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RESEARCH ARTICLE

Geodiversity on the Great Sumatran Fault on Sungai Penuh Aspiring for the Geopark Designation, Jambi, Indonesia

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Abstract

Sungai Penuh is a municipality in Jambi Province which is located in the westernmost part of the administrative region. Naturally, this region has natural beauty as a tourist attraction, where landscape on the Great Sumatran Fault in the Barisan Ranges Zone. The existence of faults plays an important role as the main actor that causes deformation of rocks and natural landscapes, so that it can produce geodiversity. Thus, conditions like this can be used as an important role in the presence of geodiversity for the identification of sustainable geotourism development. The aim of this study is to provide the latest information regarding the existence of the geodiversity in the Great Sumatran Fault for aspiring geopark designation. Research methods for conducting geodiversity features of lithology, stratigraphy, geological structure, and landscape. Then, qualitative assessment of geodiversity includes of education, scientific, and tourism of geodiversity site. Stratigraphically in the research area is composed of pyroclastic Bandan, Sheared Basalt, Sungai Penuh Granodiorite, pyroclastic Pengasih, andesitic lava and volcanic breccia of Mt. Lumut, andesitic lava and volcanic breccia of Mt. Tarasih, andesitic lava and volcanic breccia of Mt. Talang, andesitic lava and volcanic breccia of Mt. Kebongsong, andesitic to basaltic lava and volcanic breccia of Mt. Raya. It has geodiversity that can be used as a geotourism site such as Peak Depati VII Coffee, Dissected Mountains Granitoid Sungai Penuh, Ancient Lake Kerinci, Khayangan Volcanic Plateu, Sungai Penuh Cold Spring, Lake Volcano-tectonic Kerinci. These conditions provide demands for the geotourism loving community to preserve geological heritage in the concept of geological conservation to be proposed as a geological site in the geotourism aspect. So that this role can later have a positive impact on the local community around geotourism objects based on sustainable geotourism development aspiring geopark designation.

Keywords: Aspiring, Geodiversity, Geopark, Great Sumatran Fault, Sungai Penuh.

1. Introduction

Faults are part of the geodynamic manifestations of the earth's crust (Advokaat et al., 2018; Metcalfe, 2017, 2013, 2011; Novikov et al., 1998). This formation will provide a basin space on the surface of the earth which in time is occupied by geological diversity (geodiversity). Sungai Penuh Cityis one of the areas in Jambi Province which is traversed by the Active Great Sumatran Fault of the Siulak Fault segment (Daryono et al., 2023; McCaffrey, 2009; McCloskey et al., 2007; Natawidjaja, 2018a; Putra and Husein, 2016). The active fault is located in the Barisan Range orogenesis zone which forms a ridge morphology on the island of Sumatra. The geological processes that occur along this active fault zone have a significant impact on topographical changes in the Sungai Penuh, this can be seen from the many avalanche zones (Daryono et al., 2023; Metcalfe, 1986; Nabella et al., 2019; Salman et al., 2020; Supendi et al., 2022; Utama and Mulyasari, 2024). The negative impacts are proportional to the positive potential, which is to shape the morphology of the landscape that can be used as a tourist attraction. The unique morphology of this zone provides an indication of the relationship between fault formation along the zone and the orogenesis that occurs (Baillie et al., 2003; Hall and Breitfeld, 2017; Hennig et al., 2017; Sevastjanova et al., 2011). To understand this process, it is necessary to identify surface manifestations in fault movement zones, such as identifying and measuring fault areas, inventorying geodiversity that represents variations in geological unique that grow along fault zones, and later can be used for sustainable geotourism and also a nature laboratory (Brocx and Semeniuk, 2007; Carrión-Mero et al., 2024; Gunawan et al., 2014; Muslim et al., 2022; Tukiainen et al., 2023; Utama et al., 2024a; Wang et al., 2023; Zhan et al., 2017). The main manifestation of geological diversity along this zone, geological manifestations such as geothermal, the landscape of Lake Kerinci is part of a complex of geological diversity that can be understood and then utilized as sustainable geotourism in Sungai Penuh (Fig. 1).

Sungai Penuh is one of area which has various geological phenomenon or known geodiversity (geological diversity) as produce of tectonic activity regarding to volcanism (Ariani and Utama, 2023; Arias et al., 2025; Carrión-Mero et al., 2024; Rabbanni et al., 2024; Sen et al., 2024b; Sunkar et al., 2022; Utama et al., 2021a). Geodiversity found in this area include Mountain Kerinci which is the highest active volcano in Sumatra “Sumatran roof”, active fault system the associated with Gunung Tujuh Lake, the existence of waterfall, geothermal potential as well as another unique geological phenomenon (Bellier and Sébrier, 1994; Jarot et al., 2019; Muraoka et al., 2010; Utama, 2023; Utama et al., 2024b).

Geological processes that occur along the active fault zone have a significant impact on changes in surface topography in the Sungai Penuh, this is identified from the some of landslide or movement area zones that are on the fault zone. The negative impact has proportional to its positive potential, namely to form

a landscape that can used as a tourist attraction. Not a few also in the avalanche zone is occupied by geodiversity, this of course must be carried out an inventory to provide a potential that can be exploited (Aleksova et al., 2024; Liu and Zhang, 2022; Sarkowi et al., 2022; Sen et al., 2024a; Triyoso et al., 2022; Utama and Mulyasari, 2024). The research and analysis are certainly very able to provide a positive potential in the zone become a sustainable geotourism that utilizes the beauty of the landscape become a scientific narrative that relates geological manifestations be of economic value.

Implementation of ESDM Regulation No. 1 of 2020 to be recognized as a geopark, an area must meet several main criteria, including having an extraordinary geological heritage, biodiversity and cultural diversity, and being sustainably managed by involving local communities (Permana et al., 2020). In addition, geoparks must also have a clear and integrated management plan, and contribute to the economic and social development of the surrounding community. In fulfilling this, the inventory of geodiversity is an important step in identifying geological heritage that can be used as a geological site.

