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Development of Ngebel Volcano as Geoheritage and Tourism Education of Volcano, Electric Energy and Geothermal, Ponorogo, East Java

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Abstract

Ngebel area is part of the Wilis volcano complex. This volcano is a Quaternary Stratovolcano which has several educational locations in the form of volcanic activities, historical traces of the Dutch colonial era to the Japanese era, and local legends. Educational tourism locations include Ngebel Lake, Mloko Sewu, Widodaren Waterfall, Andesite Lava Autobreccia, Agglomerates, Pyroclastic Flow, Pyroclastic Fall, Hot Springs, Mud Pool, Hydroelectric Power Plant, and Dutch Channel.

The methodology used in this study is a vertical rock profile, outcrop observation, petrographic analysis, and information compilation. This study aims to provide insight into geotourism education and education about the history of the Indonesian nation. Understanding events around nature and understanding the history of the nation are expected to foster the motivation for patriotism and state defense for the Indonesian nation. By better understanding the geography and culture of the Ngebel people, we hope that in the future there will be much better ideas to improve Ngebel tourism and the welfare of the surrounding community.

Keywords: volcano, geoheritage, tourism, energy, education

I. INTRODUCTION

The research area is a mountain, hilly, forest and lake water tourism, and culinary tourism area. And this area has been known by residents around Madiun and Ponorogo with its durian fruit which tastes very sweet and thick. Apart from that, this area is the western part of the volcanic area of the Wilis Volcano Complex. However, from the tourist menu that has developed to date, this tourist area has not touched

on volcanic tourism. Essential aspects of natural volcanic phenomena are well exposed in this area. This area is also very easy to reach to the top of the volcanic crater, which is now a lake.

The aspects of volcanic phenomena exposed in this area are craters or craters, pyroclastic fall deposits, pyroclastic flow deposits, accretionary lapilli deposits, agglomerates, and lava domes. Energy aspects are also present in this tourist area, namely: electrical energy from PLTA Ngebel and geothermal energy. The electrical energy produced by PLTA Ngebel is 225 MW. Effective volume 1920 million m3 with a service area capability of 10,000 ha. Meanwhile, the estimated capacity of PLTP Wilis / Ngebel will be 3 x 55 MW. PLTP Wilis / Ngebel is still in the exploration stage, however, as a vehicle for energy education that can be presented as tourism is the appearance of several hot springs in river flows and hot mud pools. Thus, this tourist area is beautiful and has a huge opportunity to be developed, because this area has several aspects of tourism, such as agriculture/plantations, volcanoes, and electrical energy. To go to tourist sites, it can be reached from the cities of Madiun and Ponorogo by four-wheeled or two-wheeled vehicles, so that road access is easy and paved, this area has its magnetic power for tourism development in the local government area (Figure 1). With the development of tourist areas, the aspects of economic growth can be better, and the welfare of the surrounding community can increase.

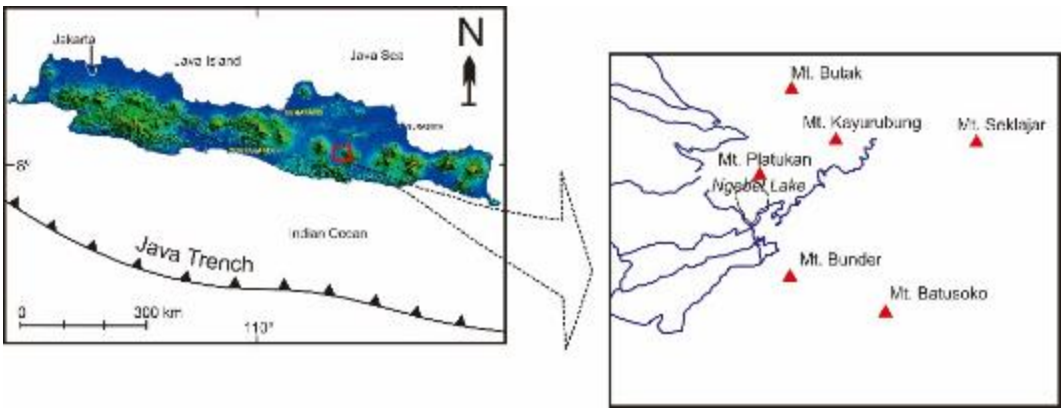

Figure 1. Location map of the Ngebel Lake research area.

