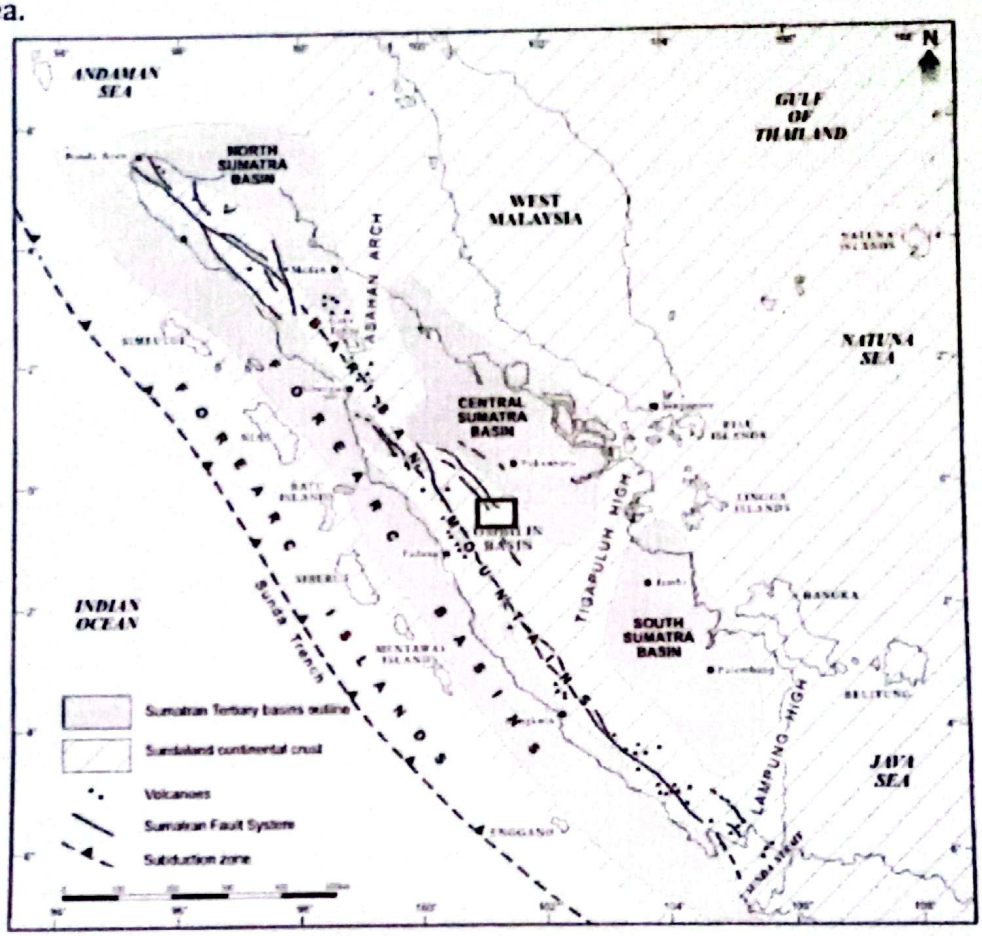

Figure 2. Location of RMSG within Barisan Mountain Range and Ombilin Basin (adapted from [8]).

2.2 Stratigraphy

Complexity of geological condition is exemplified by high diversity of lithology found in the RMSG area. The lithology in the RMSG area consists of igneous rock, sedimentary rock, and metamorphic rock (Figure 3). Furthermore, the geological age in the RMSG is also various from Carboniferous–Permian Period to Tertiary Period (Figure 4). This lithology creates stratigraphy of RMSG which can be classified into three groups based on the period: Carboniferous–Permian, Triassic, and Tertiary–Quaternary.

The oldest rock age in the RMSG area is Carboniferous–Permian. This rock is represented by Kuantan Formation, diabase, and basalt [9]. Kuantan Formation consists of three members which are Lower Member of Kuantan Formation, Limestone Member of Kuantan Formation, and Phyllite and Shale Member of Kuantan Formation. The Lower Member of Kuantan Formation is composed of quartzite and quartz sandstone with intercalation of phyllite, siliceous slate, shale, volcanic rock, chloritized tuff, conglomerate, and chert. The Limestone Member of Kuantan Formation is composed of limestone, slate, phyllite, siliceous shale and quartzite. The last member of Kuantan Formation is Phyllite and Shale Member which consists of shale and phyllite, intercalation of

quartzite-siltstone, cherts, and lava flows. The second formation is Silungkang Formation, which is composed of limestone that contains thin intercalations of shale, sandstone and tuff.

The Triassic Igneous Rock Formation is a formation that consists of granite, quartz porphyry, and quartz diorite [9]. The granite has a composition from leucogranite to quartz monzonite. Quartz porphyry is an igneous rock containing quartz and feldspar as phenocryst. The quartz diorite has a holocrystalline texture.

The Tertiary and Quaternary aged stratigraphy consists of several formations. In Tertiary stratigraphy, there are three formations which are Brani Formation, Telisa Formation, and Ombilin Formation. Brani Formation is an Oligocene aged formation that composed conglomerate lithology with some sandstone intercalations [9]. Telisa Formation is an Early–Middle Miocene aged formation and it is divided into two members: Lower Member of Telisa Formation and Upper Member of Telisa Formation. The Lower Member of Telisa Formation consists of clayey marl, lignitic sandstone, andesitic tuff, andesite breccia, and glauconitic sandstone [9]. On the other hand, the Upper Member of Telisa Formation is composed of shale and marly limestone with thin intercalations of andesitic tuff [9]. The third formation is Ombilin Formation. Ombilin Formation is an Early–Middle Miocene Formation that contributes to the Ombilin Basin genesis. The Ombilin Formation has two members named Lower Member and Upper Member. The Lower Member of Ombilin Formation consists of micaceous quartz sandstone intercalation of arkose, clayey shale, quartz conglomerate and coal [9]. Meanwhile, The Upper Member of Ombilin Formation consists of clay, marl with intercalations of sandstone, conglomerate and tuffaceous sandstone, calcareous and fossiliferous [9]. In addition, Tertiary limestone and coral-reef limestone deposits are found locally in specific places and the Quaternary stratigraphy consists of pumice tuff and river alluvium.

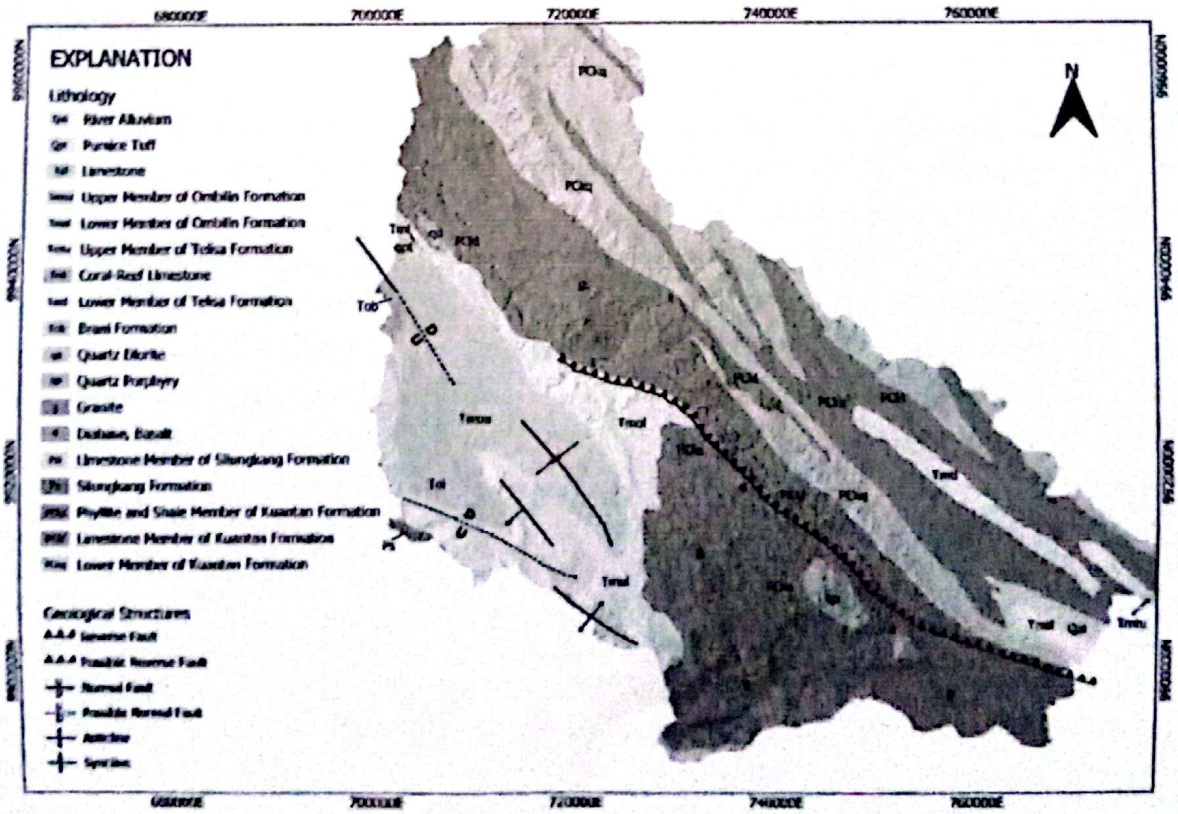

Figure 3. Geological map of RMSG (adapted from [9]).

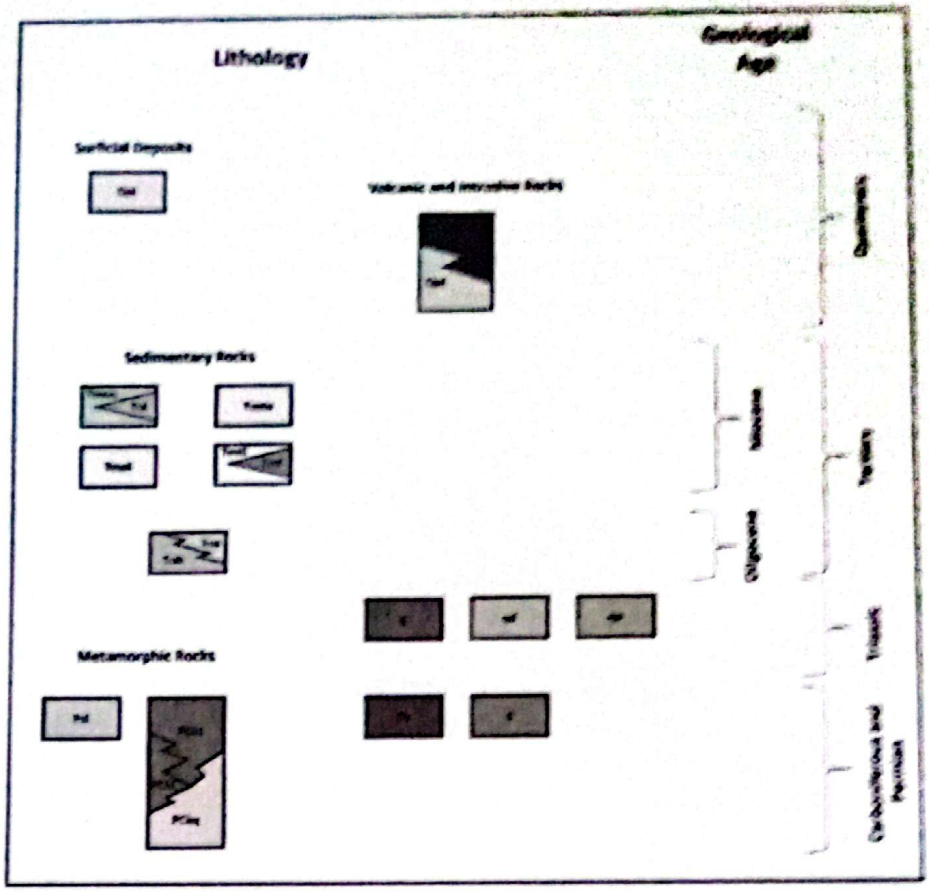

Figure 4. Stratigraphy of RMSG showing a long range of geological age from Carboniferous to Quaternary Period (adapted from [9]).

2.3 Geological Structures

The location of RMSG in the Great Sumatra Fault creates various geological structures. The geological structures found in RMSG consist of reverse fault, normal fault, syncline, and anticline (**Figure 3**). Takung Fault is a NW-SE oriented reverse fault that cuts through the Limestone Member of Kuantan Formation, Triassic igneous rock, and the Ombilin Formation. This fault causes uplifting on Limestone Member of Kuantan Formation over the Triassic igneous rock and Ombilin Formation [10]. Furthermore, two normal faults are found cutting the Ombilin Formation. These faults can be formed due to the extensional regime which results in the formation of the graben system. In addition, syncline and anticline also existed in the Ombilin Formation.

3. Methods

In order to know the eligibility of the geosites, the assessment is necessary to be done. In this research, the assessment is conducted using quantitative geomorphosite assessment based on [2]. According to [2], there are five criteria that have to be assessed on each geosites and geomorphosite which are scientific and intrinsic value, educational values, economical values, conservation values, and added values. Each criteria is then divided into several parameters. In scientific and intrinsic criteria, it contains four parameters which consist of integrity, rarity, diversity, and scientific knowledge. In Educational criteria, the parameters consist of representativeness and visibility/ clarity of the features/ processes, exemplarity and pedagogical use, existing educational products, and actual use of a site for educational purposes. The third

criteria is economical value which has three parameters such as accessibility, presence of tourist infrastructure, and local products. The fourth value is conservation value which has four parameters: actual threats and risks, potential threat and risks, current status of a site, and legislative protection. The last value is added value which has three parameters such as cultural values, ecological values, and aesthetic values.

The value of each parameter is in the range 0 – 1, with 0 is the lowest and 1 is the highest. Then the sum of the parameter will be the value of the criteria which is weighted into 100 percent. The sum of the five weighted criteria values will be the geomorphosite value and it will be used to determine the eligibility of the geosites.