The benefit of this research is to inventory geodiversity in the Great Sumatran Fault. Investigation throughout active faults are categorized as geological disaster zones to be able to utilized as sustainable geotourism (Bellier and Sébrier, 1994; Iqbal et al., 2019, 2023; Lange et al., 2018; McCloskey et al., 2007; Natawidjaja and Triyoso, 2007; Rafie et al., 2023; Weller et al., 2012; Yi et al., 2024). Initial survey through approach geology and biology with economic analysis to obtain a system sustainable geotourism. The urgency or importance of this research is to utilize regional areas geological disasters as geotourism areas by considering the main aspects from geodiversity, so it has the potential to be sustainable geotourism by emphasizing economic value.

The aim of this research is to provide a new breakthrough with regard to the active fault zone which was previously considered only as the morphology of the basin space due to past earthquakes, and later it is hoped that it will provide a result, that the active fault zone has very significant geodiversity. so that it can be used for sustainable geotourism, and in the end it can contribute to the economic growth of the area.

Sungai Penuh is a small part of the magmatic arc zone of Barisan Range is shaped like a valley extending from the northwest towards southeast which is flanked by mountains with steep slopes on both sides flank. The Kerinci Valley or Sungai Penuh Basin was then filled with sedimentary deposits resulting from the eruption surrounding volcanoes complex during Neogene-Quaternary. There are also influenced by the Siulak fault segment with dextral strike-slip faulting, which form a pull-apart graben of Sungai Penuh Basin, stated that the Sungai Penuh pull-apart graben developed in the Quaternary (Gasparon and Varne, 1995; Jarot et al., 2019; Muraoka et al., 2010; Utama et al., 2024b; Utama and Mulyasari, 2024; Zhan et al., 2017).

The physiography of the Sumatra Island is divided into several physiographic zones, including: Barisan Range, Wavy Plains and Low Hills, Tigapuluh Mountains, Outer Arc and Sunda Shelf (Barber, 2000; Barber and Crow, 2009; Utama, 2023; Utama et al., 2023, 2021b; Utama and Mulyasari, 2024). The research area is included in the Physiography of the Barisan Mountain Range which is crossed by the Great Sumatran Fault, Siulak segment. This physiography is a mountainous zone that is trending southeast-northwest and has an elongated pattern of about 1,650 km with a width of 100 km. Peak the height of this zone is Mount Kerinci (Indrapura peak) with a height 3.800 m. The orientation of this zone has a pattern interpreted as geotectonic the Sunda System, where changes occur from southeast-northwest in Sumatra is the west-east orientation on the island of Java. In this zone generally associated with active volcanoes, such as Mount Kerinci, which is located on Barisan Range elongated pattern (Metcalfe, 2017; Utama and Mulyasari, 2024; Wang et al., 2023; Zhan et al., 2017).

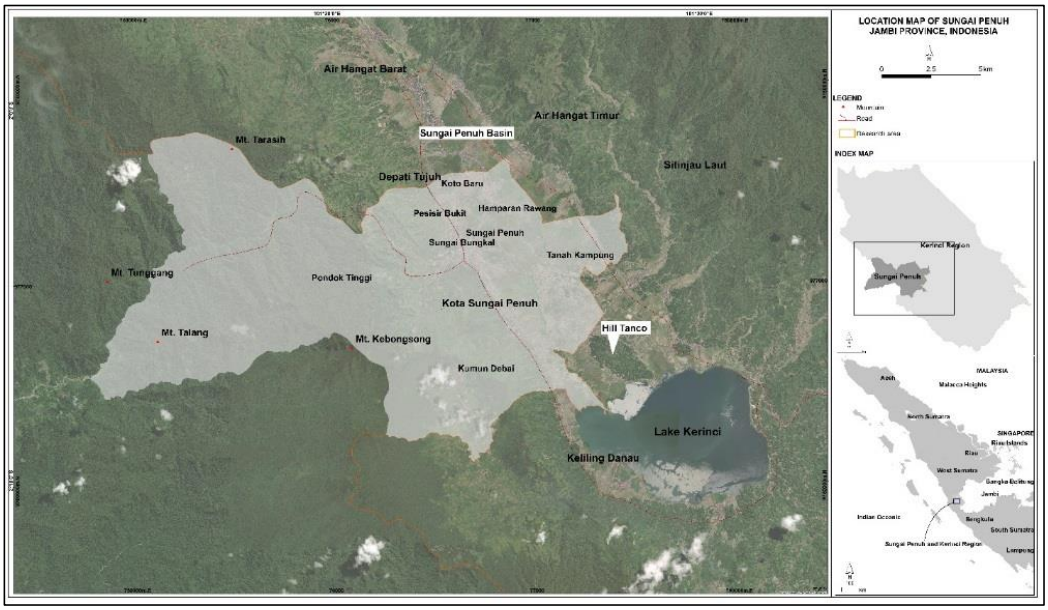

Fig. 1. Location map in the Sungai Penuh City as municipality which is the western part of Jambi Province, Indonesia. Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community 2025 (Google earth 2025)

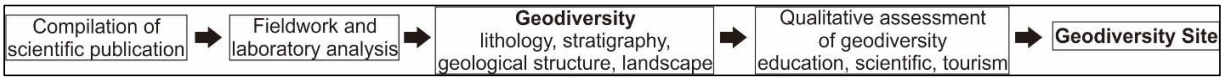

Fig. 2. Research stages used

The Great Sumatran Fault is an elongated geoanticline zone with the form of a depression zone, generally known as the Great Sumatran Faultwhich forms segmentation. Pattern this fault segmentation extends starting from Semangko (South Sumatra - Lampung) is the peak of this zone to the northwestern part of Kotaradja Aceh which is a valley and the edge of fault segment. Siulak fault segment around Lake Kerinci are one of segment of the Siulak Segment of the Great Great Sumatran Fault (Daryono et al., 2023; Natawidjaja, 2018b; Salman et al., 2020; Triyoso et al., 2022).

2. Methodology

The research area is in Sungai Penuh Citywhich is in the western part of Kerinci Regency, Jambi Province, Indonesia. Administratively, the research area in the north borders directly with Depati Tujuh District, in the east with Keliling Danau District which is part of the Sungai Penuh Basin, in the west it borders with Kerinci Seblat National Park and in the south it borders with Bukit Kerman District with the Mountain Raya of Quaternary Volcanic.