II. Literature Review

II.1. Volcano Geology of Ngebel

Volcanofosiografi Ngebel is located in the Solo zone. The Solo Zone is filled with Quaternary volcanic ranges (Bemmelen, 1949; Hartono, 1994) which stretch from west-east. These volcanic ranges are the result of the process of plate subduction between India-Australia and the Eurasian continental plate that has been going on since the Eocene Period until now, namely the Quaternary era. The line pattern in the west-east direction, according to Pulunggono and Martodjojo (1994) follows the geological structure pattern of Java. Meanwhile, according to Hartono (1994) Ngebel volcano is part of the Wilis volcano

complex caldera which is divided into per-caldera Klotok basalt and basaltic andesite, the pre-caldera Pawonsewu basaltic andesite and andesite, the caldera Ngebel dacite, the post-caldera Jeding basalt, and basaltic andesite and the post-caldera Argokalangan andesite (Figure 2).

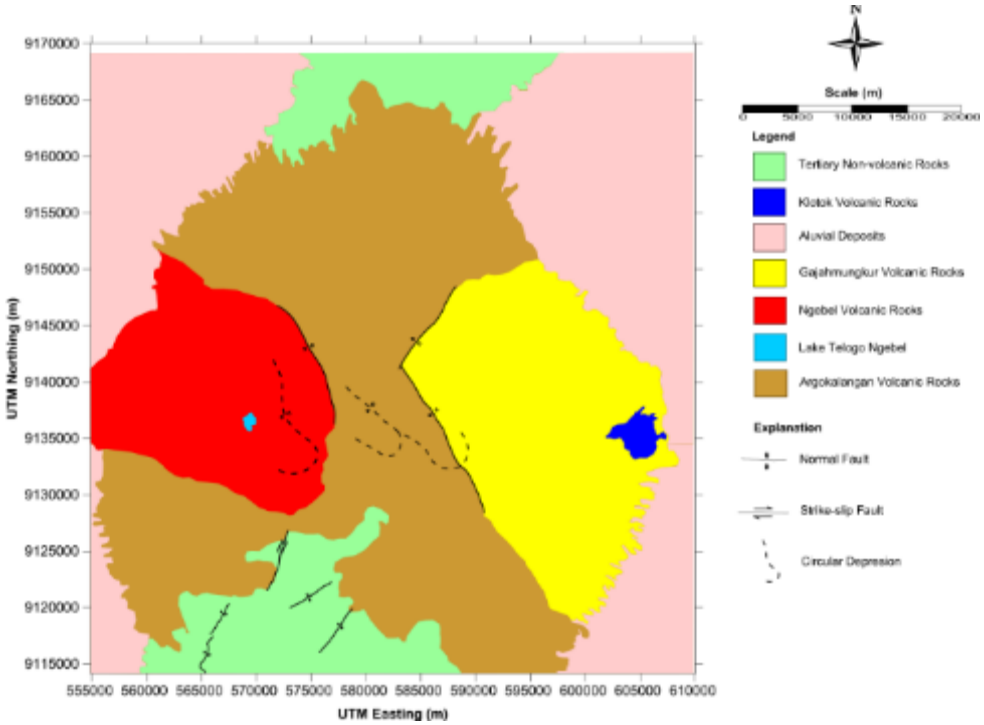

Figure 2. Geological map of the G. Wilis Ngebel Ponororogo area (Hartono et.al., 1992; Putra et al., 2014)

III. RESEARCH METHODOLOGY

In conducting this research, problem-solving was carried out using a methodology that included: mapping, observation of outcrops, making sections/profiles, measurement of rock layers, rock description, petrographic analysis, and compiling information because this research aims to provide insight into geotourism education and education about the history of the Indonesian natio

The attractive landscapes will trigger public awareness to conduct assessments. By using the theory of landscape aesthetics, the landscape can be assessed based on these landscape criteria (Setiawan, 2012). In addition to this, by considering the practicality of adopting and applying this paradigm, the theoretical background, testing, and measurement criteria, and strengths and weaknesses of thinking can be assessed (Salaudeen, et al., 2018).

The criteria used in this criterion are the parameters of scientific value, educational value, tourism value, and degradation value. The Pusat Survei Geologi (2017) has compiled scientific values , including geological scientific values that can explain geological features and processes. However, there are four criteria in science criteria, namely: a) geological heritage sites that can represent geological topics, processes, elements, and geological frameworks; b) the relationship between the conservation status of a geological site; c). geological elements that cannot be found in other locations; d) published scientific data regarding the area of the geological heritage site. The factors used in conducting a quantitative assessment of scientific values (scientific values) can be seen in Table 1. below.

Table 1.Criteria weights are used to measure a geological heritage based on scientific values (Pusat Survei Geologi, 2017).