Table 1. Geomorphosite asessement criteria and parameter according to [2]

Scientific and intrinsic values	
Integrity	• 0 - totally destroyed site, • 0.5 - disturbed site, but with visible abiotic features, • 1 - site without any destruction
Rarity (number of similar sites)	• 0 - more than 5 sites, • 0.5 - 2 – 5 similar sites, • 1 - the only site within the area of interest
Diversity (number of different partial features and processes within the geosite or geomorphosite)	• 0 - only one visible feature/processes, • 0.5 - 2 – 4 visible feature/processes, • 1 - more than 5 visible features/processes
Scientific knowledge	• 0 - unknown site, • 0.5 - scientific papers on national level, • 1 - high knowledge of the site, monographic studies about the site
Educational values	
Representativeness and visibility/ clarity of the features/ processes	• 0 - low representativeness/ clarity of the form and process, • 0.5 - medium representativeness, especially for scientists • 1 - high representativeness of the form and process, also for the laic public
Exemplarity, pedagogical use	• 0 - very low exemplarity and pedagogical use of the form and process,

	0.5 - existing exemplarity, but with limited pedagogical use, • 1 - High exemplarity and high potential for pedagogical use, geodidactics and geotourism
Existing educational products	• 0 - no products, • 0.5 - leaflets, maps, web pages, • 1 - info panel, information at the site
Actual use of a site for educational purposes (excursions, guided tours)	• 0 - no educative use of the site, • 0.5 - site as a part of specialized excursions (students), • 1 - guided tours for public
Economical values	
Accessibility	• 0 - more than 1000 m from the parking place, • 0.5 - less than 1000 m from the parking place, • 1 - more than 1000 from the stop of public transport
Presence of tourist infrastructure	• 0 - more than 10 km from the site existing tourist facilities, • 0.5 - 5 –10 km tourist facilities, • 1 - less than 5 km tourist facilities
Local products	• 0 - no local products related to a site, • 0.5 - some products, • 1 - emblematic site for some local products
Conservation values	
Actual threats and risks	• 0 - high both natural and atrophic risks, • 0.5 - existing risks that can disturb the site, • 1 - low risks and almost no threats
Potential threat and risks	• 0 - high both natural and atrophic risks, • 0.5 - existing risks that can disturb the site, • 1 - low risks and almost no threats

Current status of a site	• 0 - continuing destruction of the site, • 0.5 - the site destroyed, but now with management measures for avoid destruction, • 1 - no destruction
Legislative protection	• 0 - no legislative protection, • 0.5 - existing proposal for legislative protection, • 1 - existing legislative protection (Natural monument, Natural reservation...)
Added values	
Cultural values: presence of historical/ archaeological/ religious aspects related to the site	• 0 - no cultural features, • 0.5 - Existing cultural features but without strong relation to abiotic features, • 1 - existing cultural features with strong relations to abiotic features
Ecological values	• 0 - not important, • 0.5 - existing influence but not so important, • Important influence of the geomorphologic feature on the ecologic feature
Aesthetic values: number of colours; structure of the space, viewpoints	• 0 - one color, • 0.25 - 2 – 3 colors, • 0.5 - more than 3 colors; • 0 - only one pattern, • 0.25 - two or three patterns clearly distinguishable, • 0.5 - more than 3 patterns; • 0 - none, • 0.25 - 1 – 2, • 0.5 - 3 and more

4. Results

The geomorphosite assessment is conducted in fourteen geosites found in the RMSG area (**Figure 5**). The results of the geomorphosite assessment are mentioned in Figure 6.

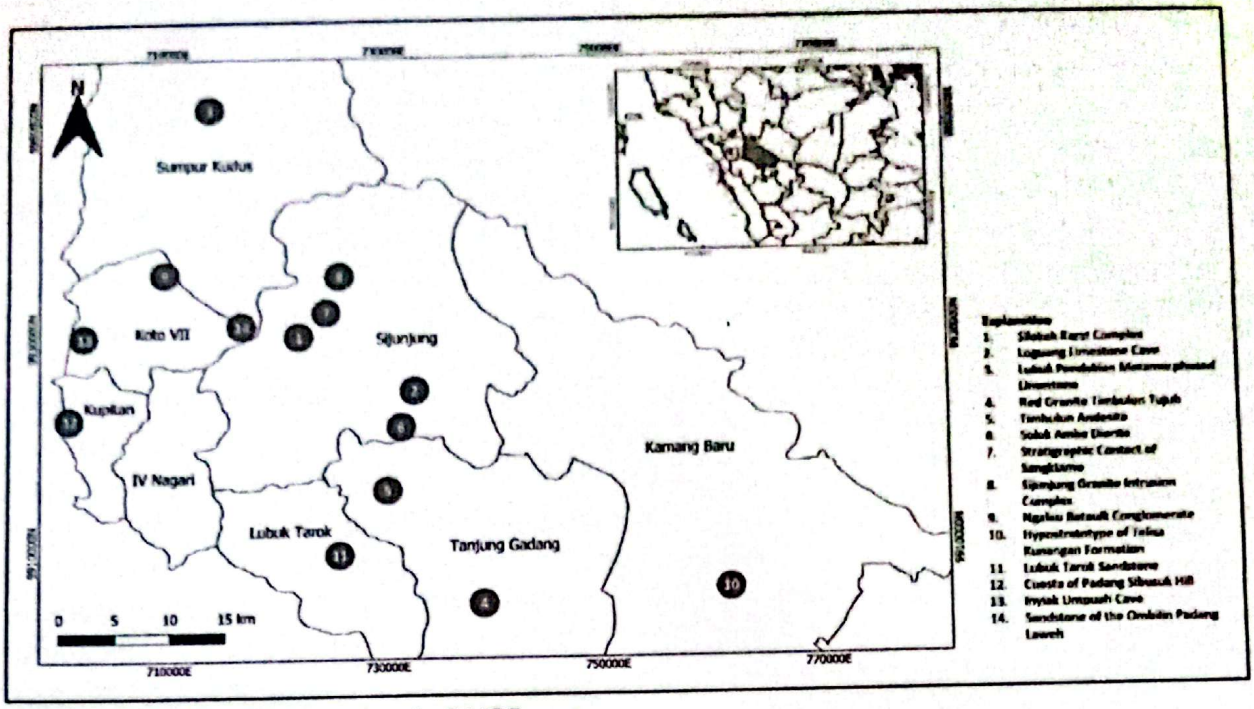

Figure 5. The location of 14 geosites in RMSG area.

Geomorphosite Assessment Criteria (Rybalkova, 2013)

No	Geosite	Scientific and Intrinsic Values						Educational Values						Economical Values						Conservation Values						Added Values					Geomorphosite Value
		I	R	D	SK	SUM	SUM (100%)	RE	EP	EEP	AE	SUM	SUM (100%)	AC	PI	LP	SUM	SUM (100%)	AR	PR	CS	LGP	SUM	SUM (100%)	C	E	A	SUM	SUM (100%)	
1	Silokek Karst Complex	1	0.5	1	1	3.5	87.5	1	1	1	1	4	100	0.5	0.5	0	1	25	1	0.5	1	1	3.5	87.5	1	1	0.75	2.75	68.75	73.75
2	Logoung Limestone Cave	1	1	0.5	0	2.5	62.5	1	1	0.5	1	3.5	87.5	0.5	0.5	0	1	25	1	0.5	1	1	3.5	87.5	0	1	0.5	1.5	37.5	80
3	Lubuk Pendulum Metamorphosed Limestone	1	1	0.5	0	2.5	62.5	1	1	0.5	0.5	3	75	0	0.5	0	0.5	12.5	1	0.5	1	1	3.5	87.5	0	0.5	0.5	1	25	52.5
4	Red Granite of Timbulun Tujuh	1	0.5	0.5	0.5	2.5	62.5	1	1	0.5	0.5	3	75	0.5	0.5	0	1	25	1	0.5	1	1	3.5	87.5	0	0.5	0.5	1	25	62.5
5	Timbulun Andesite	1	1	0.5	0	2.5	62.5	1	1	0.5	1	3.5	87.5	0.5	1	0.5	2	50	1	0.5	1	1	3.5	87.5	0	0.5	0	0.5	12.5	47.5
6	Solok Amba Diorite	1	1	0.5	0	2.5	62.5	0.5	0.5	0.5	0.5	2	50	0.5	0.5	0	1	25	1	0.5	1	1	3.5	87.5	0	0.5	1	1.5	37.5	60
7	Stratigraphic Contact of Sangkarno	1	0.5	0.5	1	3	75	1	1	1	0.5	3.5	87.5	0.5	0.5	0.5	1.5	37.5	1	0.5	1	1	3.5	87.5	0	0.5	1	1.5	37.5	60
8	Sijunjung Granite Intrusion Complex	1	0.5	0.5	0.5	2.5	62.5	1	1	0.5	0.5	3	75	0.5	0.5	0	1	25	1	0.5	1	1	3.5	87.5	0	0.5	0.75	1.25	31.25	56.25
9	Ngalau Batauik Conglomerate	1	1	0.5	0.5	3	75	1	1	0.5	1	3.5	87.5	0.5	0.5	0.5	1.5	37.5	1	0.5	1	1	3.5	87.5	0	0.5	0.5	1	25	62.5
10	Hypostratotype of Telisa Kurangan Formation	1	1	0.5	0.5	3	75	1	1	0.5	0.5	3	75	0.5	0.5	0	1	25	1	0.5	1	1	3.5	87.5	0	0.5	1	1.5	37.5	60
11	Lubuk Tarok Sandstone	1	0.5	0.5	0.5	2.5	62.5	1	1	0.5	0.5	3	75	0	0.5	0	0.5	12.5	1	0.5	1	1	3.5	87.5	0	0.5	0.5	1	25	52.5
12	Cuesta of Padang Sibusuk Hill	1	0.5	0.5	0.5	2.5	62.5	1	1	0.5	0.5	3	75	0.5	0.5	0.5	1.5	37.5	1	0.5	1	1	3.5	87.5	1	0.5	0.5	2	50	62.5
13	Inyiak Umpuah Cave	1	1	0.5	0	2.5	62.5	1	1	0.5	0.5	3	75	0.5	0.5	0	1	25	1	0.5	1	1	3.5	87.5	0	1	0.75	1.75	43.75	68.75
14	Sandstone of the Ombilin Padang Laweh	1	1	0.5	0.5	3	75	1	1	0.5	0.5	3	75	0	0.5	0	0.5	12.5	1	0.5	1	1	3.5	87.5	0	0.5	0.5	1	25	55

Explanation

Scientific and Intrinsic Values
- I = Integrity
- R = Rarity
- D = Diversity
- SK = Scientific Knowledge

Educational Values
- RE = Representativeness
- EP = Exemplarity, pedagogical use
- EEP = Existing educational products
- AE = Actual use of a site for educational purposes

Economical Values
- AC = Accessibility
- PI = Presence of tourist infrastructure
- LP = Local products

Conservation Values
- AR = Actual threats and risks
- PR = Potential threats and risks
- CS = current status of the site
- LGP = Legislative protection

Added Values
- C = Cultural values
- E = Ecological values
- A = Aesthetic values

Figure 6. The results of geomorphosite assessment which are conducted in14 geosites

4.1 Silokek Karst Complex

Silokek Karst Complex is a geosite located in Nagari Silokek, Sijunjung District (Figure 5). This geosite shows karst morphology of Carboniferous–Permian limestone lithology. The karst morphology features a cave named Ngalau Basurek. Several karstification products can be seen in Ngalau Basurek such as stalactite, stalagmite, and cave pillar. Furthermore, there is a cave painting which was established from the Dutch Indies Era. There is also a cave located in another cliff which is believed to have been previously used as a local people protection place from Dutch Indies. The geological features and cultural features of this geosite are shown in Figure 7.

According to geomorphosite assessment, this geosite possesses a score of 73.75% with each of the criteria values shown in Figure 6. In scientific and intrinsic values, this geosite earns a score of 87.5%. The high score in this criteria is because the geosite condition is well preserved without any destruction. Furthermore, this geosite exhibits some geological features such as limestone outcrop, cave, stalactite, stalagmite, pillars, and joints as a geological structure. Several geological

research has been conducted in this geosite which has been published in several journals. However, the rarity of this geosite is weakly significant because there is another geosite with the same lithology as this geosite.

The second criteria is educational value which earns a score of 100%. This geosite has the highest educational value because the geological outcrop represents the karstification process and geological history of Kuantan Formation which is suitable for educational purposes. Furthermore, this geosite has been an excursion place for students and also is established as a geotourism site. In addition, the information about this geosite has been included in the geotrack map and also there is an information site near the cave entrance.

The third criteria is economical value which earns a score of 25%. This criteria earns a low value because of the low accessibility to public transportation. However the distance between the parking area and the geosite is only several meters so it is still accessible using private vehicles. In addition, the tourist facilities are approximately 5–10 km far from the geosite and the local products sold near this geosite are also absent.

The fourth criteria is conservation value which earns a score of 87.5%. This criteria earns a high score because this geosite is well preserved without any destruction. However, there is a potential natural threat such as heavy rain which can intensify the karstification process and destroy some parts of the geosite. In addition, this geosite is protected by existing law as a geoheritage which can reduce the potential threats from anthropogenic factors.

The last criteria is added value which gains a score of 68.75%. This criteria gains a high score because of the existence of cultural value in the geosite. Inside the Ngalau Basurek, there is a human painting which was established during Dutch Indies Colonization. Moreover, there is one cave hideout located on a different cliff which was used by local people as a shelter to protect themselves from the Dutch Indies assault. Not only cultural value, this geosite also has high ecological value as a habitat for local animals such as bats. Then this geosite has aesthetic value which is shown by the variety of limestone from white to reddish brown due to the oxidation process. In addition, some parts of the karst cliff exhibit joints and the cave interior consists of a variety shape of stalactite and stalagmite.