The method used in this research aims to be detailed each stage of the research (Fig. 2). With compilation of scientific publication from the latest literature review related to active faults, especially on the Great Sumatran Fault, then research references related to geodiversity inventory. Regional Geological Map Sheet of Sungai Penuh and Ketahun at a scale of 1:250.000 as the main reference for geological maps which aim to determine the stratigraphy formations, regional geological structures that make up the geology of the Sungai Penuh, Jambi Province. Primary data in the form of topography with a scale of 1:50,000 is sourced from Indonesian Earth Form (IEF/RBI/BATNAS) Inageoportal of Geospatial Information Agency (BIG) with layers of toponymy, hypsography, hydrography, and transportation. This RBI data is processed digitally to create maps research scale topography.

Topographic data processing is carried out to obtain a digital elevation model based on topographic hillshade modelling of scale 1:50.000 processing, making it easier to delineate lineaments and geological structures. This analysis of course also needs to pay attention to and the analyze of drainage pattern which reflects lithological characteristics, geological structure, dissolution processes such as in karst areas, and other geological controls. Data will be later combined with regional geological maps, so that it will a tentative geological map was obtained which was used as a guide for fieldwork research and studio analysis. Fieldwork begins with active fault measurements in the form of measurements fault structure and line structure using a compass. The measurements too including the dimensions of the fracture. This dimension will be integrated with analysis geological structure in digital elevation models. The purpose of this analysis is to determine the lithology of stratigraphy formation along Siulak Fault segment.

The most important work in this research is to conduct an inventory of geodiversity along the Great Sumatran Fault. This geodiversity will later be recorded based on its type and availability, including lithology, stratigraphy, geological structure, and landscape characteristics. So that with this data, geodiversity is obtained which is formed as a result of geological processes.

Integration of fieldwork and data analysis will produce a geological map. This includes an assessment of the distribution of geodiversity as a manifestation of geological processes along active faults. This data will later be analyzed and given a **qualitative assessment** by considering the educational, scientific, and tourism aspects of each geodiversity, referring to the assessment by (Ansori, 2018; Ansori et al., 2024a, 2024b, 2023, 2022; Permanadewi et al., 2024). With this method, of course, a geodiversity site will be obtained that is based on sustainable geotourism. The management of geotourism objects also has a concept based on local wisdom, so that sustainable geotourism will be realized positively in sustainable development.

The geological map is the result of field observations integrated with regional geology through remote sensing studies. The differences in rock stratigraphic formations from previous geological mapping at a scale of 1:250.000 by ("Kusnama et al. 1992," n.d.), especially the presence of volcanic rock formations which are divided in more detail than before. Another difference is the existence of geological structures such as faults which were identified based on field data and also scale 1:50.000 digital hillshade imagery, then with the 2023 revision of the Indonesian Stratigraphy Code (ISC/SSI), which no longer uses the term Tertiary and is replaced with the term Paleogene and also Neogene, the rock formation symbols will also be adjusted.

3. Result

3.1 Stratigraphy

Field identification of the study area is integrated with the results of observations by remote sensing, obtaining a stratigraphic structure of Sungai Penuh City, covering by Eocene Bandan Formation (Peb) is consist of welded tuff, volcanic breccia, and agglomeratic tuff; Miocene Kumun Formation (Nmk) is composed by sandstone, conglomerate, breccia, lignite, and tuff intercalation; Pliocene Sheared Basalt (Npb) is basalt related tectonics and silicified sheared; Pliocene Sungai Penuh Granodiorite (Npgds) is granodioirte, tonalite, and quartz diorite; Pliocene-Pleistocene Pengasih Formation (QNp) is consist of pumiceous claystone, tuffaceous siltstone, tuffaceous sandstone with lignite and conglomerate; Mountain Lumut (Qvl) is consist of andesitic lava, volcanic breccia, and tuff which andesitic basaltic composition; Mountain Tarasih (Qvtr) is composed by andesitic lava, volcanic breccia, and tuff breccia; Mountain Talang (Qvtl) is composed by andesitic lava, volcanic breccia, and tuff breccia; Mountain Kebongsong (Qvkb) is consist andesitic lava, volcanic breccia, and tuff breccia; Mountain Raya (Qvr) is consist of andesitic to basaltic lavas, tuff, and laharic breccia; and Alluvium (Qa) (Fig 2).

This stratigraphic arrangement reflects that the geological setting of Sungai Penuh began with the formation of volcanic rocks from the Eocene Bandan Formation. One of the interesting geological settings of Sungai Penuh is that it is traversed by an active fault of the Siulak Segment which is part of the Great Sumatran Fault which dextral strike-slip faulting. This fault starts from the southern valley of Mount Kerinci and ends in the southeastern part of Mount Kunyit which is separated by a compressional zone from the Dikit Segment which is also part of the Great Sumatran Fault in Merangin Regency, Jambi Province. The fault structures found are dextral strike-slip faults and sinistral strike-slip faults. The existence of this fault structure is believed to be part of a series of formations of the Great Sumatran Fault from the Siulak Segment which has been active since the Middle Miocene (Bradley et al., 2017; Chlieh et al., 2008; Daryono et al., 2023; Lange et al., 2018; Marliyani et al., 2024; Sieh and Natawidjaja, 2000; Sosdian et al., 2024; Weller et al., 2012).

The landscape of Sungai Penuh in the eastern part is part of the Kerinci Ancient Valley or also known as the Sungai Penuh Basin which is composed of volcanic and volcaniclastic rocks of the Bandan Formation, Kumun Formation, and Pengasih Formation, Sungai Penuh Granodiorite, Sheared Basalt, and Alluvium. Meanwhile, in the south is the northernmost part of the Lake Kerinci landscape which is composed of the Kumun Formation, Pengasih Formation, Quaternary Volcanic Complex of Moutain Kunyit and Mountain Kebongsong, and also Alluvium. In the western and northern parts of Sungai Penuh is

part of the Barisan Range which is associated with the Siulak Segment composed of the Bandan Formation, Kumun Formation, Pengasih Formation, Sungai Penuh Granodiorite, Sheared Basalt, and Quaternary Volcanic Complex of Moutain Talang, Mountain Tarasih, Mountain Kebongsong, and Alluvium.