No.	Criteria	Score
1.	The location that represents a geological framework	30
2.	Key research locations	20
3.	Scientific understanding	5
4.	Geological site / site conditions	15
5.	Geological diversity	5
6.	The existence of geological heritage sites in one area	15
7.	Location usage barriers	10
	Total	100

IV. FINDING AND DISCUSSION

With the results obtained from geological mapping, rock outcrop observations, cross-sections/profiles, petrographic incisions, and information compilation, a research report on the geotourism of the research area can be prepared. Based on the assessment criteria, the geotourism location of the research area has a value of 30 for the types of geological tourism, including volcano tourism and energy tourism. Meanwhile, natural tourism and historical tourism have a value of 5. Things that support the presentation of information about volcanic tourism, nature tourism, historical tourism, and energy tourism (as in Figure 3) and can be explained as follows:

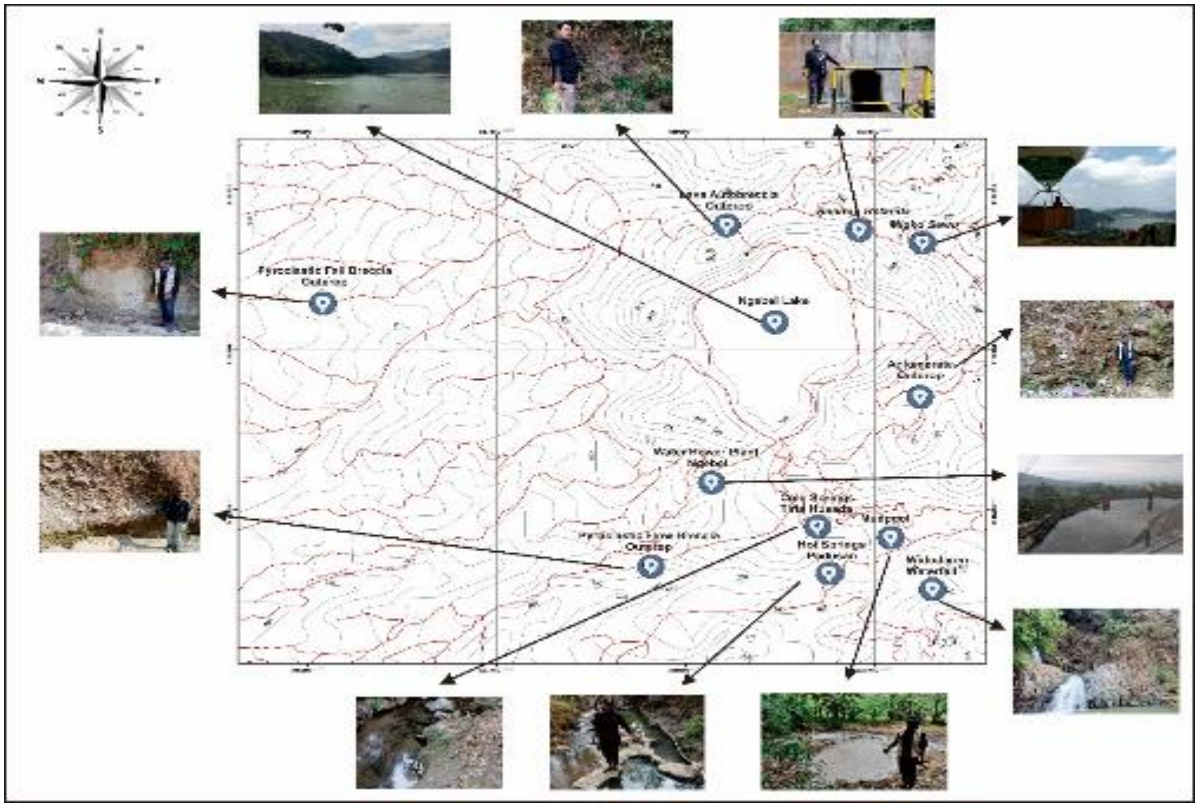

Figure 3. Map of tourist locations in the Ngebel area.

IV.1. Volcano Tourism

Ngebel volcano object is a tourist area that includes phenomena or evidence of volcanic eruptions that have occurred and were exposed at Ngebel Volcano. The phenomenon of the explosion that is well exposed and can be used as a tourism development with the topic of volcanoes is as follows:

IV.1.1. Ngebel Crater Lake

Ngebel Lake is a natural lake located in the Ngebel sub-district, Ponorogo district. Ngebel Lake has found about 30 km from downtown Ponorogo or known as the City of Reog. The community around Ngebel Lake has a tradition of celebrating "Suroan" or the New Year's 1 Muharam in the form of offering at the Ngebel Lake tourist attraction. Telaga Ngebel has a unique phenomenon, namely the death of fish and floating on the lake Ngebel caused by the emergence of sulfur from the lake. This phenomenon

occurs every year in May and August. The edge of Ngebel Lake is surrounded by a crater wall that has a rock composition in the form of andesite lava (Figure 3), agglomerates, pyroclastic fall deposits, and accretionary lapilli, which form a tuff ring on the edge of Ngebel Lake with thick sediment between 0.5-1.5 m. Andesite lava with the jointing structure composed of 60% plagioclase, 15% pyroxene, and 25% groundmass forms a porphyritic texture with a degree of hypocrystalline crystallization, moderate phaneritic granularity, subhedral crystal form, and lithospheric in equigranular relations (Figure 4).