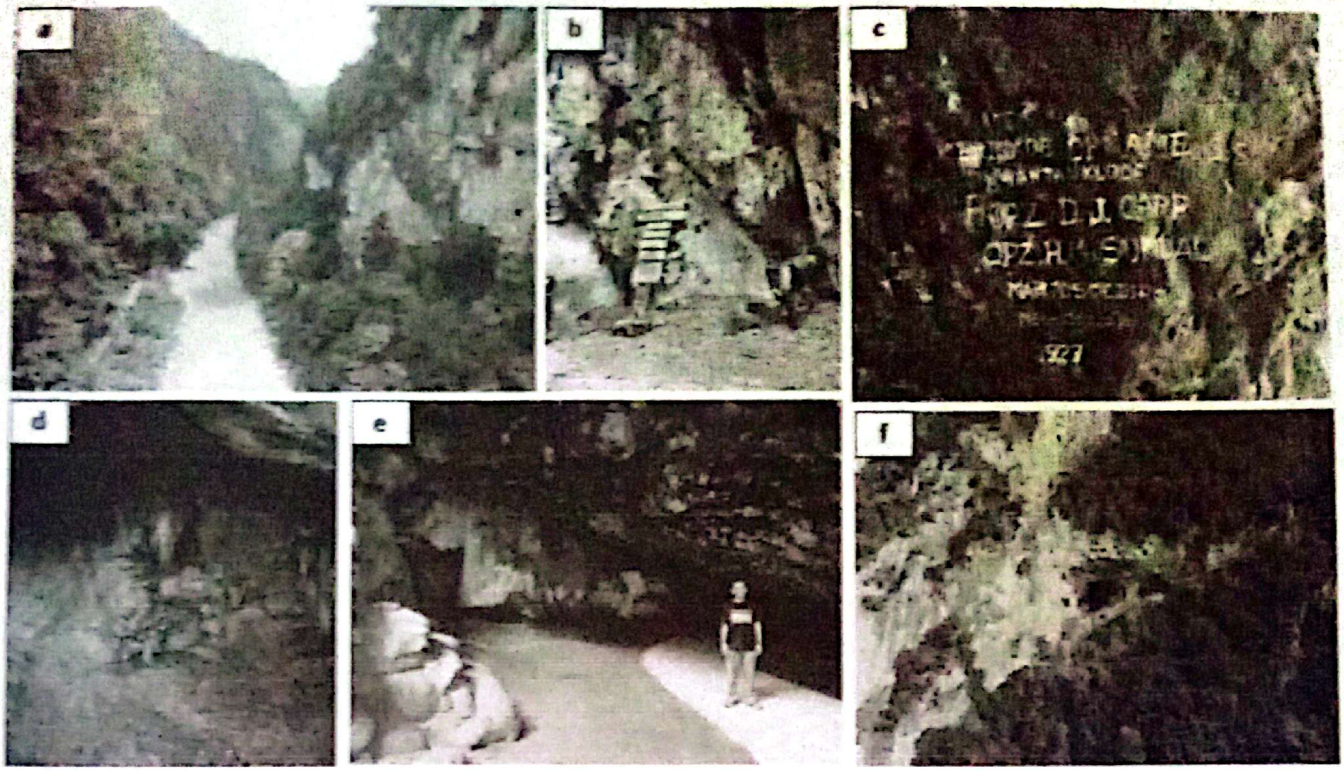

Figure 7. Silokek karst complex is part of Limestone member of Kuantan Formation. (a) Towering Limestone which is cutted through by Indragiri River [11]; (b) Tension fracture has the same direction and it looks like a bedding (actually, it is not really bedding); (c) The inscription was created since Dutch Indies colonization; (d) Ngalau Basurek Cave is one of karstification products. In the cave, stalactites are well-preserved; (e) Dissolve calcite can easily be observed from outside of the cave [11]; (f) The other cave is located on the upper part of towering limestone [11].

4.2 Loguang Limestone Cave

Loguang Limestone Cave is a geosite located in Aie Angek Nagari, Sijunjung District (Figure 5). This geosite features Carboniferous–Permian limestone which is part of Kuantan Formation. This geosite is formed due to the karstification process. The karstification process created cave which followed by the formation of cave features such as stalactite, stalagmite, and pillar. In addition, this geosite is unique due to the presence of a hot spring near the cave. This hot spring has become a tourist attraction for local people to have recreation. This hot spring might be formed because of the existence of a non-volcanic geothermal system which the heats sources are come from the consolidated magma chambers [12]. The geological features and the hot sping of this geosite are shown in Figure 8.

According to geomorphosite assessement, Loguang Limestone possesses a 60% score on the geomorphosite value with the value of each criteria can be shown at Figure 6. In scientific and intrinsic criteria, this geosite earns a score of 62.5%. This criteria gains a high score because this geosite condition is well preserved without any destruction. Moreover, some geological features can be found in this geosite such as limestone outcrop, caves, stalactite, stalagmite, and hot spring. The occurrence of hot springs near the limestone cave gives a rarity value on this geosite because of the unique and uncommon features found in the RMSG area. However, the research about this geosite is still minimal which gives a low value in scientific knowledge.

The second criteria is educational value which scores 87.5%. This score is high because the geological outcrop represents the karstification process and geological history of Kuantan Formation which is suitable for educational purposes. In addition, this geosite has been an

excursion place for geological courses and the information about this geosite has been added to the geotrack map.

The third criteria is economical value which earns a score of 25%. This criteria earns a low score because of the low accessibility to public transportation. However, the distance between the geosite and parking area is approximately less than 1 km so it is still accessible using private vehicles. In addition, the tourist facilities are approximately 5–10 km far from the geosite and the local products sold near this geosite are also absent.

The fourth criteria is conservation value which acquires a score of 87.5%. This criteria acquires a high value because the geosite condition is well preserved without any destruction. However, there is a potential natural threat such as heavy rain which might intensify the karstification process and destroy some parts of the limestone outcrop. In addition, this geosite is protected by existing law which can reduce the potential threats from anthropogenic factors.

The last criteria is added value which gains a score of 37%. This criteria gains a low score because the cultural values in this geosite are absent. However, the influence of the geosite to the existing ecology is significant because the cave is a habitat for bats. Furthermore, this geosite still has aesthetic values from the color variation from white to reddish brown in the limestone outcrop as a consequence from oxidation process. In addition, the cave interior contains many patterns of the stalactite and stalagmite which gives an extra value on the aesthetic parameter.

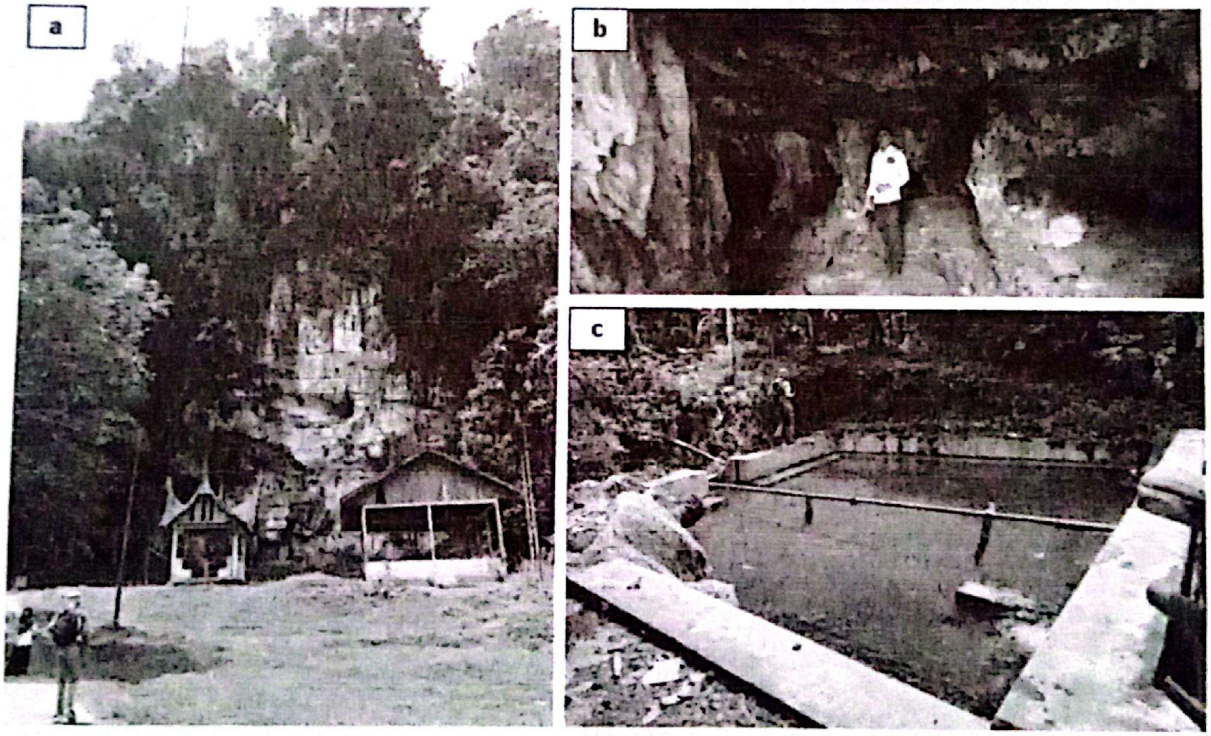

Figure 8. Loguang Limestone is part of Kuantan Formation Limestone Member. (a) The limestone experienced deformation indicated by fracture both vertically and horizontally [11]; (b) As a product of karstification, Loguang Cave shows stalactites and soluble limestone on the wall of cave [11]; (c) There is a hot spring near from the cave. It is an additional tourist attraction near the cave [11].

4.3 Lubuk Pendakian Metamorphosed Limestone

Lubuk Pendakian Metamorphosed Limestone is a geosite located in Sumpur Kudus Nagari, Sumpur Kudus District (Figure 5). This geosite features three waterfalls which are surrounded by crystalline limestone rock from Kuantan Formation. This crystalline limestone was affected by structural deformation which is represented by the folding structure observed in this area. Interaction between granitic magma and Kuantan Limestone was the cause of marble formation. Furthermore, quartz veinlets can be observed in the waterfall's wall and there are also calcite

veins which are shaped like hair in the limestone fragments. These features show that the alteration process was happened due to the hydrothermal fluid passing through the joint in the rock. The geological features of this geosite are shown in Figure 9.

According to geomorphosite assessment, Lubuk Pendakian Metamorphosed Limestone possesses a 52.5% score of geomorphosite value with the value of each criteria shown in Figure 6. In scientific and intrinsic criteria, this geosite earns a score of 62.5%. This criteria earns a high score because this geosite is still preserved without any destruction. Furthermore, this geosite is the only geosite with metamorphosed limestone outcrop found in the RMSG area which is high in rarity value. This geosite also shows some geological features such as quartz and calcite veins, metamorphosed limestones, and folds as a geological structure. However, study about this metamorphosed limestone in this geosite is still minimal which reduces the scientific knowledge value of the geosite.

The second criteria is educational value which gains a score of 75%. This criteria gains a high score because the outcrops represent fold and veinlets which is suitable for learning specific geological topics such as structural geology process and hydrothermal alteration process. In addition, this geosite has been an excursion place for a specific geological course and the information about this geosite has been added to the geotrack map.

The third criteria is economical value which gains a score of 12.5%. This criteria gains a low score due to the low accessibility both of using public transportation. Moreover, the distance between the geosite and the parking area is over 1 km which indicates the use of private vehicles is also not effective. In addition, the tourist facilities are approximately 5–10 km far from the geosite and the local products sold near the geosite are also absent.

The fourth criteria is conservation value which gains a score of 87.5%. This criteria gains a high score because this geosite is well preserved without any destruction. However, there are some potential natural threats such as heavy rain and floods which can cause erosion. In addition, this geosite is protected by existing law as a geoheritage which can reduce the potential threats from anthropogenic factors.

The last criteria is added value which gains a score of 25%. This criteria gains a low value because the cultural values in this geosite are absent. Moreover, the influence of geosite to the existing ecology is weakly significant. However, this geosite still has an aesthetic value from the colors of the rock, the pattern of the folded rock, and veinlets pattern from calcite and quartz mineral.

Figure 9. Lubuk Pendakian consists of metamorphosed rocks caused by granitic magma intrusion. (a) The metamorphosed rock are the bed of the waterfall [11]; (b) In this area, the rocks were deformed until nearly vertical [11]; (c) A close up photo of metamorphosed limestone. The rock was cutted by quartz veins [11].

4.4 Red Granite Timbulun Tujuh

Red Granite Timbulun Tujuh is a geosite located in Sibakur Nagari, Tanjung Gadang District (Figure 5). This geosite features a waterfall approximately 4 m high. The waterfall wall consists of granite which is Triassic aged. Furthermore, this granite is unique because of its reddish color. This reddish color can occur due to the abundant composition of alkali feldspar. The geological fatures and hand specimen of the outcrop are shown in Figure 10.

According to the quantitative geomorphosite assessment, Red Granite Timbulun obtains a score of 55% with the value of each criteria is shown in Figure 6. In scientific and intrinsic criteria, this geosite obtains a score of 62.5%. This criteria gains a high score because this geosite is well preserved without any destruction. Furthermore, this geosite shows some geological features such as waterfall, granite outcrop, and joints. The research about the granite in this geosite has been conducted and published in several journals. However, the rarity value of this geosite is weakly significant because there are other geosites with similar lithology as this geosite.

The second criteria is educational value which obtains a score of 75%. This criteria gains a high score because the geological outcrop represents magmatism and geological history of Triassic igneous rock which is suitable for educational purposes. In addition, this geosite has been an excursion place for geological courses and the information about this geosite has been included in the geotrack map.

The third criteria is economical value which earns a score of 25%. The low value of this criteria is affected by the low accessibility to public transportation. However, the distance between the geosite and the parking area is approximately less than 1 km so it is still accessible using private vehicles. In addition, the tourist facilities are approximately 5–10 km far from the geosite and the local products sold in this area are also absent.

The fourth criteria is conservation value which earns a score of 87.5%. This criteria earns a high value because the geosite condition is well preserved without any destruction. However, there are some potential natural threats such as heavy rain and floods which might cause erosion to the granite. In addition, this geosite is protected by existing law as a geoheritage which can reduce the potential threats from anthropogenic factors.

The last criteria is added value which gains a value of 25%. This criteria gains a low value because the cultural value is absent in this geosite. Moreover, the influence of the geosite to the existing ecology is weakly significant. However, this geosite still has aesthetic value from the various colors of minerals found in the granite.

