

Geotourism of Telomoyo Volcano complex: an in-depth analysis for future development

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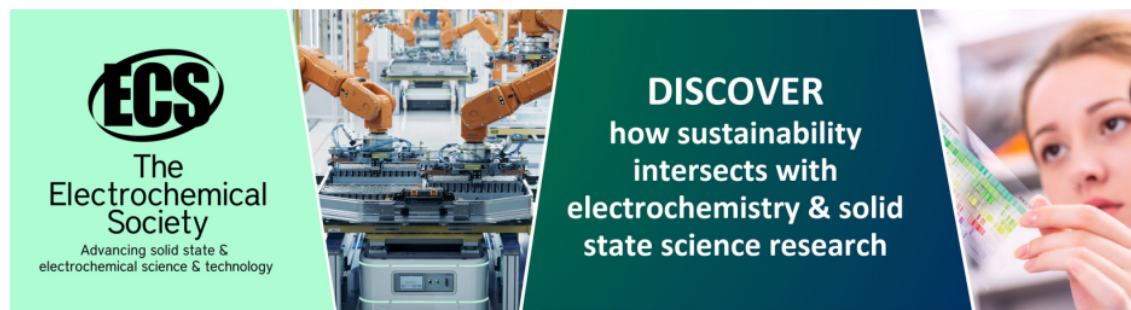
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Geotourism of Telomoyo Volcano complex: an in-depth analysis for future development

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Abstract. Indonesia is located between the three world tectonic plates, the Eurasian Plate, the Indo-Australian Plate and the Pacific Plate. The collision of these three plates creates a series of volcanoes and tectonics activity in various regions, especially the subduction of the Indo-Australian Plate in southern Java. This subduction forming a row of tertiary-aged volcanoes in the south of the island of Java and quaternary in the central part of the island of Java. One of the Quaternary Volcanoes on the island of Java that is extends in a northwest-southeast, the volcanoes are Ungaran - Telomoyo - Merbabu - Merapi. The use of the geotourism analysis method is used to develop the existing geotourism potential in the Telomoyo Volcano Complex by carrying out a geodiversity inventory carried out through field activities to collect geological component data in the research area. The data collected is minerals, rocks, geological and morphological structures or landscapes that include several stages of work include categorization, assessment, evaluation, clustering and determination of geodiversity. This work is accomplished by identifying geoheritage to increase geological diversity into geological heritage through the stages of determining geodiversity and then classified to determine the status, value, meaning and function of geoheritage. The score ranking carried out to determine the geoheritage ranking by comparing the geotourism of the research location with the geotourism of other locations. The Telomoyo Volcano Complex holds a variety of unique and interesting geological phenomena so it had a promising geological conservation-based tourism potential. However, the lack of public knowledge about the potential for geology-based tourism or geotourism has caused the development of this tourism potential to be less than optimal and less desirable. Education, development and good management of the tourism sector are needed so that the potential of geotourism can be recognized by the wider community and can have a good impact, especially for the surrounding community, especially in the economic field.



1. Introduction

The Telomoyo Volcano Complex (TVC) holds a variety of unique and interesting geological phenomena that have promising geological conservation-based tourism potential. However, the lack of public knowledge about the potential of geology-based tourism or geotourism causes the development of this tourism potential to be less than optimal and less attractive. Education, development, and good management of the tourism sector are needed so that the potential of geotourism can be recognized by the wider community so that it can have a good impact, especially for the surrounding community, especially in the economic field.

In TVC there are two volcanic cones namely the Telomoyo Cone and Andong Cone, also consist of two craters from two old volcanoes they are Kelir Old Volcano and Gajah Volcano. Telomoyo Volcano Complex is an inactive volcano but still has traces of volcanic activity such as warm springs, material from volcanic eruptions, and morphological remains in the form of calderas [1]. The eruption of volcanoes produces volcanic stratigraphy with different properties with other volcanoes [2].

Geotourism analysis methods is used to develop the geotourism potency in the Telomoyo volcano complex by conducting an inventory of geodiversity carried out through field activities to collect data on geological components. The method used to identify geological diversity and geological heritage are as proposed by Kubalikova [3] by using through the stages of determining geodiversity. The purpose of this paper is to assess the geological properties for geotourism for there are many hidden tourist locations with geological value in the TVC. With the creation of this paper, it is hoped that it can become one of the geoheritages in Indonesia such as the Gunungsewu exokarst in the southern mountains [4] which became an international heritage and was recognized by UNESCO in 2013.