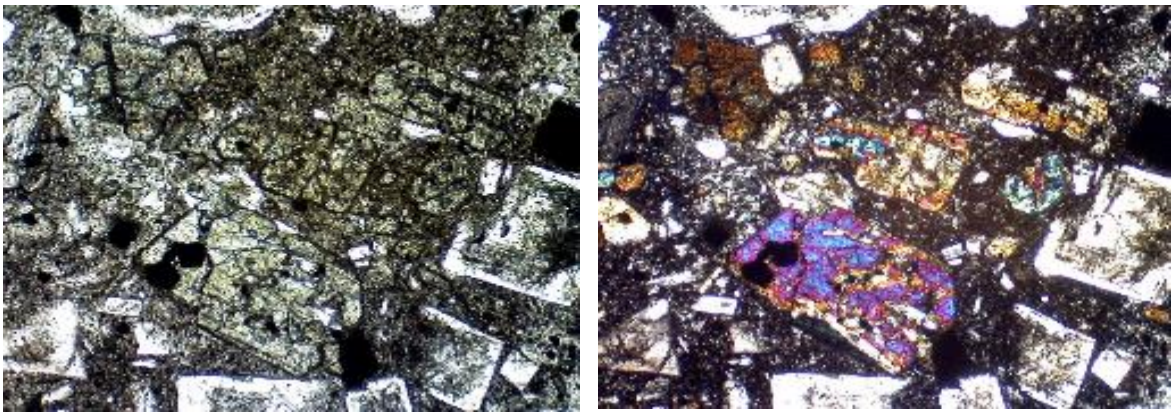

Figure 4. Petrographic photo of pyroxene andesite showing the presence of phenocrysts (plagioclase, pyroxene, and opaque minerals) surrounded by volcanic glass groundmass.

IV.1.2. Widodaren Andesite Waterfall

The location of Widodaren Andesite Waterfall is in Tritis hamlet, Talun Village, Ngebel District, Ponorogo Regency. To reach this location, it takes about 15 minutes from Ngebel Lake. There is andesite lava (Figure 3) with a columnar joint structure with a degree of hypocrystalline crystallization, a moderate degree of phaneritic granularity, a subhedral crystal form, a lithospheric in equigranular relation, a plagioclase mineral composition of 65%, 5% pyroxene, and a groundmass of the volcanic glass of 30% with a porphyritic texture.

IV.1.3. Andesite Autobreccia Lava

Andesite lava exposed to the east of Lake Ngebel (Figure 3) shows an autobreccia structure (Figure 5) with a porphyritic texture with a degree of hypocrystalline crystallization, a moderate degree of phaneritic granularity, subhedral-anhedral crystal shape, lithospheric in equigranular relation. This lava is composed of 70% plagioclase, 5% pyroxene, and 25% base mass. The base of the volcanic glass covers these phenocrysts.

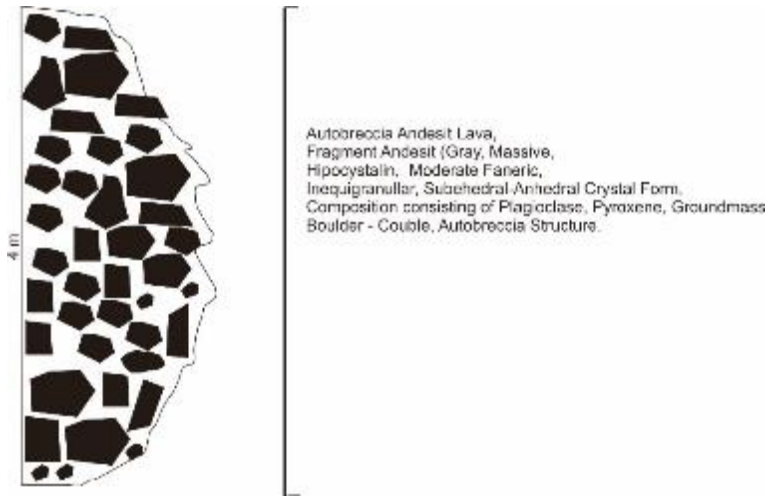

Figure 5. Profile of andesite autobreccia lava exposed showing autobreccia structure.