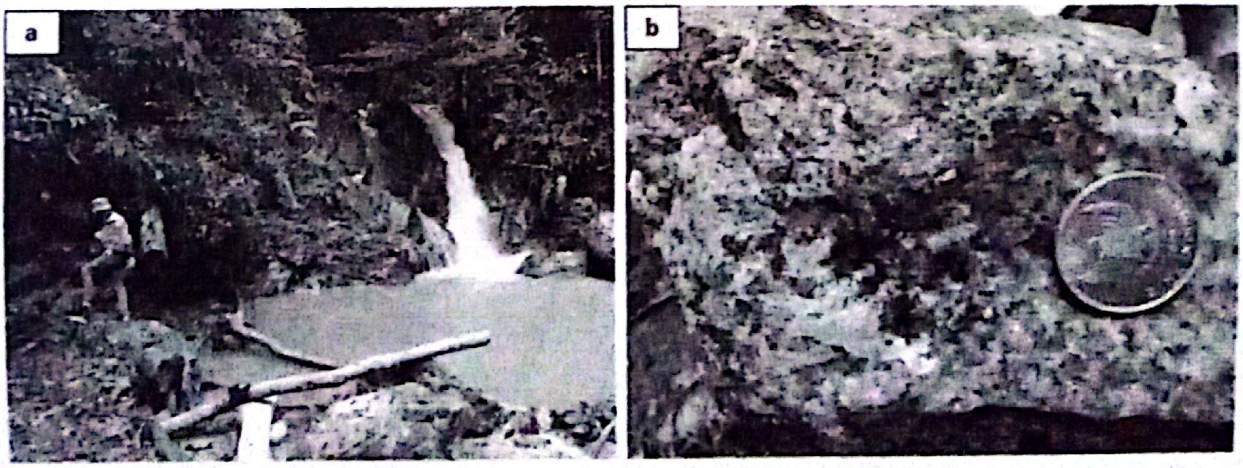

Figure 10. (a) Tectonic force made discontinuity in the red granite and it was a pathway for water flowing even becoming a waterfall [11]; (b) the red granite mainly consists of k-feldspar and other minerals, such as quartz, biotite, muscovite, and hornblende [11].

4.5 Timbulun Andesite

Timbulun Andesite is a geosite located in Timbulun Nagari, Tanjung Gadang District (Figure 5). This geosite features two waterfalls which are flowed by Batang Kulampi River. These two waterfalls consist of 2 m height waterfall in the upper part and 4 m height waterfall in the lower part. Alongside the waterfalls, andesite is exposed in brecciated condition. In some parts of the andesite, brecciation shows N312°E/84° orientation, while in the other part the orientation is not clearly defined. The geological features of this geosite are shown in Figure 11.

According to the geomorphosite assessment, this geosite acquires a score of 62.5% with the value of each criteria is shown in Figure 6. Specifically, this geosite earns a score of 62.5% in scientific and intrinsic value criteria. This criteria earns a high score because this geosite is well preserved without any destruction. Furthermore, this geosite is the only geosite with andesite outcrop found in the RMSG area, thus high value of rarity. This geosite also shows some geological features such as waterfalls, andesite outcrop, and brecciation with varying orientation. However, the research about andesite outcrop in this geosite is still minimal which makes the scientific knowledge value is weakly significant.

The second criteria is educational value which gains a score of 87.5%. This criteria gains a high score because its geological outcrop represents magmatism and geological of Triassic igneous rock which is suitable for educational purposes. Furthermore this geosite has been an excursion spot for geological courses and also for public geotourism. In addition, the information about this geosite has also been included in the geotrack map.

The third criteria is economical value which obtains a score of 50%. This criteria obtains a moderate value due to the low accessibility to public transportation. However, the distance between the parking area and the geosite is less than 1 km so it is still accessible using private vehicles. In addition, the tourist facilities are located approximately several meters from the geosite and some local products are sold near this geosite, but without emblematic of the site.

The fourth criteria is conservation value which obtains a score of 87.5%. This criteria obtains a high score because the geosite is well preserved without any destruction. However, there are some potential natural threats such as heavy rain and floods which might cause erosion on the geosite. In addition, this geosite is protected by existing law which can reduce the potential threats from anthropogenic factors.

The last criteria is added value which only earns a score of 25%. This criteria earns a low score because the cultural values in this geosite are absent. Furthermore, the influence of the geosite to the existing ecology is weakly significant. However, this geosite has an aesthetic value from the shape of the rock which consists of rounded and angular form. In addition, there is also a variation of the brecciation orientation which gives an extra value on the aesthetic parameter.

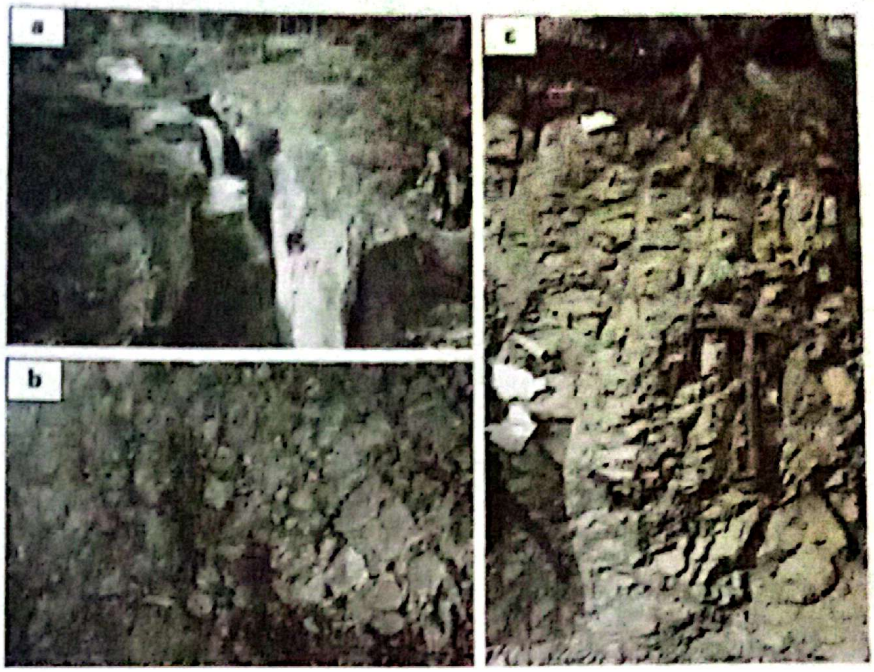

Figure 11. (a) Waterfalls which consists of andesite lithology [11]; (b) The brecciation occurs in the andesite [11]; (c) The brecciation of andesite with N312°E/84° orientation.

4.6 Solok Amba Diorite

Solok Amba Diorite is a geosite located in Solok Amba Nagari, Sijunjung District (Figure 5). This geosite exhibits a geological outcrop with diorite as the lithology. The unique feature in this outcrop is the greenish color due the presence of chlorite mineral. Chlorite mineral is a product from alteration process caused by hydrothermal fluid. When the high temperature of hydrothermal fluid passes through the rock, the mineral in the rock will react with hydrothermal fluid and cause the changing of rock composition. The geological features of this geosite are shown in Figure 12.

According to the geomorphosite assessment, this geosite earns a score of 47.5% in the geomorphosite value with the criteria values shown in Figure 6. In Scientific and intrinsic criteria, the value is 62.5% This criteria gains a high value because of the well preserved condition of the outcrop without any destruction. Moreover, this geosite is the only greenish color diorite found in the RMSG area which makes the high value of rarity. Some geological features can be found in this geosite such as diorite and alteration evidence by presence of chlorite mineral. However, research about the alteration process in this geosite has not been conducted or published which reduces the scientific knowledge value of this geosite.

The second criteria is educational value which gains a score of 50%. This criteria has a moderate score because the outcrop represents the magmatism and geological history of Triassic igneous rock which is more suitable for geological research. In addition, this geosite has been an excursion spot for geological courses and the information about this geosite has been included in the geotrack map.

The third criteria is economical value which acquires a score of 25%. This criteria acquires a low score due to the low accessibility to public transportation. However, the distance between the geosite and the parking area is approximately less than 1 km so it is still accessible using private vehicles. In addition, the tourist facilities are approximately 5–10 km far from the geosite and the local products sold near this geosite are also absent.

The fourth criteria is conservation value which earns a score of 87.5%. This criteria earns high value because the outcrop condition is well preserved without any destruction. However, there is a potential natural threat such as heavy rain which can cause erosion to the outcrop. In addition, this outcrop is protected by existing law as a geoheritage which reduces the potential threats from anthropogenic factors.

The last criteria which is the added value,this geosite earns a score of 12.5%. This criteria gains a low score because the cultural values in this geosite are absent. Furthermore, the influence of the geosite to the existing ecology is weakly significant. The aesthetic value of this geosite is also low because this geosite only presents green color with minimum variation of color and pattern.

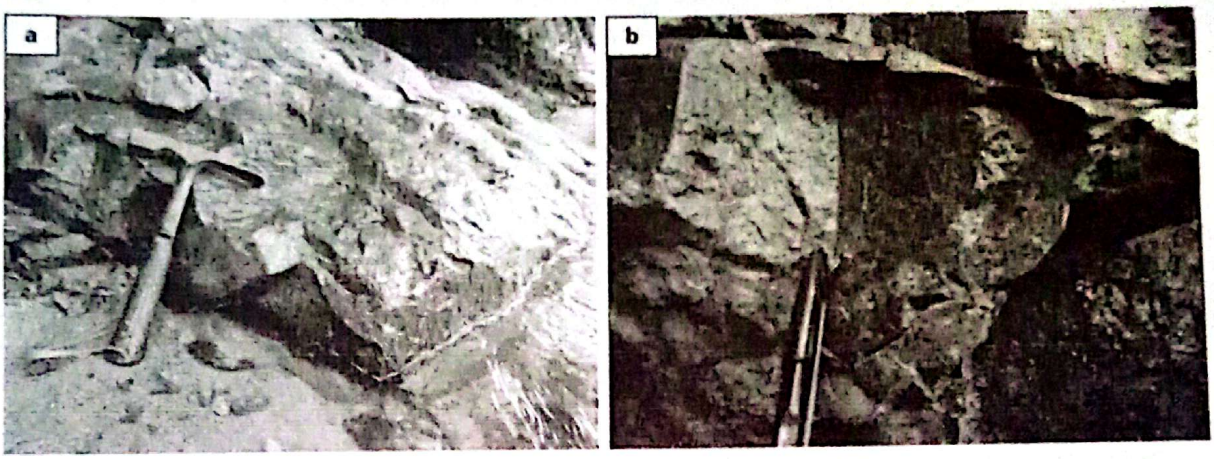

Figure 12. (a) The appearance of Solok Amba Diorite outcrop [11]; (b) The close up photos show greenish color in the inner part of rock whereas on the rock surface the weathering has been ongoing, indicated by the reddish color [11].

4.7 Stratigraphic Contact of Sangkiamo

Stratigraphic Contact of Sangkiamo is a geosite located in Silokek Nagari, Sijunjung District (Figure 5). This geosite exhibits a Triassic-aged granite situated in Kuantan River. This granite outcrop shows brecciation with many orientations due to the movement of the Great Sumatran Fault. In this geosite, a microgranite dike is also found which cuts through the granite. The geological features and hand specimen of granite are shown in Figure 13.

Based on the geomorphosite assessment, this geosite possesses a score of 65% in geomorphosite value with the value of each criteria is shown in Figure 6. In the scientific and intrinsic criteria, this geosite obtains a score of 75%. The high score in this criteria is due to the good condition of the outcrop without any destruction. Furthermore, some geological features are also found in this geosite such as massive granite outcrop, microgranite dike, and brecciation with varying orientation. Some research about this granite has been published both in national and international scientific journals. However, the rarity of this geosite is weakly significant because there are some geosite with the same lithology as this geosite.

The second criteria is the educational value which obtains a score of 87.5%. This criteria gains a high value because the granite outcrop represents the magmatism and geological history of Triassic igneous rock which is suitable for educational purposes. In addition, this geosite has been an excursion spot for geological courses and the information about the geosite has been included in the site panel and geotrack map.

In the third criteria which is economical value, this geosite earns a score of 37.5%. This criteria earns a low score due to the low accessibility of public transportation. However, the distance between the parking area and the geosite is only several meters so it is still accessible

using private vehicles. In addition, the tourists facilities are approximately 5–10 km far from the geosite and some local products are sold near this geosite, but without emblematic of the site.

The fourth criteria is conservation value which gains a score of 87.5%. This criteria gains a high value because the outcrop condition is well preserved without any destruction. However, there is a potential natural threat such as heavy rain and floods which can cause erosion to the granite outcrop. In addition, this geosite is protected by existing law as a geoheritage which reduces the potential threats from anthropogenic factors.

In the added value criteria, this geosite earns 37.5%. This criteria has a low value because the cultural values in this geosite are absent. Moreover the interaction between the geosite and the existing ecology is weekly significant. However, this geosite has a high aesthetic value from the variety colors of minerals found in the rock and the varying brecciation pattern also gives an extra value to the aesthetic parameter.