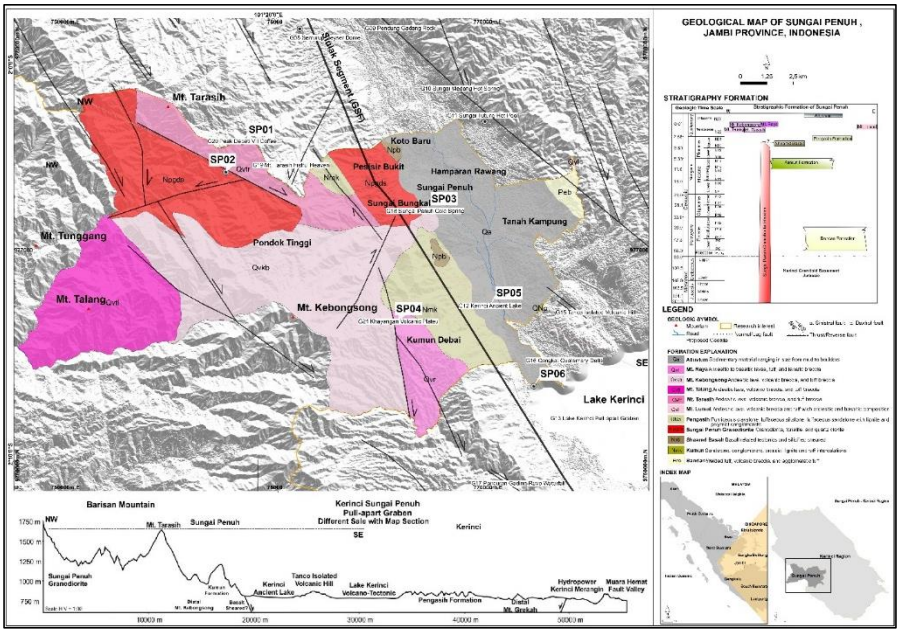

Fig. 3. Geological map and geodiversity site of the Sungai Penuh Municipality, modified from (Utama and Mulyasari, 2024)

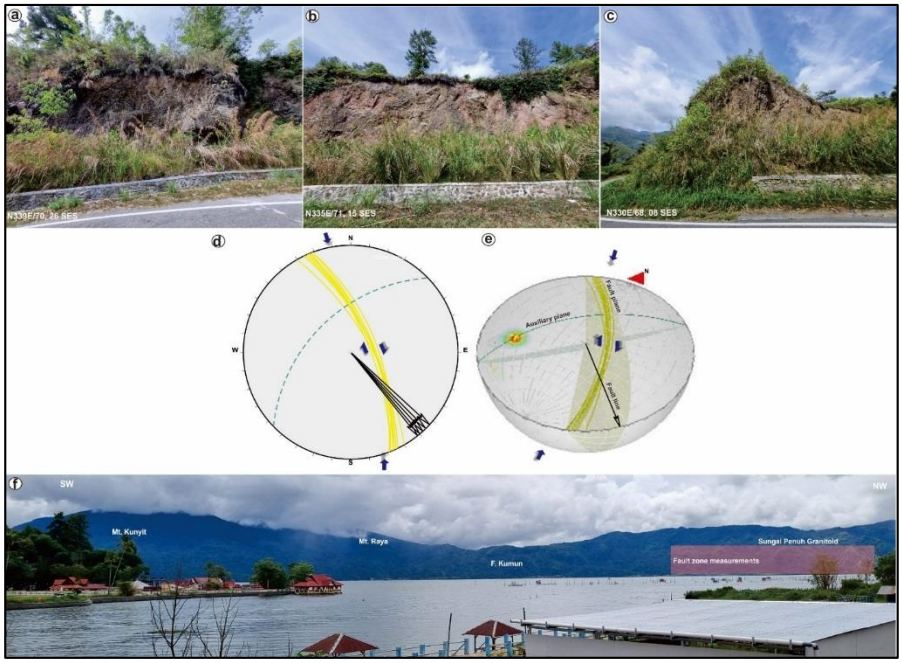

Fig. 4. View of The Great Sumatran Fault, Siulak Segment in Sungai Penuh; a. Steep fault cliffs of granitoid rocks, b. Fault cliffs form landslide zones, c. Fault zone in volcanic rocks, d. Stereographic analysis model on fault structure, e. Hemispherical stereographic model showing a right-moving oblique fault model, f. The morphological landscape of the western highlands that forms mountains as seen from Lake Kerinci

3.2 Geological Structure and Neotectonics

Sungai Penuh City is an area with 3/4 of its part occupying the morphology of the peak of the Barisan Range (west), while about 1/4 of the area is in the valley area of the Sungai Penuh Basin (east). The structure of the Great Sumatran Fault is present between the striking morphological differences forming a dextral strike-slip fault in general with the formation of a right strike-slip fault, and an oblique fault (Fig 3). The large fault is known as the Siulak Fault with a segment length that passes through Sungai Penuh City of about 12.08 km which divides the research area and has a relatively NW-SE direction. The eastern block is relatively shifted obliquely to the southeast against the western highland plane. The highest cliff peak in the west reaches 1421 m a.s.l. in Depati VII Coffee with volcanic rock lithology from Mount Tarasih and Sungai Penuh Granitoid, while the lowest part in the eastern block has an elevation of 783 m a.s.l. in Lake Kerinci with products from alluvial deposits and volcaniclastic sediments from the Kumun Formation.

The steep cliffs that form the fault scarp are clearly visible as the presence of a northwest-southeast trending fault (see Figures 4a, 4b, 4c, and 4f). The tectonic process that occurred

in the Middle Miocene (Neogene) on the back of the Barisan Range was the initial phase of the formation of faults along Sumatra Island that stretch from Aceh (northwest) to Semangko Bay, Lampung (Southeast). This process is a response to the extension of the Andaman Sea that occurred in the Paleogene-Neogene and resulted in the Barisan Range being divided into two irregular parts, namely the morphology in the east and the morphology in the west.

The subduction process that occurred in the western part of Sumatra Island is a tectonic process that accompanies the deformation that occurs, where the Indian Plate moves relatively to the N-NE causing the western part of the Barisan Range ridge to move to the northwest and the eastern part to move to the southeast. The movement of the fault that occurs forms segments as a result of the difference in resistance of the deformed rocks. The research area is crossed by the Siulak Segment with a segment length of 70 km crossing Kerinci Regency and Sungai Penuh City with the Sungai Penuh section at 12.08 km (see Fig 3).