IV.1.4. Agglomerates

Agglomerates are exposed in the northeast of Lake Ngebel (Figure 3). Agglomerates are a type of pyroclastic rock that falls, and these deposits originate from explosive volcanic eruptions that have grain sizes> 32 mm. Agglomerates are almost the same as conglomerate rocks, but conglomerates are a type of clastic sedimentary rock. The outcrops of these agglomerates in the study area show massive structures. These deposits are brownish-grey in color, and fragments are lapilli-box sized (256-4 mm). The shape of the fragments is rounded and embedded in the volcanic ash matrix. The fragments consist of andesite, oxidized andesite, together with a volcanic ash matrix <0.125 mm in size consisting of the tuff, and grain sorting is low (Figure 6).

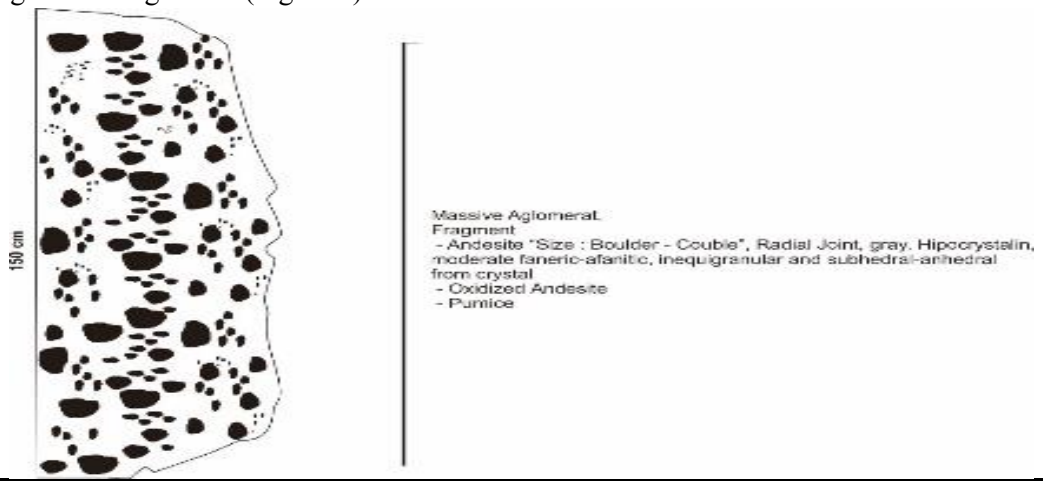

Figure 6. Profile of agglomerates exposed in the study area. Annotation: andesite ox: oxidized andesite

IV.1.5. Pyroclastic flows (hot clouds)

These pyroclastic flow deposits are exposed in the southwestern part of Lake Ngebel. These deposits consist of rock fragments that have the size of transported boulders mixed with volcanic gas and ash. Pyroclastic flows can also occur due to: the collapse of Plinian eruptive columns, direct eruptions in one direction, avalanches of lava domes or lava tongues, and flow on the ground (surge). Pyroclastic flows are highly controlled by gravity and move through low areas or valleys. The movement of pyroclastic flows is influenced by the release of gas from magma or lava or heated air while flowing. In the research area, the pyroclastic flow deposits are brownish, have a layering structure with chunks to gravel fragments (2-4 mm), and some> 64 mm in size. The shape of the spherical grains is embedded in volcanic ash measuring <0.1-0.3 cm. The fragments consist of blocky andesite, scoria andesite, and pumice in the volcanic ash matrix. The rock texture shows poor sorted and unconsolidated outcrop conditions (Figures 3 and 7).

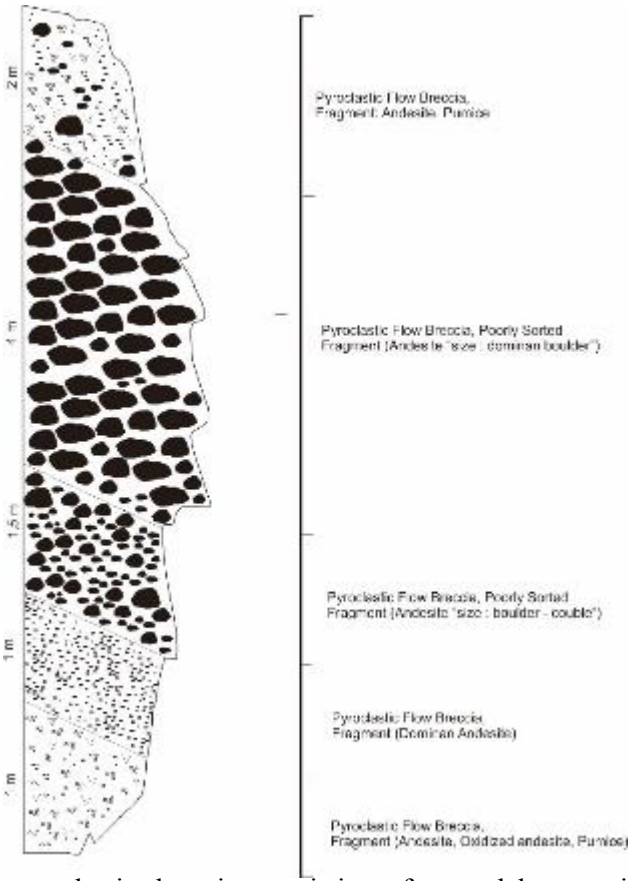

Figure 7. Profiles of flow pyroclastic deposits consisting of several layers with varying thicknesses between 1-4 m.