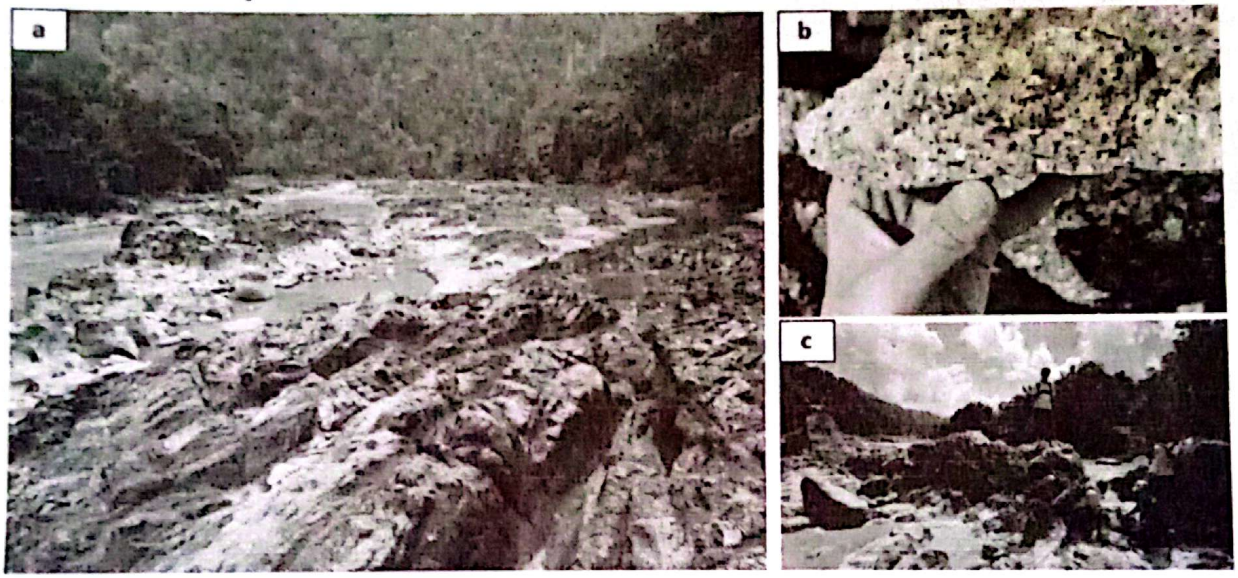

Figure 13. In some parts of Kuantan River, there are suitable areas for observing the Triassic Granite, such as in the Sangkiamo area. (a) If the river recedes, the bed of Kuantan River will be exposed. The rock is the highly fractured Triassic Granite cutted through by numerous faults [11]; (b) A close-up hand sample granite; (c) A dike cutted older than the granite. The dike has finer minerals than the surrounding granite.

4.8 Sijunjung Granite Intrusion Complex

Sijunjung Granite Intrusion Complex is a geosite located in Silokek Nagari, Sijunjung District (Figure 5). This geosite features a waterfall which originated from Taye River. This waterfall also exposes triassic aged granite which is enriched by biotite minerals. The enriched biotite results in black colored granite. Thus, the enriched biotite originated from the more evolved magma which has lower temperature than the primitive magma [12]. Lower magma temperature is suitable for the formation of biotite. The geological features of this geosite and hand specimen of the outcrops are shown in Figure 14. In addition, Sijunjung granite categorized as A-type granite which formed due to the extensional regime which results melting of continental crust [13].

According to the geomorphosite assessment, this geosite earns a score of 56.25% with each value of the criteria is shown in Figure 6. In the scientific and intrinsic criteria, this geosite gains a value of 62.5%. This criteria gains a high value because the geosite condition is well preserved without any destruction. Furthermore, this geosites exhibits some geological features such as granite outcrop, waterfall, and joints as a geological structure. Some research about Sijunjung granite has also been published in several journals. However, the rarity value of this granite is

weakly significant because there are some geosites with the same lithology as the Sijunjung Intrusion Complex.

In the second criteria, educational value, this geosite earns a score of 75%. This criteria gains a high value because the granite outcrop represents the magmatism and geological history of Triassic igneous rock which is suitable for educational purposes. In addition, this geosite has been an excursion spot for geological courses and the information about this geosite has been included in the geotrack map.

The third criteria is the economical value which acquires a score of 25%. The low score is the consequence from the low accessibility to public transportation. However, the distance between the geosite and parking area is less than 1 km so it is still accessible by using private vehicles. In addition, the tourist facilities are approximately 5–10 km far from the geosite and the local products sold near this geosite are also absent.

In the fourth criteria, conservation value, this geosite gains a score of 87.5%. The high value in this criteria is because the current condition is still preserved without any destruction. However, this geosite might be prone to the natural threat such as heavy rain which causes erosion. In addition, this geosite is protected by existing law as a geoheritage to reduce the potential threats from anthropogenic factors.

In the fifth criteria which is added value, this geosite obtains a score of 31,25%. Based on the aesthetic parameter, although the granite is composed of mainly biotite, the other spot in this geosite also contains granite with a variety of mineral colors such as white, reddish brown, and transparent. In addition, the waterfall wall shows a massive and columnar pattern which increases the aesthetic value. However, the ecological interaction with this geosite is weakly significant and the cultural value of this geosite is also absent.

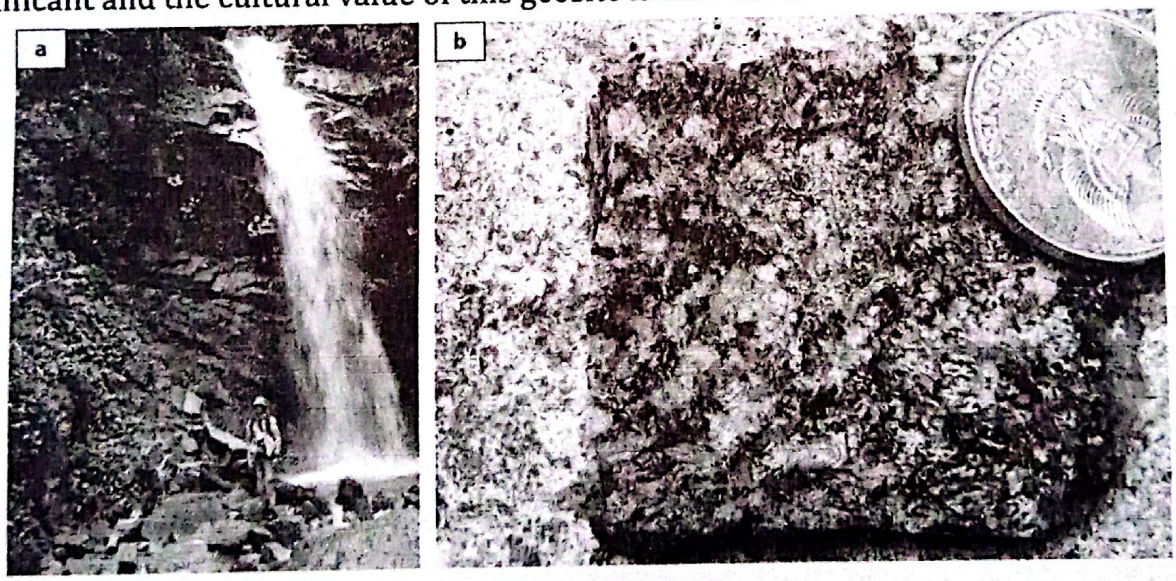

Figure 14. (a) This site is renowned with a waterfall flowing on top of Triassic Granite [11]; (b) The granite rock dominantly consists of biotite and the minerals give the black color [11].

4.9 Ngalau Batauik Conglomerate

Ngalau Batauik is a geosite located in Tanjung Nagari, Koto VII District (Figure 5). Ngalau Batauik features a narrow valley with the upper part gradually becoming narrow and almost converging. This narrow valley is composed of layering conglomerate and sandstone from Brani Formation. Layering conglomerate and sandstone is previously deposited in an alluvial fan depositional environment [14] in [15]. In this environment, the sediment will experience shetflood deposition mechanism which results layering outcrop [16]. The geological features of this geosite are shown in Figure 15.

According to the geomorphosite assessment, Ngalau Batauik earns a score of 62.5% with each criteria can be shown in Figure 6. In scientific and intrinsic value, this geosite obtains a score of 75%. The score in this criteria is high because this geosite is still preserved with no destruction and also this geosite is the only conglomerate outcrop found in the RMSG area.The variety parameter of the geosite is moderately high because of presence of some geological features such as sandstone and conglomerate outcrop. In addition, the scientific knowledge of this geosite is moderately high because some research in this geosite has already been published in national and international journals.

In the second criteria which is educational value, this geosite obtains a score of 87.5%. This criteria obtains a high score because the outcrop of this geosite represents sedimentation process and geological history of Brani Formation which is suitable for educational purposes. In addition, this geosite has been an excursion spot for geological courses and information about this geosite has been included in the geotrack map.

The third criteria is economical value which earns a score of 37.5%. The low score of economical value is because of the low accessibility using public transport. However, the distance between the geosite and parking area is approximately less than 1 km so it is still accessible using private vehicles. In addition, the tourist facilities are approximately 5–10 km far from the geosite and some local products sold near this geosite, but without emblematic of the site.

The fourth criteria is conservation value which earns a score of 87.5%. This geosite has high conservation value because the geosite condition is well preserved without any destruction. However there is a potential natural threat such as the rainy season which might cause erosion to the geosite. In addition, this geosite is protected by existing law as a geoheritage to prevent the destruction from anthropogenic causes.

The fifth criteria is added value which obtains a score of 25%. This criteria gains a low score because the cultural values in this geosite are absent and the geosite influence to the existing ecology is weakly significant. However, this geosite has an aesthetic value from the variety of colors and patterns which come from the lithology of the outcrop.

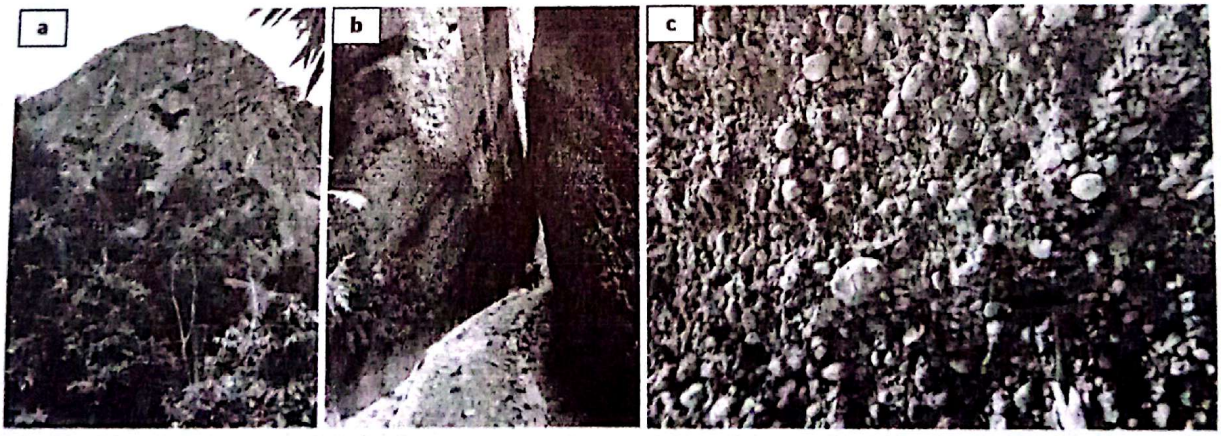

Figure 15. Conglomerate is a typical rock which consists of rounded fragments. It indicates that the rock was flowing so far in the past. (a) Towering conglomerate was uplifted by tectonic force [11]; (b) and (c) are closer look of conglomerate and it shows imbrication feature representing ancient current [11].

4.10 Hypostratotype of Telisa Kunangan Formation

Hypostratotype of Telisa Kunangan Formation is a geosite located in Kunangan Parik Rantang Nagari, Kamang Baru District (Figure 5). This geosite is a remnant lake from the coal mining activity which is surrounded by geological outcrops from Lower Member of Telisa Formation. The outcrops consist of interbedded fine sandstone and light gray shale. Some fossils also found in this outcrop such as carbonized leaf fossils and mollusk fossils. The existence of those fossils indicate

that this formation experienced a transitional depositional environment. According to Argakoesoemah (2005), the sandstone of the Lower Member of Telisa Formation is deposited in shallow marine. Thus, this geosite exhibits a different depositional environment between shallow marine and transitional areas. The remnant lake and geological features of this geosite are shown in Figure 16.

According to the geomorphosite assessment, this geosite earns a score of 60% in the geomorphosite value with each value of the criteria can be shown in Figure 6. In the intrinsic and scientific, this geosite acquires a score of 75%. The high score in this criteria is caused by the high value of integrity and rarity parameter which is evidenced by the preserved condition of the outcrop without any destruction and the only place in the RMSG area where carbonized leaf fossils and mollusk fossils are found. Moreover, this geosites also exhibits other features such as interbedded sandstone and light gray shale, and remnant lake from mining activity. In addition, several researches about this sandstone and shale have been published in several journals.

The second criteria is educational value which obtains a score of 75%. This criteria obtains a high score because the geological outcrop represents the sedimentation process and geological history of the Lower Member of Telisa Formation which is suitable for educational purposes. In addition, this geosite has been a place for geological excursion and the information about this geosite has been included in the geotrack map.

The third criteria is the economical value which earns a score of 25%. This criteria has a low score because of the low accessibility to public transportation. However, the distance between the geosite and the parking area is approximately 500 m so it is still accessible using private vehicles. In addition, the tourist facilities are approximately 5–10 km far from the geosite and the local products sold near the geosite are also absent.

The fourth criteria is conservation value which gains a score of 87.5%. This criteria has a high score because the outcrop condition is well preserved without any destruction. However, potential natural threats such as the rainy season might cause erosion which can destroy some parts of the outcrops. In addition, this geosite is protected by existing law as a geoheritage which can reduce the potential threats from anthropogenic factors.

The last criteria is added value which obtains a score of 37.5%. This criteria gains a low score because the cultural values in this geosite are absent and the influence of the geosite to the existing ecology is weakly significant. However, this geosite still has an aesthetic value which is shown by many features such as leaf and mollusks fossils, and also the variety pattern and color which come from the lithology of the outcrop.