2. Research Method

Research activities are divided into several stages starting with the preliminary stage, began with studying research area from previous research includes geological setting, lithology, minerals and location of surface manifestation. Data acquisition, in this stage data collected such as lithology, structural geology, location that have tourism potential and variation of opinion from local citizens. At the data synthesis stage, each data collected was analyzed qualitatively to obtain the geological setting and ended by identifying geodiversity in the research area.

The methods used to identify and assess biodiversity are based on the regulations of the Ministry of Energy and Mineral Resources [5], and the method used are geotourism assessment by Kubalikova [3]. The Kubalikova's assessment consist of categorization, assessment, evaluation, clustering and determination of geodiversity where every geotourism location must have high value to understanding the local geological framework, have historical key and various geological features, furthermore the geosite location must be safe and comfortable for tourist to visit. For the analysis, (table 1) is used where qualitative data is converted into quantitative to facilitate assessment according to [3].

Table 1. Parameter and scoring for geotourism assessment according to Kubalikova [3].

Parameters	
Scientific and Intrinsic Values	
Integrity	0-Totally destroyed site
	0.5-Disturbed site, but with visible abiotic features
Rareness	1-Site without any destruction
	0-More than 5 sites, 0.5-2-5 similar sites,
Diversity (numbers of different partial features and processes within the site)	1-The only site within the area of interest
	0-Only one visible feature/processes, 0.5-2-4 visible features/processes
Scientific Knowledge	1-More than 5 visible features/processes
	0-Unknown site, 0.5-Scientific papers on national level
Representativeness/visibility/ clarity of features/processes	1-High knowledge of the site
	Educational Values
Exemplarity/pedagogical use	0-Low representativeness/clarity of the form and process
	0.5-Medium representativeness, especially for scientists
Existing of educational products	1-High representativeness of the form and process, also for public
	0-Very low exemplarity and pedagogical use of the form and process
Actual use of the site for educational processes (excursion, guided tours)	0.5-Existing exemplarity, but with limited pedagogical use
	1-High exemplarity and high potential for pedagogical use and geotourism
Accessibility	0-No products
	0.5-Leaflets, maps, web pages, 1-Info panel, information at the site
Actual use of the site for educational processes (excursion, 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,
	1-More than 1000 m 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, related to a site
	1-Emblematic site for some local products
Conservation Value	
Actual threats and risks	0-High both natural and atrophic risks,
	0.5-Existing risks that can disturb the site,
Potential threats and risks	1-Low risks and almost no threats
	0-High both natural and atrophic risks,
Current status of the site	0.5-Existing risks that can disturb the site,
	1-Low risks and almost no threats
Legal protection	0-Continuing destruction of the site,
	0.5-The site destroyed, but now with management measures for avoid the destruction,
Cultural values; presence of historical/ archeological/ religious aspect related to the site	1-No destruction
	0-No legislative protection, 0.5-Existing proposal for legislative protection,
Ecological values	1-Existing legislative protection (natural monument, natural, reservation)
	Added values
Ecological values	0-No cultural features,
	0.5-Existing cultural features but without strong relation to abiotic features,
Ecological values	1-Existing cultural features with the strong relations to abiotic features
	1-Not important, 0.5-Existing influence but not so important,
Ecological values	1-Important influence of the geomorphologic feature on the ecologic feature

3. Geological Setting

Research area located in Telomoyo Volcano Complex, Magelang and Semarang Regency, consist of two volcanoes which is Telomoyo and Andong Volcanoes, there is also two craters from Kelir Old Volcano and Gajah Volcano [1]. This Volcano complex is created from the subduction of Indo-Australia Oceanic Crust and Eurasia Continental Arc. Although firstly formed Volcano arc are the Tertiary Volcano Arc located in Southern Java, the magma source migrated to north caused the inactivity of the Tertiary Volcano Arc and new Volcano arc formed in the mid of Java. The movement of magma source occurred because the subduction slope becomes increasingly shallow, this creates the Quaternary Volcano Arc (figure 1).