IV.1.6. Pyroclastic falls

Pyroclastic falls occur as a result of explosive volcanic eruptions that form relatively high smoke columns. When the energy runs out, the ash will spread according to the wind direction and then fall again to the face of the earth. In the study area, pyroclastic falls are scattered around Ngebel Lake, occupying parts of the hills that surround the lake, where the top of the hill has some agglomerate outcrops. Pyroclastic fall outcrops can be found at locations in the western part of Lake Ngebel. These pyroclastic falls are brown, have a lamination structure, and graded bedding with a size of crustal fragments to gravel (2-4 mm), and some> 64 mm. The shape of the spherical grains is embedded in volcanic ash measuring <0.1-0.3 mm.

The components of the pyroclastic drop deposit include scoria andesite, blocky andesite, and pumice embedded in the volcanic ash matrix. At this location, brownish paleo soil layers were also found. The texture of the pyroclastic fall shows well-sorted and shows that the condition of the outcrop is not compactly consolidated (Figures 3 and 8).

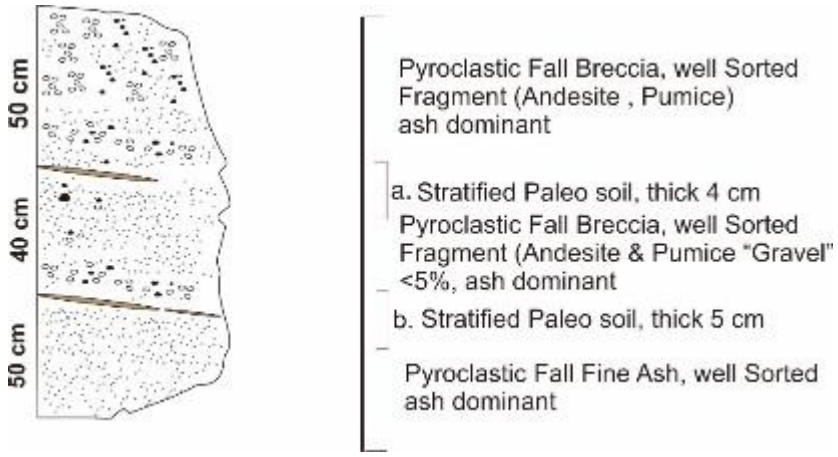

Figure 8. Profile pyroclastic fall by showing the sedimentary structure of graded bedding.

IV.2. Nature Tourism

A natural tourism area is a tourist area that is manifested in beautiful natural scenery spots, be it natural scenery or cultivation or engineering tourism. The natural scenery in the Ngebel area is as follows:

IV.2.1. Mloko Sewu

The tourist area is located at an altitude of 800 meters above sea level, precisely in Prumbon Hamlet, Pupus Village, Ngebel District, Ponorogo Regency. The scenery that can be enjoyed is not only the lake but also the gardens that are well laid out and cared for. From the Mloko Sewu tourist park, you can see Ngebel Lake, which is surrounded by hills that form a circle. Pyroclastic rocks that can be found in Mloko Sewu are a type of agglomerate (Figures 3 and 9).

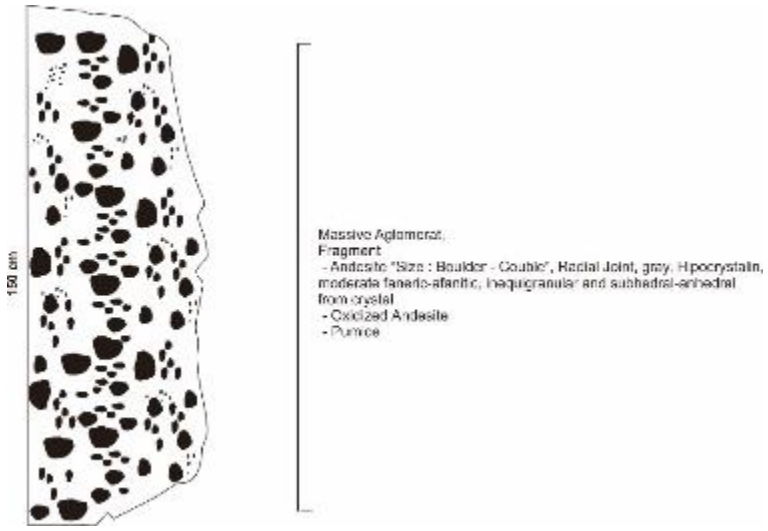

Figure 9. Profile of Mloko Sewu agglomerate deposits composed of andesite composed fragments.