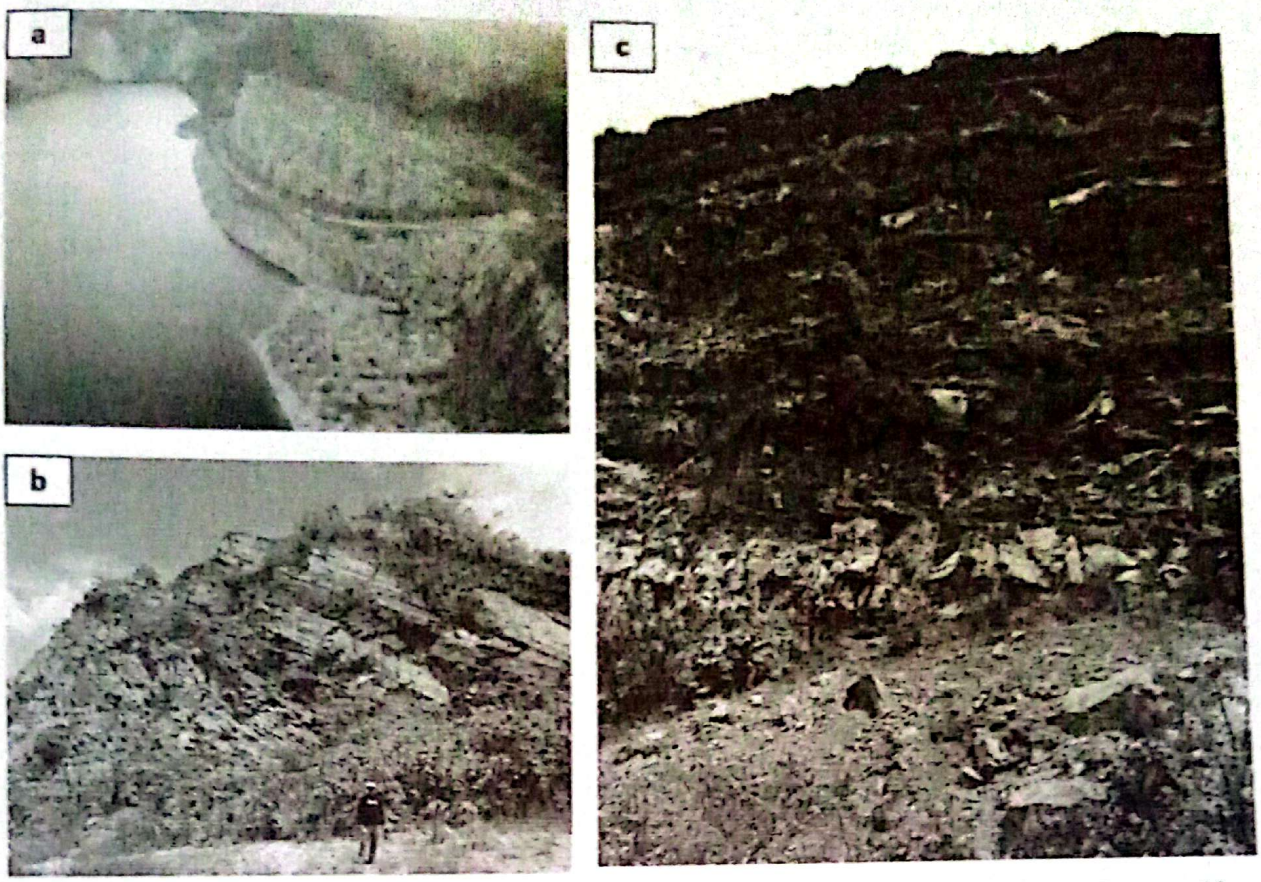

Figure 16. (a) An aerial view of Telisa Formation [11]; (b) The sedimentary rock inclined caused by tectonic force [17]; (c) A closer view of interbedded sandstone and light gray shale of lower part of Telisa Formation [17].

4.11 Lubuk Tarok Sandstone

Lubuk Tarok Sandstone is a geosite located in Lubuk Tarok Nagari, Lubuk Tarok District (Figure 5). Specifically, this geosite is a sandstone outcrop which is situated near Batang Kurimo River. The sandstone is a part of the Lower Member of Ombilin Formation which is deposited in a transitional (coastal) depositional environment. The outcrop also features parallel bedding which is formed due to the high flow regime with high current flow velocity [16]. The geological features and the hand specimen in this geosite are shown in Figure 17.

According to geomorphosite assessment, this geosite obtains a score of 52.5% on geomorphosite value with each value of criteria shown in Figure 6. In scientific and intrinsic criteria, this geosite earns a value of 62.5%. This geosite earns high value in this criteria because its condition is still preserved with no destruction, many geological features are exhibited such as sandstone and parallel bedding, and some researches about this sandstone are published in national journals. However, the rarity of this geosite is not significant because there are some other geosites with the same lithology as Lubuk Tarok Sandstone.

The second criteria is educational value which gains a score of 75%. This criteria has a high value because the sandstone outcrop represents the sedimentation process of the Lower Member of the Ombilin Formation which is suitable for educational purposes. In addition, this geosite has become an excursion spot for students and the information about this geosite is included in the geotrack map.

The third criteria is the economical value which gains a score of 12.5%. This criteria gains a low score because of low accessibility to public transportation and the location of the geosite is

more than 1 km far from the parking area. In addition, the tourist facilities are approximately 5–10 km far from the geosite and the local products sold near the geosite are also absent.

The fourth criteria is conservation value which gains a score of 87.5%. This criteria has a high score because the outcrop condition is well preserved without any destruction. However, potential natural threats such as the rainy season might cause erosion and rockfall which can destroy some parts of the outcrop. Additionally, this geosite is already protected by existing legislative law as a geoheritage which reduces the potential anthropogenic threats.

The last criteria is added value, which gains a score of 25%. This criteria gains a low score because the cultural value of the outcrop is absent and the influence of the outcrop to the existing ecology is weakly significant. However, this outcrop still has aesthetic value which evidenced by the parallel bedding resembles sheets of a book.

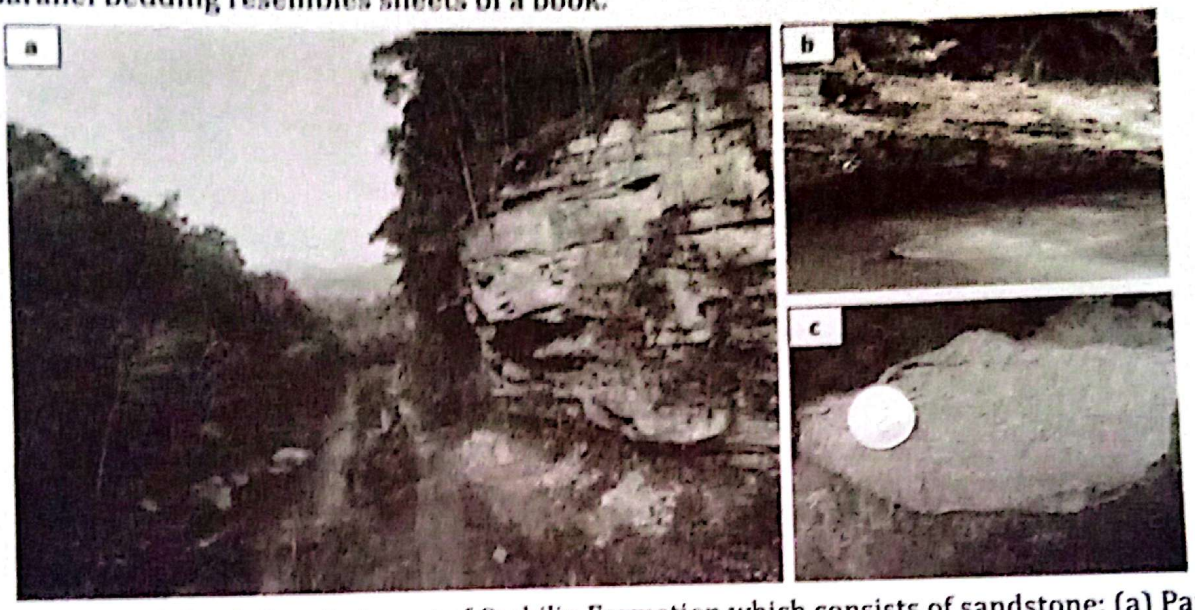

Figure 17. Lubuk Tarok Geosite is part of Ombilin Formation which consists of sandstone; (a) Parallel bedding of sandstone was exposed on the road side [11]; b) Another sandstone outcrop found near to the river [11]; (c) A close up hand sample of sandstone [11].

4.12 Cuesta of Padang Sibusuk Hill

Cuesta of Padang Sibusuk Hill is a geosite located in Padang Sibusuk Nagari, Kupitan District (Figure 5). This geosite is a cuesta which is a hill with slope less than 45 degree. This hill exhibits layers of sandstone with varying grain size from coarse grained to fine grained. This sandstone is a part of the Lower Member of Ombilin Basin which is deposited due to the transgression event in Late Oligocene–Middle Miocene Epoch. Transgression causes the sea level rise which results in sedimentation and creates layering sandstone. The geological features and cultural features of this geosite are shown in Figure 18.

According to geomorphosite assessment, this geosite possesses a score of 62.5% in geomorphosite value with each value of criteria is shown in Figure 6. In scientific and intrinsic criteria, this geosite earns a score of 62.5%. The value of this criteria is high because the outcrop is still preserved without any destruction. Moreover, this geosite shows several geological features such as fine grained and coarse grained sandstone. Then, the research about this sandstone has been published in several national journals. However, the rarity value of this geosite is not significant because this sandstone outcrop can also be found in other geosites.

The second criteria is educational value which earns a score of 75%. This criteria has a high score because this geosite also represents the sedimentation process in the Lower Member of the Ombilin Formation which is suitable for educational purposes. In addition, this geosite has

become an excursion spot for students and the information about this geosite has been included in geotrack maps.

The third criteria is economical value which obtains a score of 37.5%. This criteria has low value because of the low accessibility to public transportation. However, the distance between the geosite and the parking area is just several meters so it is still accessible using private vehicles. In addition, the tourist facilities are approximately 5–10 km far from the geosite and some local products are sold near this geosite, but without emblematic of the site.

The fourth criteria is conservation value which gains a score of 87.5%. This criteria has a high score because the outcrop condition is well preserved without any destruction. However, there is a natural potential threat such as the rainy season which can cause erosion. In addition, this geosite is protected by existing law as a geoheritage which can reduce the potential anthropogenic threats.

The last criteria is added value which earns a score of 50%. This criteria gains a moderate score because of high cultural value. Near from this geosite, there is a tunnel which is used for trains to distribute the commodity. However, the influence of the outcrop to the existing ecology is weakly significant. In addition, this geosite still has aesthetic value which is shown by layering sandstone with a variety grain size.

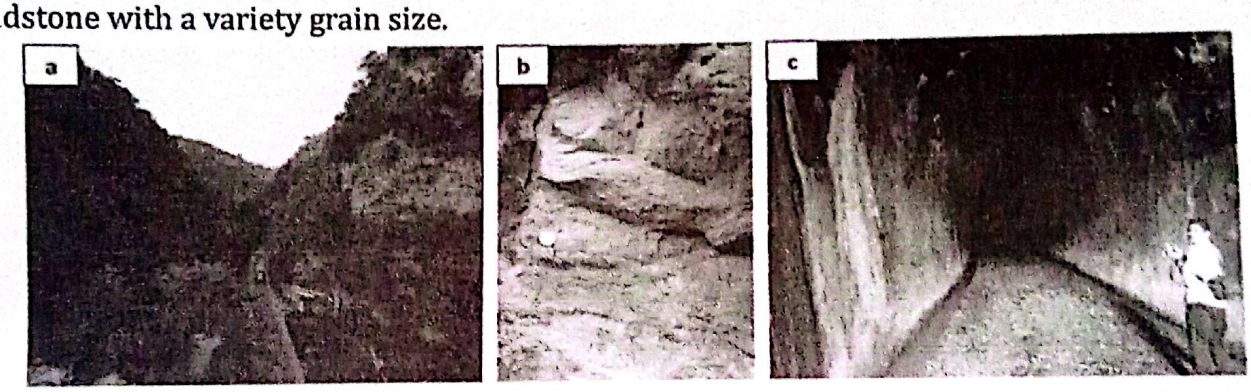

Figure 18. (a) The cuesta morphology of Padang Sibusuk can be observed clearly [11]; (b) A close up brownish sandstone [11]; (c) The tunnel passed through the Ombilin Sandstone near Padang Sibusuk Cuesta [17] .

4.13 Inyiak Umpuah Cave

Inyiak Umpuah Cave is a geosite located in Bukit Bual Nagari, Koto VII District (Figure 5). Unlike majority caves which are composed of limestone, Inyiak Umpuah Cave is composed of sandstone which makes this cave unique. The sandstone of this cave is also part of the Lower Member of Ombilin Formation. The occurrence of the sandstone cave is caused by the existence of poorly lithified sand sediment. Poorly lithified material will create pathways for fluid to erode and create a sandstone cave [18]. Additionally, this geosite also presents a cross bedding layer which indicates marine depositional environment. The geological features of this geosite are shown in Figure 19.

According to geomorphosite assessment, this geosite earns a score of 58.75% with each value of criteria shown in Figure 6. In scientific and intrinsic criteria, this geosite obtains a value of 62.5%. The high value in this criteria is because the geosite condition is still preserved without any destruction. Furthermore, this geosite has a high rarity value due to the presence of a sandstone cave which is a unique geological feature. Moreover, several geological features can be seen such as a sandstone outcrop, cave, cross bedding, and seasonal waterfall. However, research about the occurrence of the cave has not been conducted so it could be an opportunity to increase the scientific knowledge of this geosite.

The second criteria is educational value which earns a score of 75%. This criteria has a high score because this geosite also represents the sedimentation process in the Lower Member of the Ombilin Formastion, so it is suitable for educational purposes. In addition, this geosite also has been an excursion place for students and the information about this geosite is also included in the geotrack map.

The third criteria is the economical value which gains a score of 25%. This criteria has a low value because of the low accessibility to public transportation. However, the distance between the geosite and the parking area is approximately less than 1 km so it is still accessible using private vehicles. In addition, The tourist facilities are approximately 5–10 km far from the geosite and the local products sold near this geosite are also absent.

The fourth criteria is the conservation value which earns a score of 87.5%. This criteria has a high score because this geosite is well preserved without any destruction. However, there is a potential natural threat such as the rainy season which might cause erosion. In addition, this geosite is protected by existing law as a geoheritage which can reduce the potential threats from anthropogenic factors.

The last criteria is added value which earns a score of 43.75%. Despite the absence of the cultural value, this geosite has high value in ecological and aesthetic parameters. The cave in this geosite is the habitat for the local animals such as bats. Furthermore, the aesthetic value of this geosite is evidenced by a variety of geological features such as cave, seasonal waterfall, and cross bedding sedimentary structure.