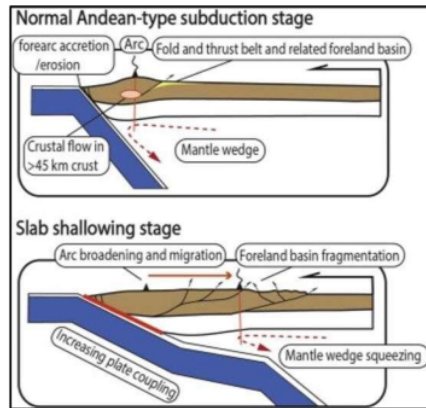


Figure 1. Schematic shows the relation between subduction angle and island arc. Model created by Gianni [6].

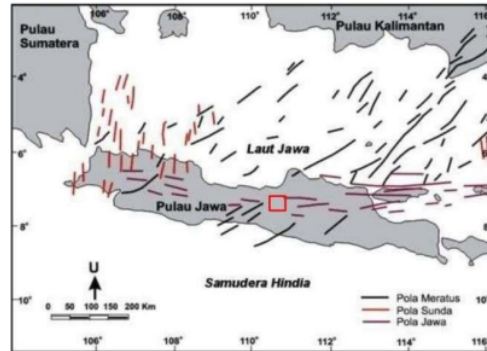


Figure 2. Structural regime in Java Island model created by Martodjojo & Pulungono [7], research area shows by red rectangle.

According to PSDG [8], TVC formed as a result of major strike-slip fault aged from Pre-Pleistocene that create the quaternary Volcano arc Ungaran-Telomoyo-Merbabu-Merapi with NW-SW orientation. There are three structural regimes (figure 2.) assist the forming of TVC, namely Sunda Regime with N-S orientation, Meratus Regime with NE-SW orientation, and Java Regime with E-W orientation according to Martodjojo & Pulungono [7]. Telomoyo Volcano Complex are one of the quaternary Volcano arc, they had intermediate magma known from the appearance of Hornblende and Pyroxene minerals. Lithology found in this area are andesitic – hornblend, andesitic – pyroxene and andesites rock, with mineral composed of Hornblende, Augite, Hypersthene, Diopside, Enstatite, plagioclase and quartz [8].

4. Result

The research area located in Telomoyo Volcano Complex (TVC), administratively in Central Java, divided into two regency which are Semarang and Magelang (figure 3). In geographical coordinates it is located at Lat $7^{\circ}23'57.60''S$ - $7^{\circ}18'43.63''S$; Long $110^{\circ}19'51.54''E$ - $110^{\circ}26'19.04''E$. This area is the quaternary volcanoes in middle of Java Island, where consist of few old volcanoes from the oldest are Soropati, Gilipetung, Gajah, Kendil, Andong and the youngest is Telomoyo [3].

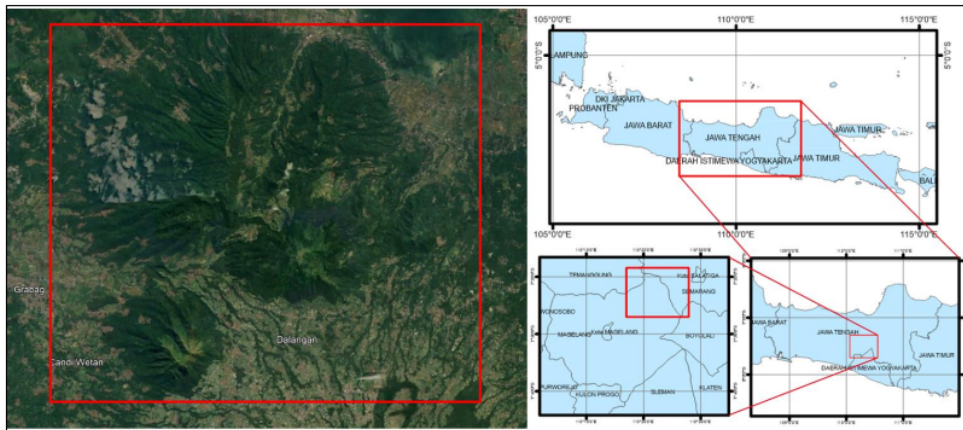


Figure 3. Map location of the research area.