IV.3. History Tourism

Historical tourism is a place or area that has historical values and historical evidence that functioned as a tourist spot, for example, historical museums, temples, and sites or buildings that have history. In this case, historical tourism in the tourist area of Ngebel is the Dutch Tunnel.

IV.3.1. Dutch Tunnel

The tourist site is still located in the Ngebel Lake tourist area (Figure 3). Precisely in the East of Ngebel Lake, Gondowido Village. To reach the Dutch Tunnel, it is necessary by foot or bypassing stairs, which are 150 m from the parking location. Along these trajectories are exposed pyroclastic flow deposits with an observable sorting of low fragments. That is thought to be the result of old volcanic eruptions, as well as pyroclastic fall and agglomerate peaks, which are new products of the Ngebel volcano (Figures 10 and 11). In this outcrop, pyroclastic drop deposits were inserted by accretionary lapilli deposits. These deposits are indicative of a paroxysmal eruption associated with the formation of the Ngebel crater, and the products of this eruption are associated with the phreatomagmatic system. Accretionary lapilli is small balls formed from volcanic ash plumes so that they are shaped like little balls falling due to

explosive eruptions. According to residents, the year the Dutch tunnel was built was during the Dutch colonial period. However, the year of construction is uncertain. However, this Dutch tunnel was repaired by the State Electricity Company (PLN) in 2003.

Figure 10. Rock outcrops in the form of contact positions of agglomerate layers and accretionary lapilli located around the Dutch Channel area.

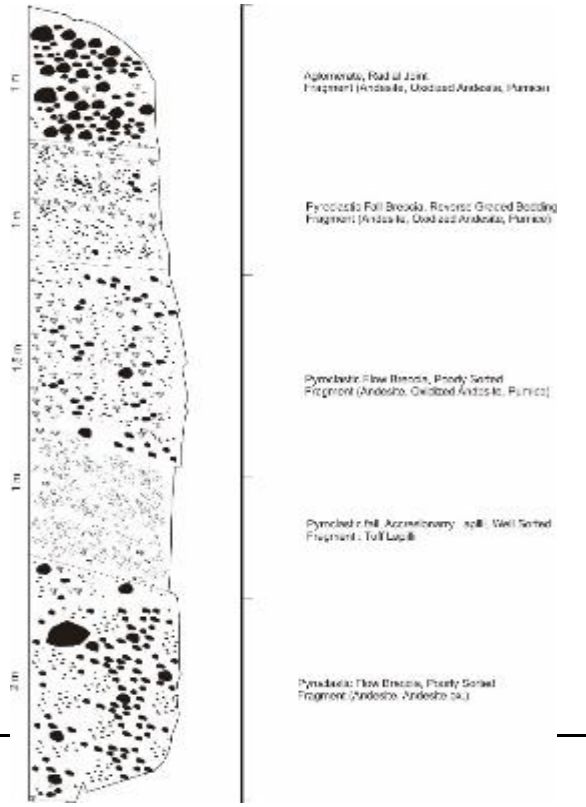

Figure 11. The outcrop profile of pyroclastic fallout deposits found around the Dutch Channel area as part of the walls of the Ngebel Lake Crater.

IV.4. Energy Tourism

The energy tourism area is a tourist area, which is a scenic spot regarding the phenomenon of signs of natural energy or energy engineering technology that can be used as a vehicle for education for students or the general public. By arranging this energy tourism area, people can know and learn about the various processes of energy formation. Energy tourism in the Ngebel area is geothermal energy tourism in the form of geothermal manifestations and tourism for hydroelectric energy. The explanation of this energy tourism can be followed as follows:

IV.5. Geothermal Energy

As a vehicle for geothermal energy education, the Ngebel area has signs or phenomena of the geothermal system, namely hot springs, cold springs, and mud pools. The description of the geothermal manifestations can be followed as follows:

IV.5.1. Tirta Husada hot springs and cold springs.

There are two locations in the village of Wagir Lor, Ngebel District, namely: hot springs and cold springs or what is known as the three-flavored spring. Getting to the location only takes about 15 minutes by driving from the Ngebel Lake Tourism Complex. There are about six hot springs scattered along this river with the lowest temperature around 40^{o}C to the highest temperature of 72^{o}C. The pH of hot water, as measured from this hot water, is 5.8. There is also light saline travertine attached to the bedrock from the hot water flow (Figure 3). The three flavors of cold springs are located 300 m to three hundred meters from the hot springs. The three-flavored spring has a pH of about 6 with a temperature of 26^{o}C. This water has a sour and salty taste. The appearance of three cold springs can be seen in Figure 12.