This fault segment moves actively singly (single fault-bend), where the fault is delineated from the southern part of Mount Kerinci turning southwest through the Neogene Granitoid Sungai Penuh basement rock to Mount Kunyit in Lempur, Gunung Raya District (southern part of Lake Kerinci), Kerinci Regency with a slip rate of 1 cm/yr. In this fault zone, a relatively steep valley is formed as a transformation of the strike-slip fault movement that forms a transtension fault, thus forming the Sungai Penuh Basin which is currently evidenced by the existence of the Ancient Lake Kerinci and Lake Kerinci. In this fault zone, volcanic belts are also formed, such as Mount Raya, Mount Kebogsong, Mount Tarasih and Mount Talang which are located in Sungai Penuh City (see Fig 3).

Table 1. Comparasion of Merangin Jambi UGGp, Toba Caldera UGGp, and aspiring Sungai Penuh Geopark designation

Criteria Assesment	Merangin Jambi UGGp	Toba Caldera UGGp	Sungai Penuh Aspiring Geopark
Rock assemblages	Wood Fossil, leaf fossil, black shale, claystone, sandstone, ignimbrite, agglomerate, schist, phyllite, slate, quartzite, conglomerate, volcanic breccia, granitoid, basaltic lava, andesitic lava	Dacitic lava, rhyolitic lava, andesitic lava, tuff, ignimrite, agglomerate, volcanic debris, mudstone	Welded tuff, volcanic breccia, agglomerate, andesitic lava, basaltic lava, tuff, lignite, conglomerate, sandstone, claystone
Volcanic cone	Mount Masurai, Mount Sumbing, Mount Hulunilo, Mount Tungkat	Volcanic complex of Toba Caldera	Mount Talang, Mount Kebongsong, Mount Tarasih, Mount Raya
Age of formation	299 Ma (Cisuralian Permian) – Holocene Quaternary	Carboniferous – Holocene Quaternary	Eocene Paleogene – Holocene Quaternary
International Geosite / Geodiversity	Teluk Gedang Wood Fossil, Muara Karing Leaf Fossil, Mengkarang Fossilized Brachiopods	Sipisopiso-Tongging, Silalahi-Sibungan, Haranggaol, Taman Eden, Balige-Liang Sipege-Batu Basiha-Meat, SItumurun-Uluan, Hutaginjang, Muara-Sibandang, Sipinsur, Bakkara-Tipang-Baktiraja, Tele-Efrata-Sihotang, Pusuk Buhit-Sianjur Mula-Mula, Hutatinggi-Sidihoni, Ambarita-Tuktuk-Tomok, Danau Toba	Peak Depati VII Coffee (SP01), Dissected Mountains Granitoid Sungai Penuh (SP02), Ancient Lake Kerinci (SP03), Khayangan Volcanic Plateu (SP04), Sungai Penuh Cold Spring (SP05), Lake Volcano-tectonic Kerinci (SP06)
Tectonic basement	Airbatu Batholith Late Triassic Basement features of Cathaysianland of West Sumatra Block	Sibumasu Block and West Sumatra Blokc	Sungai Penuh Granitoid Pliocene
Basement group	Peusangan	Tapanuli	Young stratigraphy
Great Sumatran Fault	Dikit segment	Renun Segment - Toru segment	Siulak segment
Landscape	Structural, volcanic, karst, fluvial	Coffee plantation	Volcanic, structural, fluvial
Other geological information	Only one in the world, remnant of Cathaysianland	Super volcano on 74 Ka and Gondwana block	Earthquake risk area, with recorded earthquakes from 1995 to the present

4. Discussion

Geodiveristy in Sungai Penuh City is a single entity with the Geodiversity of Kerinci Regency, only this study focuses on the Geodiversity of Sungai Penuh City, considering that both are different administrative areas. Based on UNESCO assessment guidelines, if the distance between world geopark candidates is less than 100 km, the score decreases. The theme of each UGGp must be different if several UGGp are on the same island. There are three UGGp and three national geoparks on Sumatra Island. UGGp Belitong in Bangka Belitung is located in the eastern part of Sumatra and has the theme of Granite Landscape and Tin Heritage; UGGp Toba Caldera is located in North Sumatra and has the theme of Super Volcano and Traces of Civilization; UGGp Merangin Jambi is the closest geopark to Sungai Penuh City which is only administratively limited by Kerinci Regency, this geopark has the theme of Merangin Jambi Represent Finest and Complete the Last Early Permian Flora Fossils. The comparison is only made with the location of the Merangin Jambi UGGp Geopark, because the distance between the geopark locations is relatively close (Table 1).

The geological conditions of the Sungai Penuh Geopark candidate are a combination of a small part of the Merangin Jambi UGGp and the Toba Caldera UGGp, such as the presence of Granitoid Intrusion which has similarities with the Merangin Jambi UGGp Geopark, then the volcanic complex and the Great Sumatran Fault segment have similarities with both UGGp geoparks. The geological process that forms the Great Sumatran Fault line, volcanic cones, and inter-arc basins are a common geological characteristic of the three geopark areas. Thus, in terms of geodiversity, the Sungai Penuh Geopark candidate is a

composition of geological heritage exposed along the Barisan Mountain Range. Then the characteristics of the landscape also have similarities between the two geoparks and the geopark candidate. This geological setting is the best evidence of the formation process of the Great Sumatran Fault and its control over other geological conditions.

4.1 Peak Depati VII Coffee

Peak Depati VII Coffee is unique in its geological aspect in its natural landscape. The uniqueness of the landscape at this location is very interesting, because from a distance you can see the morphology of the Sungai Penuh Basin which contain geodiversity includes Lake Kerinci, Ancient Lake Kerinci, and Tanco Isolated Volcanic Hill (Kerinci Regency) and also several other mountains such as Mount Melintang which is administratively included in Kerinci Regency. The lithology at the site is composed of Pliocene Sungai Penuh Granodiorite which is shaped like a Granodiorite Batholith. Geological structures such as dextral and sinistral strike-slip faults control this intrusion, so the are interpreted to cause transpression (see Fig 3). Biodiversity at this is is very complex, but the main commodity is *Cinnamomum, Cardyline fruticosa, Citrus, Ficus, Toona sureni, Alstonia scholaris*, and other. The existence of this biodiversity is proportional to the fertile soil content of granodiorite rocks and is also supported by climatic conditions and topography (Fig 3).