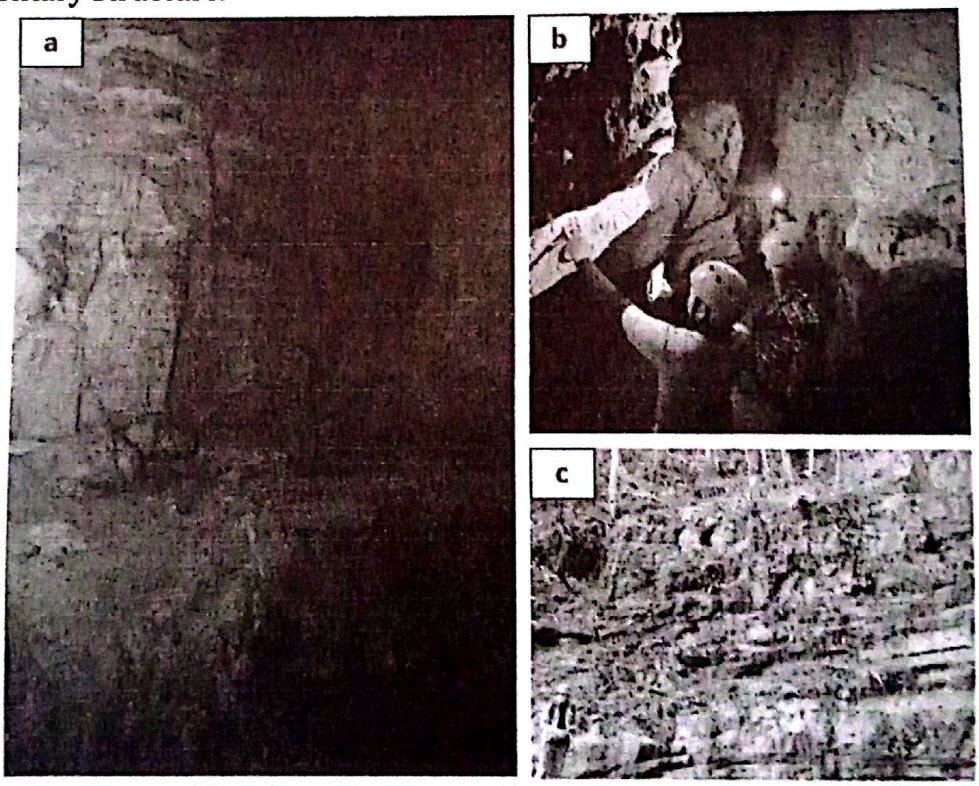

Figure 19. (a) Bedding of sandstone can be seen inside of Inyiak Umpuh Cave [11]; (b) It was caving activity with complete gear which consisted of safety helmet and torch [11]; (c) The figure shows cross bedding on sandstone with the lowest part being the thickest sandstone [11].

4.14 Sandstone of the Ombilin Padang Laweh

Sandstone of the Ombilin Padang Laweh is a geosite located in Padang Laweh Nagari, Koto VII District (Figure 5). This geosite is a sandstone outcrop which is also part of the Lower Member of Ombilin Basin. This geosite consists of three layers which are fine sandstone layer, conglomerate

layer, and intercalated quartz sandstone-conglomerate layer. The fine sandstone layer is situated at the bottom part of the outcrop, while conglomerate is in the middle part of the outcrop. The upper part of the outcrop is composed of intercalated quartz sandstone-conglomerate. The fine sandstone layer shows flaser lamination sedimentary structure which indicates tidal flat depositional environment [19]. The middle layer which is conglomerate shows cross lamination sedimentary structure. This sedimentary structure indicates a coastal depositional environment. In the upper layer, the intercalation between quartz sandstone and conglomerate indicates a fluvial depositional environment. In addition, geological contact is also found between conglomerate layer and quartz sandstone-conglomerate layer which indicate chinging depositional environment from coastal to fluvial. The geological features of this geosite are shown in Figure 20.

According to the geomorphosite assessment, this geosite acquires a score of 55% on the geomorphosite value with the value of each criteria shown in Figure 6. In scientific and intrinsic criteria, this geosite earns a score of 75%. The high value of this criteria is because the geosite is well preserved without any destruction and high rarity value due to the appearance of three lithology layers with different depositional environments. Furthermore, several geological features can be found such as sandstone and conglomerate outcrops, cross lamination, and flaser sedimentary structure. In addition, some research about this sandstone and conglomerate have been published in several journals.

The second criteria is educational value which earns a score of 75%. This criteria has a high score because the outcrop in this geosite represents the sedimentary process in Lower Member of Ombilin Formation. The evidence of the sedimentary process is shown by the presence of cross lamination and flaser sedimentary structure. In addition, This geosite has been a place for student excursions and the information related with the geosite is included in the geotrack map.

The third criteria is economical value which gains a score of 12.5%. This criteria has a low score because of the low accessibility to public transportation and the location distance is more than 1 km from the parking area. Furthermore, the tourist facilities are approximately 5–10 km far from the geosite and the local products sold near this geosite are also absent.

The fourth criteria is conservation value which gains a score of 87.5%. This criteria earns a high score because the geosite is well preserved without any destruction. However, there is a potential natural threat such as the rainy season which can cause the river to flood and trigger erosion. In addition, this geosite is protected by existing law as a geoheritage which can reduce the potential threats from anthropogenic factors.

The last criteria is added value which obtains a score of 25%. This criteria obtains a low score because the cultural value in this geosite is absent and the influence of the geosite to the existing ecology is weakly significant. However, this geosites still have an aesthetic value which is shown by the appearance of three layers with different lithology and depositional environment, and also the presence of sedimentary structures such as flaser structure.

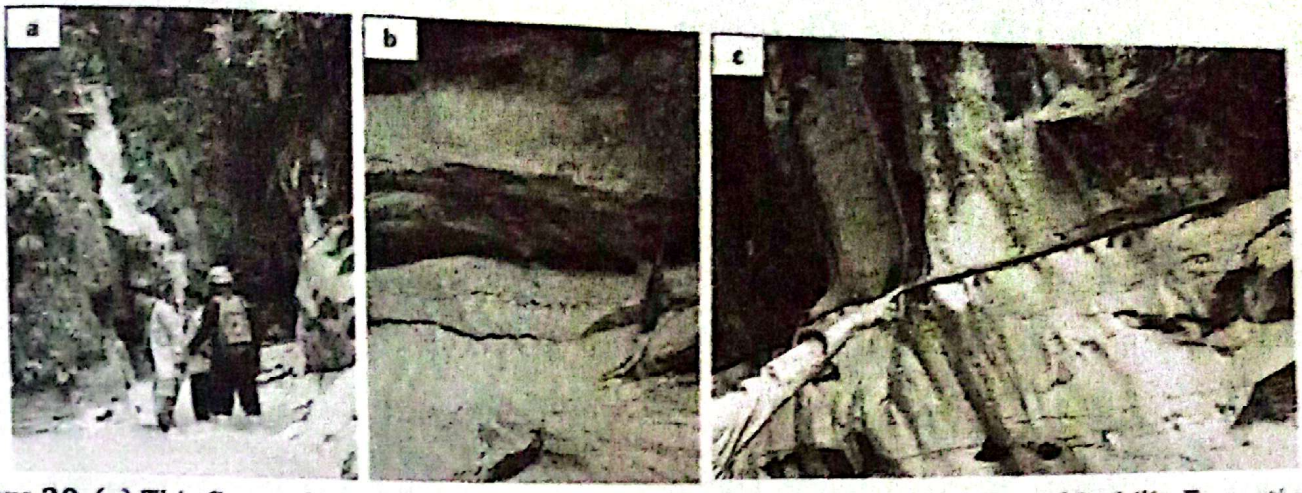

Figure 20. (a) This figure shows an excursion activity to observe the lower member of Ombilin Formation [11]; (b) A sedimentary structure appears on the sandstone [11]; (c) Lower part is finer than the one at the top. On the lower part can be observed parallel lamination (reddish color) [11].

5. Discussion

According to the geomorphosite assessment, most of the geosite earn a score over 50% with the highest value being 73.75% in the Silokek Karst Complex geosite. However, there is one geosite which obtains a value below 50%. Solok Amba Diorite geosite is the only geosite that earns a value 47.5% which is below the 50%. Figure 21 shows the geomorphosite value of each geosites.

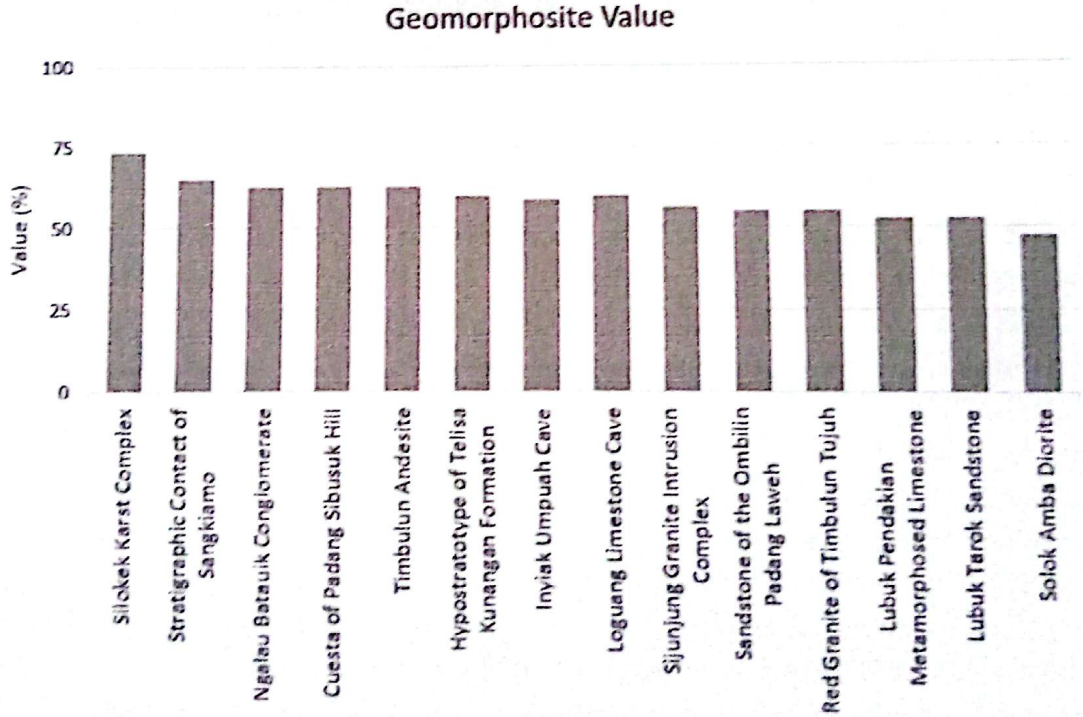

Figure 21. Geomorphosite value of all geosites.

According to the scientific and intrinsic criteria, all of the geosites earn a value above 50% (Figure 22). The first reason is due to the high integrity parameter value in which each geosites condition is still preserved without any destruction. The second reason is some geosites such as Ngalau Batauik, Timbulun Andesite, Hypostratotype of Telisa Kunangan Formation, Inyiak Umpuah Cave, Loguang Limestone, Sandstone of Ombilin Padang Laweh, and Solok Amba Diorite gain a high value of rarity because those geosites are unique and the only found In RMSG area. On the other hand, the rest of the geosite gain a rarity value, but not really significant because of the similarities in the lithology and geological features. The third reason is most of the geosites in the

RMSG area have moderate diversity parameter value because the amount of features that can be found in a geosite is in the range 2–4 features. The last reason is the moderate value of scientific knowledge which can be calculated by the amount of research conducted in each geosites. Most of the geosites have been conducted in research which is published in national journals or even international journals. However, some of the geosite have not been conducted in any research which impacts the scientific value parameter. Thus, the research encouragement is necessary to be conducted in order to improve the scientific value of those geosites.

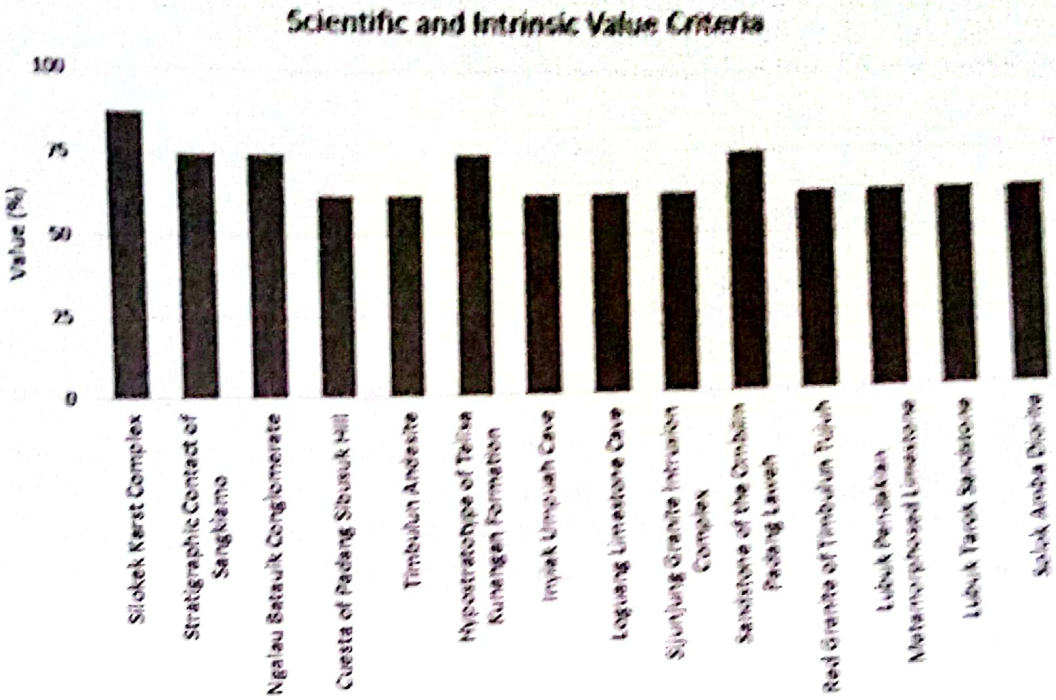

Figure 22. Scientific and intrinsic value criteria of all geosites.