Figure 12. Photo showing the source of the three flavour springs of Tirta Husada.

IV.5.2. Banyu Lirang/mud pool

The mud pool in the research area is called Banyu Lirang. This mud pool emits a small amount of CO steam, and gas_2 and is not condensed. Generally, the fluid that appears comes from the condensation of vapor. The addition of liquid sludge causes CO gas to come out. The released sludge is liquid due to the condensation of hot steam. Meanwhile, the explosions that occur are due to the emission of CO gas.

In the research area, the geothermal manifestation found was a mud pool in Talun village, Ngebel District. Residents call this location Banyu Lirang. To reach the place, you can walk through the rice fields arranged in a siring terrace. The measured mud pool temperature is 55^{o}C, and the hot steam is 85^{o}C. At this location, there are many salty travertines scattered around the mud pool. These saline travertines are salt deposits that are deposited around the mud pool (Figures 3 and 13).

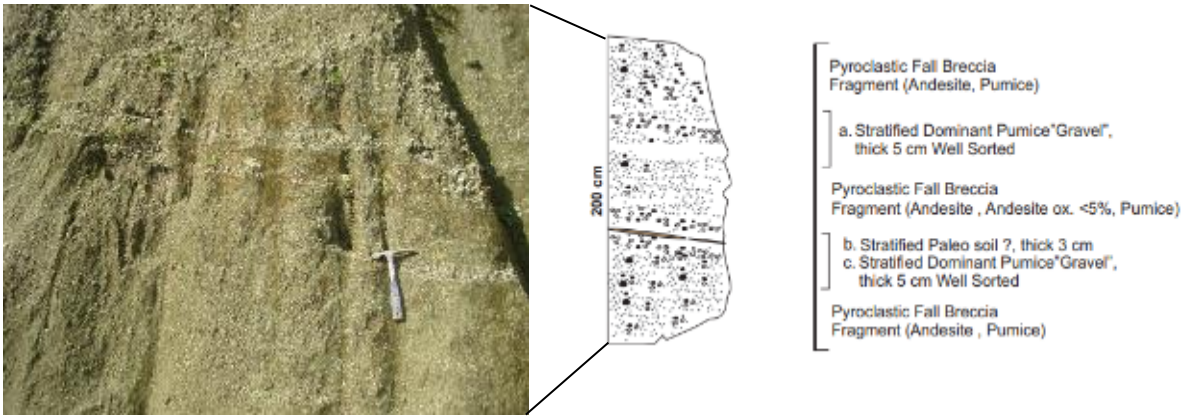

Figure 13. The figure shows a pyroclastic fall profile at the site of the Tirta Husada hot spring and mud pool.

IV.6. Hydroelectric Power Plant (PLTA) Ngebel

The Hydroelectric Power Plant (PLTA) is located in the village of Wagir Lor, Ngebel District, Ponorogo Regency, East Java. Because the Ngebel area is a good water recharge area or river basin (DAS), the Ngebel crater area or lake can be filled with enough water to make a power plant so that this area can be developed as a tourist area for electrical energy with water as raw material. The Ngebel hydropower plant can generate 225 MW of electricity, thus increasing the Java-Bali electricity supply. Another use of this hydropower dam is flood control. Hydroelectric Ngebel was built in 1958 and started operation in 1968. The hydropower plant is currently managed by PT. Pembangkitan Java Bali (Figure 3).

V. CONCLUSION

The Ngebel Lake area has the potential for education on natural geotourism, volcanoes, energy, and education on the history of the Indonesian colonial era by the Dutch. This tourist area is part of the Ponorogo Regency, which still needs to be developed and published. There are many potential locations for creating a tour with values of 30 and 5. As a potential for volcanic tourism, Telaga Ngebel has volcanic rock products such as sheeting joint lava, autobreccia lava, agglomerates, pyroclastic flows, pyroclastic falls, and accretionary lapilli. In contrast, the energy potential includes geothermal energy and water energy. The prospect of geothermal energy is currently found in the phenomenon of geothermal manifestations in the form of hot springs and mud pools. The potential for natural scenery includes the Mloko Sewu tourist area, which is in the form of a beautiful hilltop, where if you are in this location, you can enjoy the beauty of Ngebel Lake. The potential for water energy is the Ngebel Hydro Power Plant (PLTA), which has a capacity of 225 MW. Apart from that, there is a potential for historical tourism, namely the Ngebel hydropower plant and the Dutch water tunnel. The construction of these tourist attractions occurred when the Dutch colonized Indonesia. This Dutch tunnel functions to fill Ngebel Crater Lake so that the lake water can generate hydroelectric power. With the development of the tourist area in Ngebel Lake, it is beneficial to improve the economy and welfare of the community, especially in Ngebel Lake.

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