This geodiversity has an elevation of 1421 m a.s.l. which is located on andesite lava rocks, volcanic breccias, and tuffs from the products of Mount Tarasih which are of Quaternary. The view from this height is very easily accessible from the main road of the South Pesisir of West Sumatra towards Sungai Penuh City, so the location of this geodiversity is very strategic to visit. The educational aspect with easy access, of course, this geodiversity location can be used as a place to learn earth sciences such as studying geomorphological landscapes, earth geodynamics from the active fault zone of the Great Sumatran Fault and others. In line with the educational aspect, from the scientific side, this location is no less interesting, with the existence of steep mountain morphology, the existence of the Great Sumatran Fault, the Sungai Penuh Basin as a volcanic-tectonic basin, identified volcanic cones such as Mount Tarasih, Mount Kebongsong as evidence of the earth's evolutionary process that occurred during the Neogene-Quaternary. Tourist facilities such as culinary delights in the mountainous areas, various biodiversity such as the Cinnamon Tree make this location a very high attraction for tourists, of course with the background view of the Barisan Mountains and the Sungai Penuh Basin, as well as Mount Kerinci as the highest active volcano in Indonesia (see Fig 5a).

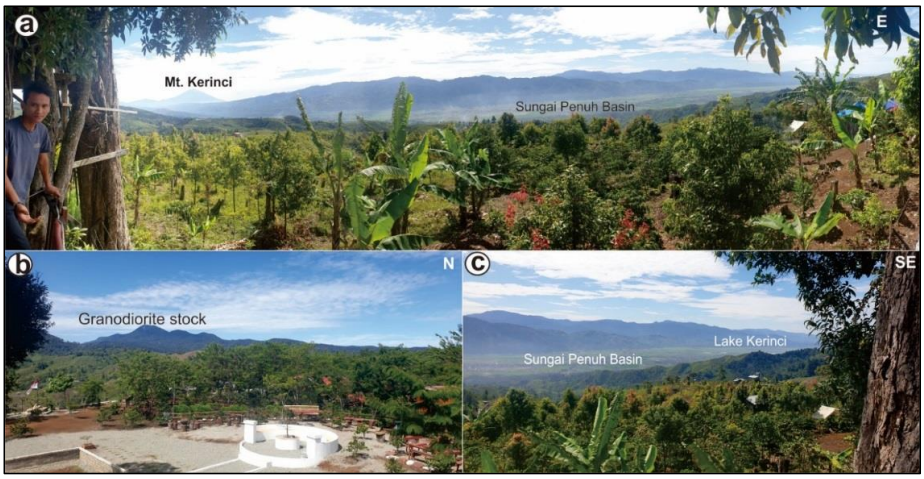

Fig. 5. Overview of Panorama Peak dengan geodiversity; a. The natural landscape visible from the viewing post consists of the Sungai Penuh Basin, Mount Kerinci which is part of the Barisan Ranges b. The landscape of the Barisan Ranges with granodiorite intrusions forms the Granodiorite Stock, c. The natural landscape of Sungai Penuh Basin and Lake Kerinci

Fig. 6. a. View of Dissected Mountains Granitoid Sungai Penuh, b. Tourism site Hill Teletubbies, c. Deformed granitoids of the active fault zone of the Great Sumatran Fault

Fig. 7. a. Ancient Lake Kerinci with Mount Lumut background, b. Close up view of geodiversity of ancient lake

4.2 Dissected Mountains Granitoid Sungai Penuh

Sungai Penuh Granitoid is composed of intrusive rocks such as granodiorite, metagranodiorite, and granite exposed around the main road of Kerinci - South Solok and the main road of South Pesisir - Sungai Penuh, Pondok Tinggi District and Pesisir Bukit District, Sungai Penuh City. These rocks are grouped into the Sungai Penuh Granitoid which is Pliocene, meaning the youngest plutonic magmatism. The outcrop of this rock is traversed by the Great Sumatran Fault from the Siulak Segment. The presence of metagranodiorite is evidence of fault control of the metamorphism of this rock (cataclastic metamorphism), but still shows the original rock structure (palimsest). The mineralogical composition of granitoid in granite rocks is characterized by the presence of mafic biotite minerals, while in granodioiri rocks it is characterized by the presence of mafic hornblende and biotite minerals, apart from the main minerals that make up both rocks such as quartz, k.feldspar, plagioclase. Both rocks in this granitoid group show that this granitoid has Type-I which indicates the result of the Indian Plate subduction process on the western edge of Sumatra Island. The dextral movement process of the Great Sumatran Fault Siulak Segment in the Neogene-Quaternary resulted in deformation of the granitoid rocks.

The landscape of this granitoid is present forming a ridge that extends in line with the western fault segment of the Siulak Fault with an elevation of around 825 m a.s.l., while the highest part reaches 1425 m a.s.l. forming mountains that are split by faults to form valleys, so this geodiversity is proposed as "Dissected Mountains Granitoid Sungai Penuh" (Fig 6). Strike-slip faults and very intense fractures are found in this rock. The presence of this rock is an indication of the presence of exposed basement even though it is young. Tectonics is the main control of the uplift of this rock to the surface. This granitoid is a complement to the geodiversity in the Kerinci-Sungai Penuh Geopark Candidate and as evidence of the tectonic orogenesis event that caused the exposure of this basement rock. Scientific value as basement rock exposed on the surface. In addition, this granitoid is evidence that there is a role for the active fault structure of the Great Sumatran Fault which is capable of changing some of the physical properties of rocks in the Pliocene time span of around 5.3 – 2.6 Ma.

This location is very strategic to visit because it is located on the main road. Its position on the main road certainly makes this location very easy to visit by tourists, but the facilities for visitors are not yet adequate, so for tourists who want to go to this location, they must bring supplies to enjoy the beautiful scenery with mountains stretching out, downstream to the Sungai Penuh Basin in the east, such as the Bungkal River. This access certainly has an influence on this location being used as an educational object that can learn how to utilize natural resources as a tourist attraction, then this location can also be used to learn about the mountainous landscape.