According to the educational value criteria, most of the geosites earn a value above 70% (Figure 23). The highest value of this criteria is 100% which is obtained by the Silokek Karst Complex geosite. Majority of the geosites earn a value between 75–87.5% because of the high representativeness of the geological outcrop which is suitable for learning geological process and history. Then majority of the geosites information have been included in the gaotrack map, while some of the geosites such as Silokek Karst Complex and Stratigraphic Contact of Sangkiamo geosite have an information panel on the site which can assist the visitor to learn about the geosite. Furthermore, majority of the geosites have been used for geological excursion, while some of them are already used for guided geotourism such as Silokek Karst Complex, Ngalau Batauik Conglomerate, Timbulun Andesite, and Loguang Limestone. However, there is one geosite which has a value below the 50%, Solok Amba Diorite. In order to improve the educational value of that geosite, the information about this geosite should be upgraded by using various media and socialization about this geosite is necessary to be conducted to enhance people's knowledge.

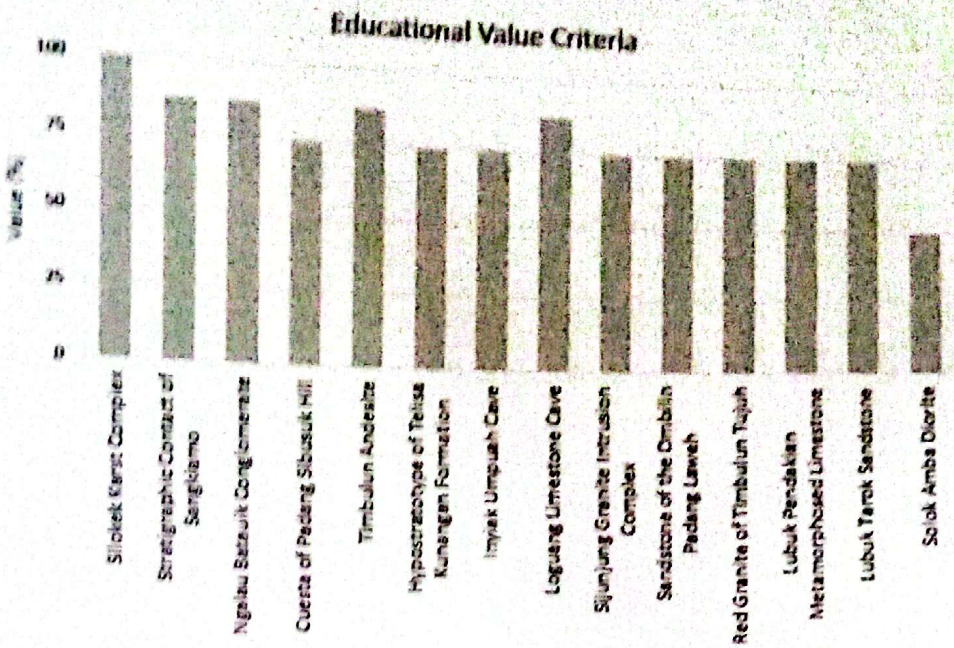

Figure 23. Educational value criteria of all geosites.

According to the economical value criteria, most of the geosites earn a value below 40% (Figure 24). The low value in economical criteria because of the low accessibility. All of the geosites in the RMSG area are not integrated to public transportation due to a less proper public transportation system. Hence, all of the geosites are accessible by using private vehicles. Despite it being accessible using private vehicles, visitors have to walk several meters or even kilometers from the parking area to reach the geosites. One of the problems is the location of some geosites that are several kilometers far from the parking area which can cause exhaustion of the visitors. In order to reduce the impact, the establishment of the new parking area is needed or local people can give a transportation service using small vehicles such as motorcycles to reach the geosite.

The second problem is lack of tourist facilities near the geosite. Most of the gosites in the RMSG area are located 5–10 km far from the tourist facilities. The presence of the tourist facilities is important for the liveability and sustainability of geotourism. However, the development of the tourist facilities is challenging enough because not every geosites location is near to the local settlements. For example, Timbulun Andesite geosite is relatively near to the local residence where the development of the tourist facilities are more oriented than the remote geosite. The feasible measurements that can be done is by providing basic tourist facilities such as toilets.

The third problem in the majority of the geosites is lack of local products. This problem is also related to the location of the geosites whether it is remote or not. The remote location of the geosites is challenging to develop the local product shops because the demand of the product is not significantly high. The feasible measures to encounter this problem is by promoting the geosites and improving accessibility of the geosites which aim to increase the number of visitors. High number of visitors will result a high demand of product so allowing local people to sell their products near the geosite.

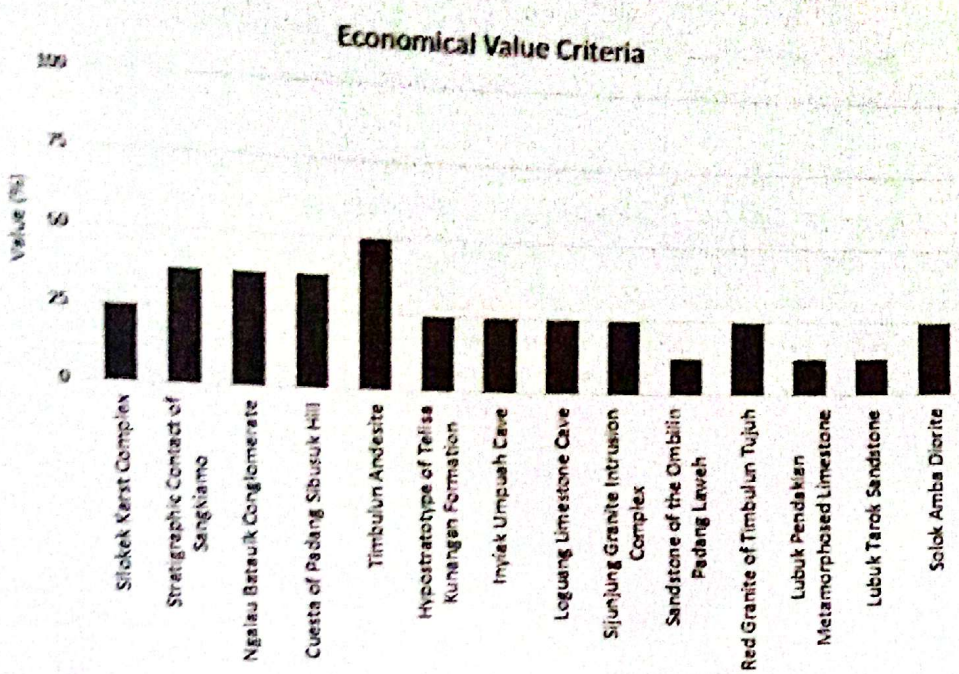

Figure 24. Economical value criteria of all geosites.

According to the conservation value criteria, all of the geosites in the RMSG area gain a value of 87.5% (Figure 25). The high value of this criteria is because of the low existing threats from natural and anthropogenic factors. Furthermore, the condition of all geosites are still preserved without any destruction. Existing law from the government also protects the geosites as a geoheritage which makes the geosites sustain without any human disruption. However, all of the geosites have potential natural threats such as heavy rain and floods for some geosites, which might cause erosion and ruin some parts of the geological outcrops.

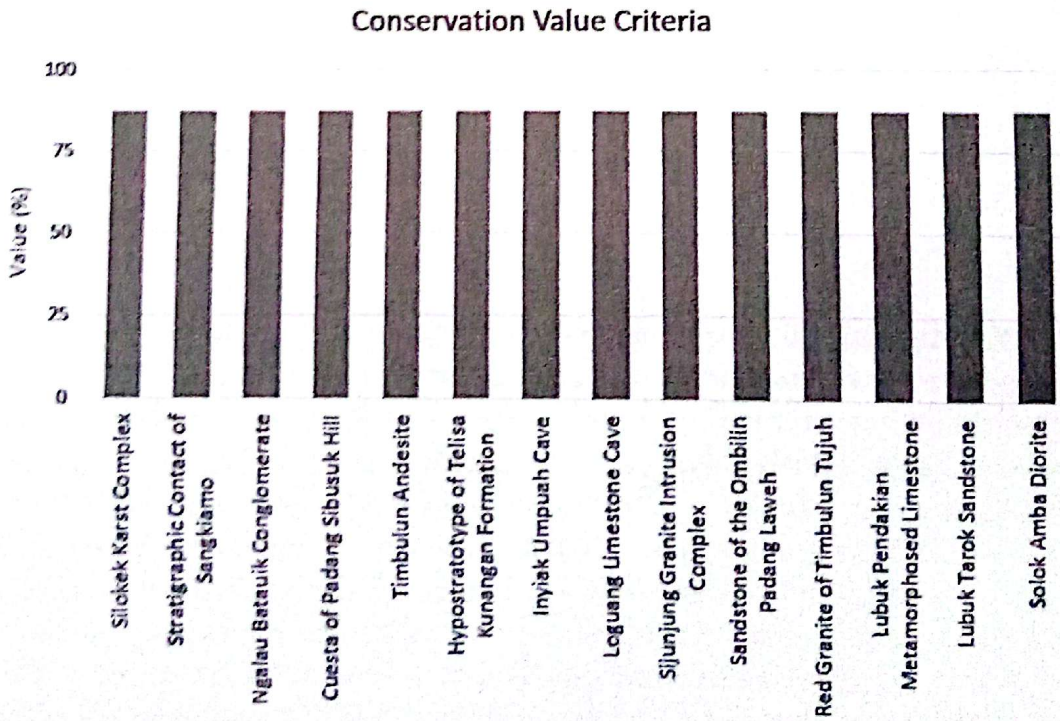

Figure 25. Conservation value criteria of all geosites.

According to the added value criteria, most of the geosites gain a value below of 50% (Figure 26). The low value in this criteria is because the cultural value is absent in the majority of the geosites. Only two geosites that have identified the cultural values such as Silokek Karst

Complex and Cuesta of Padang SIbusuk Hill which results in a higher added value than the rest of geosites. In order to improve the cultural value, interviews and conversation with the local people are necessary to be done.

On the other hand, most of the geosites have aesthetic values which are shown by at least 2–3 varying colors and patterns of outcrops, rocks, and minerals. In addition, most of the geosites in the RMSG area have a weakly significant ecological value. The value is not really significant because the influence of the geosite to the existing ecology is not really important. However, some geosites such as SIlokek Karst Complex. Loguang Limestone Cave, and Inyiak Umpuah Cave have an significant ecological value because the cave serves as the habitat of endemic animals such as bats.

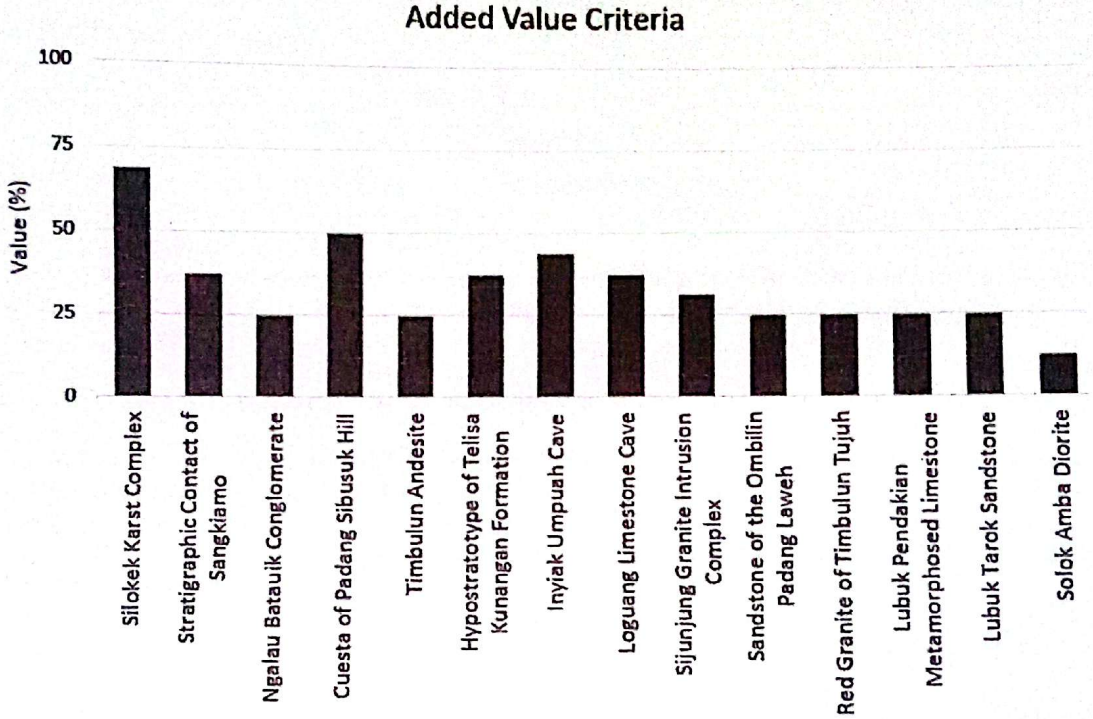

Figure 26. Added value criteria of all geosites.

6. Conclusion

Ranah Minang Silokek Geopark (RMSG) is part of Barisan Mountain Range and Ombilin Basin which is an intermountain basin in Sumatera. The geopark summarizes a wide range geological history from Carboniferous Period to Tertiary Period which is represented by fourteen geosites spread throughout Sijunjung Regency. Based on the five criteria from geomorphosite asssessment, the fourteen geosites have three criteria which have value percentage dominantly more than 50%, the criteria namely scientific and intrinsic values, educational values, and conservation values. The three of them should be improved overtime in order to enhance geopark's existence. Whereas the rest criteria dominantly have value percentage less than 50% which consists of economical values and added values. From the economical values viewpoint, public transport is suggested to be linked from the city center to each geosite or from the nearest parking before geosite may use the smaller vehicle to carry the visitors. Other than that, basic needs such as public restrooms should be improved in terms of function and facilities. In terms of local products, it can be improved by endorsement by local government and society as contributors to introduce to many people. To improve the added value parameter, interviews and

deep research to local people to obtain a relationship between each geosites with cultural aspects should be carried out. For ecological relationships, further research may be performed to get some novelties about ecological values. Ultimately, from all those things, the Ranah Minang Silokek Geopark (RMSG) is eligible for further development.

Acknowledgement

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