4.3 Ancient Lake Kerinci

Ancient Lake Kerinci is located in the administrative area of Sungai Penuh City and Kerinci Regency with an elevation of 794 m a.s.l. This ancient lake fills the Kerinci-Sungai Penuh Basin in the NW-N part of the current Lake Kerinci. This lake is composed of volcaniclastic sedimentary lithology deposited in a lacustrine environment consisting of siltstone, mudstone, sandstone, tuffaceous mudstone, pumice, conglomerate with lignite as a component of the Pengasih Formation and also alluvial deposits from sedimentation products of the Pengasih Formation. This ancient lake is part of the current highland of Lake Kerinci. The landscape of this lake is surrounded by the highlands of the Barisan Mountain Range, so that sedimentation from the current highlands leads to the ancient lake through the media of the Siulak River and Merao River as the main rivers and other rivers, such as the Kapur River, Penuh River, Hitam River, Sangkai River, Tebingtinggi River, Kerinci River, and Jujun River which flow into Lake Kerinci. Meanwhile, the flow of Lake Kerinci downstream into the Batang Merangin River (Pardosi et al., 2018). Ancient Lake Kerinci or also known as the Kerinci Valley is a lake formed by the structural process of the Great Sumatran Fault associated with volcanic activity characterized by the presence of the Pengasih Formation as a product of sedimentary-volcaniclastic rocks.

Currently, Ancient Lake Kerinci has developed rapidly, including a long bridge over the swamp, Depati Parbo Airport and other buildings. During the day or evening, many people are found fishing from the edge of the lake bridge, but it has not become a special tourist attraction. Of course, ideas are needed to utilize this location, one of which is the creation of an information board about Ancient Lake Kerinci as a volcanic trace in the Kerinci Valley-Sungai Penuh. This geodiversity is evidence of ancient volcanic events related to the fault system of the Great Sumatran Fault. Then the geological process is followed by the process of sedimentation of volcanic rocks in the lacustrine environment in the graben basin zone. The ongoing tectonic activity of fault movements and the presence of sedimentation of volcanic products in the Southeastern part of the basin, has caused part of ancient lake to slowly rise, while the southeastern part, namely Lake Kerinci, is currently

experiencing a decrease or depression, so that the valley landscape of Ancient Lake Kerinci is formed (Fig 7).

4.4 Khayangan Volcanic Plateu

Khayangan Volcanic Plateau is located in Renah Kayu Embun, Kumun Debai District, Sungai Penuh City which is at an elevation of 1500 m above sea level with a distance of about 30 km from Sungai Penuh City. This location is geologically composed of volcanic breccia volcanic rocks and also andesite lava which are located between volcanic products from Mount Raya which is of Quaternary age and Kumun Formation which is of Miocene. This volcanic plateau is better known as Bukit Khayangan which is the result of a volcanic eruption process controlled by a fault. This location has been made a natural tourist attraction of Bukit Khayangan. So, it is necessary to understand how the geodiversity potential is at this location. This hill is also known as the land above the clouds. From this location, many cinnamon trees are found with the landscape of Lake Kerinci which is clearly visible, then Ancient Lake Kerinci, the Siulak Segment zone, and Mount Kerinci (Fig 8).

Andesite lava and volcanic breccia at this location provide an indication of volcanic activity in the past. If observed from the Sungai Penuh Geological Map (see Fig. 3), this product is located in the medial facies of Mount Raya. Then the geological structure of the strike-slip fault limits the product of this mountain with the Kumun Formation and also from the morphology of Mount Kebongsong which is of Quaternary. From the location it can be understood, the presence of more than one volcanic cone indicates that Sungai Penuh is located around a volcanic complex. With the status of the volcano being inactive and more than half of it not being documented from the data of the Indonesian Center for Volcanology and Geological Disaster Mitigation until 2025, except for Mount Raya, it indicates that there are still many geological mysteries that have not been revealed regarding the geological history of Sungai Penuh. Thus, this condition is worthy as a place for earth science education, be it geology. The Great Sumatran Fault in the Eastern part provides important information regarding the geological evolution that occurred in this volcanic plateau. Therefore, comprehensively this geodiversity has a geological heritage that is integrated with other geodiversity.

This geodiversity is located at the height of Sungai Penuh with a sloping morphological ridge formation to the Eastern part of Sungai Penuh City. This location has previously been used as a tourist spot with good access both by two-wheeled and four-wheeled vehicles. Tourist facilities are equipped with culinary places, observation posts, places of worship, and others. To enter this tour, of course, visitors need a fee as a levy for tourism development.

4.5 Sungai Penuh Cold Spring

Sungai Penuh Cold Water is located in Sungai Penuh, precisely in the Al-Akbar Mosque. This location is in the pull-apart graben basin of Kerinci-Sungai Penuh with lithology of Quaternary sand deposits. Sungai Penuh Cold Water was formerly known as Air Sumur Pulai which is at an elevation of 806 m a.s.l. In the Western part of the data or around <5 km from the location, there is Sungai Penuh Granitoid Intrusion rock which is passed by the Great Sumatran Fault Siulak Segment (Fig 9). This location characterizes its own uniqueness of the existence of cold water that never decreases, even in the dry season and is widely used by the people of Sungai Penuh Cityand even Kerinci Regency. The origin of the name Sungai Penuh comes from this location. To meet the needs of clean water for the community and the water is always abundant, even though it has been channeled. The existence of this cold water is interpreted as a spring that appears on the surface through the permeability zone of the Great Sumatran Fault Siulak Segment with its base being aquifug rock from Sungai Penuh Granitoid.

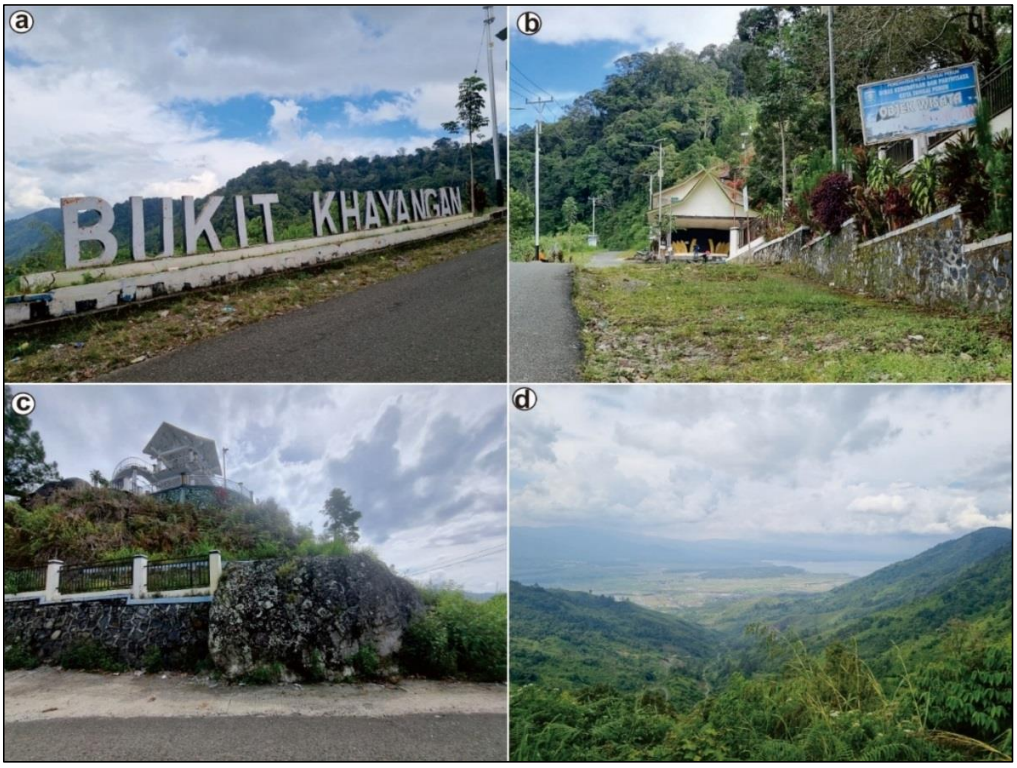

Fig. 8. a. Overview of Khayangan Volcanic Plateu, b. Tourism object of Khayangan Volcanic Plateu, c. Andesitic lava and volcanic breccia as a product of Mount Raya exposed at the tourism object, d. Landscape Lake Kerinci on the Eastern part of Khayangan Volcanic Plateu

Fig. 9. Scenery of Lake Kerinci with a) A lake with a backdrop of Barisan Range, on the edge of the lake there is a habitat for biodiversity, b) Sight of Hill Tanco is the northern part of Lake Kerinci, c) Lake Kerinci seen of eastern side wich biodiveristy like Coconut tree, Rose-apple tree, d) Fish cage presence on the Lake Kerinci is cultural diversity of local wisdom

4.6 Lake Volcano-tectonic Kerinci

Lake Kerinci is a volcanic-tectonic lake, which means the lake was formed by volcanic activity and faulting from tectonic processes with elevation 783 m a.s.l. This evidences can be seen from the existence of a lake in the valley of the Kerinci Ancient Valley or also known as the Sungai Penuh Basin. This lake is part of the active fault manifestation of the Great Sumatran Fault of the Siulak Segment. Therefore, the current lake is part of the Kerinci Ancient Valley and is located in the deepest zone. Volcanic rocks from the Pengasih Formation are believed to be the main product of filling the valley covered by the Alluvial Quarter Deposits from the current sedimentation process, but the existence of the main source from Mount Pengasih is still a mystery and research until now. The uniqueness of geodiversity really supports the presence of biodiversity such as *Cardyline fruticosa, Coleus, Furcraea foetida, Allamanda cathrica, Acalypha wilkesiana, Rhoeo discolor, Aglaonema,* and other. Until now, speculation of the formation of Lake Kerinci is still under research. Some researchers explain that this lake is the result of tectonic activity as evidenced by the existence of the Pengasih Formation which is Plio-Pleistocene (Neogene-Quaternary). No less important than the existence of this lake is the existence of the Great Sumatran Fault which limits this lake with the Barisan Mountains which are composed of younger volcanic cones of Pleistocene-Holocene such as Mount Raya, Mount Kunyit, Mount Kebongsong, Mount Tarasih, and Mount Talang in the Western part of this lake. Then in the northern part of this lake there is an isolated hill composed of volcaniclastic sedimentary rocks from the Pengasih Formation known as the Tanco Volcanic Isolated Hill. Furthermore, in the northern part again there is the Ancient Lake Kerinci. This evidence of geodiversity is certainly a sign of the geological evolution process that occurred so that it formed this lake which is currently known as a volcano-tectonic lake.

Lake Kerinci is included in two administrative areas, namely Sungai Penuh City and Kerinci Regency. This lake has long been used as a tourist attraction, and every year it is known for the "Lake Party" agenda which is generally held after Eid al-Fitr. The lake party, which is a routine event, is an attraction for tourists to visit this tourist attraction. Worship facilities, rest areas, culinary, and other public facilities are available at this location. So this location is a strategic income for tourism entrepreneurs in Kerinci Regency and also Sungai Penuh City.

5. Conclusion

- Based on the results of research on the Great Sumatran Fault, Siulak Segment, Sungai Penuh City, there are several geodiversities characterized by lithology, stratigraphy, geological structure, and landscape. These geodiversities include Peak Depati VII Coffee, Dissected Mountains Granitoid Sungai Penuh, Ancient Lake Kerinci, Khayangan Volcanic Plateu, Sungai Penuh Cold Spring, Lake Volcano-tectonic Kerinci.
- Geodiversity is an important aspect for identifying the geological scientific value, educational value, tourism value, and degradation risk of a geological manifestation location. Membandingkan geodiversity sebagai bentuk pendekatan untuk mengetahui status geodiversity
- Geodiversity plays an important role in realizing geopark areas, of course supported by aspects of biodiversity and cultural diversity.
- To obtain aspiring geopark designation and recognition, a geodiversity study is required to obtain a complete geological heritage and valuable geological sites by comparing geological sites that have been designated as geological sites in geopark areas, both nationally and globally.
- With six geodiversity in Sungai Penuh City, it can be concluded that Ancient Lake Kerinci and Lake Volcano-tectonic Kerinci can be developed as a site of global value, considering that there is no similar geological site in Indonesia. Then other geodiversity can be developed as a

national site such as Sungai Penuh Cold Spring, while other geodiversity needs to be studied a lot to get national recognition or more

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