The TVC is not well known to the public, it causes many tourist destinations are neglected due to its accessibility and remote location. Based on geological mapping, lithology & stratigraphy analysis, petrographic study there are few potential geosite in the TVC shown by (figure 4.)



Figure 4. Potential location for geotourism around Telomoyo Volcano Complex.

4.1. Scoria Mountain

This mountain is home to one of the Hindu temples on the island of Java namely Brawijaya V Temple (figure 5). This mountain located in coordinate Lat. -7.311192° , Long. 110.425648° or administratively in Rowoboni Village, Banyubiru Subdistrict. To access this temple visitors, have to climb up the stairs to get to the top of the mountain, where the temple resides. Along the way to the top there are many scoria fragments scattered, shows the materials that make up this hill. According to local citizen, the temple is the heritage of King Brawijaya V last king of the Old Mataram Kingdom.

The scoria can be found in exposure around the mountain (figure 6), this scoria provide insight that the magma is relatively felsic so the scoria can be formed. Scoria forms when there are lots of volatile gas that trapped within coagulated magma, and released after the magma was solidified. In this area warm spring can be found, it is located adjacent to Rawa Pening Lake.



Figure 5. Scoria Mountain (Left) where Brawijaya V Temple (Right) located at the top.

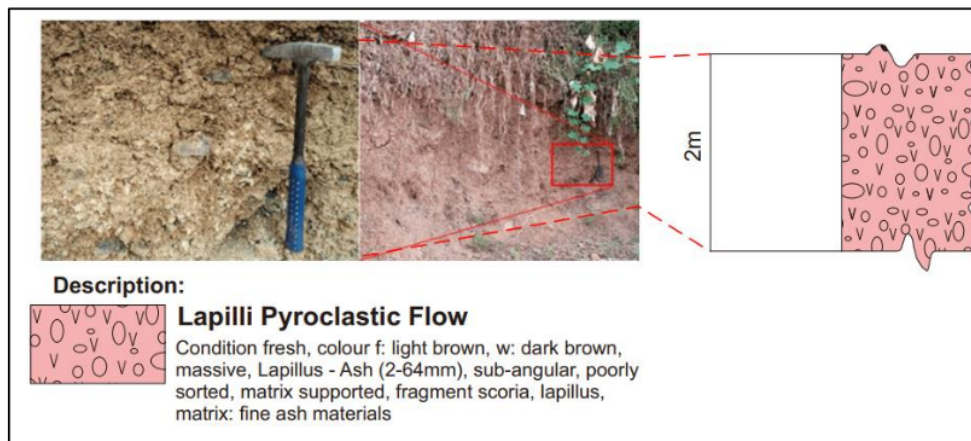


Figure 6. Scoria exposure which composed the mountain.

Near the temple there is warm spring manifestation (figure 7), adjacent to the Rawa Pening lake. The manifestation located behind the residential area and can be accessed by motorbike or car as it has pretty good road. The water in this warm spring has temperature of 37°C and pH-7, with relatively clean water. The warm spring not well known to the public because the water debit cannot accommodate to be a pool of warm spring. So, water intake must be limited to keep the manifestation from disappearing.



Figure 7. Water spring manifestation located near the Brawijaya V Temple.

Based on parameters showed on the (table 1). For the scientific and intrinsic values have 75% and educational values 63% because this place have warm spring and scoria fragment but few paper gave explanation about the scoria. The economic value 33%, conservation value 100% and added values 75% clarified because this location is around the Hinduism temple, one of the cultural landmarks and protected place by law.

4.2. Pyroclastic Deposit

This place located in coordinate Lat. -7.330415°, Long. 110.427035° or administratively in the Tegaron Village, Banyubiru Subdistrict, 10km northeast of telomoyo mountain. The exposure indicates the pyroclastic deposit with sulphur content, this place shown the process of hydrothermal alteration with the pyroclastic deposit. The exposure 5m tall, top of the exposure are consolidated tuff, in the middle are the consolidated pyroclastic flow, in the bottom are the phreato-magmatic that have been altered (figure 8). At this exposure visitors can examine different pyroclastic transportation where the tuff is from the pyroclastic surge, the pyroclastic flow where it flows from crater opening and the phreato-magmatic from the volcanic mudflow consist of variety volcanic rocks.

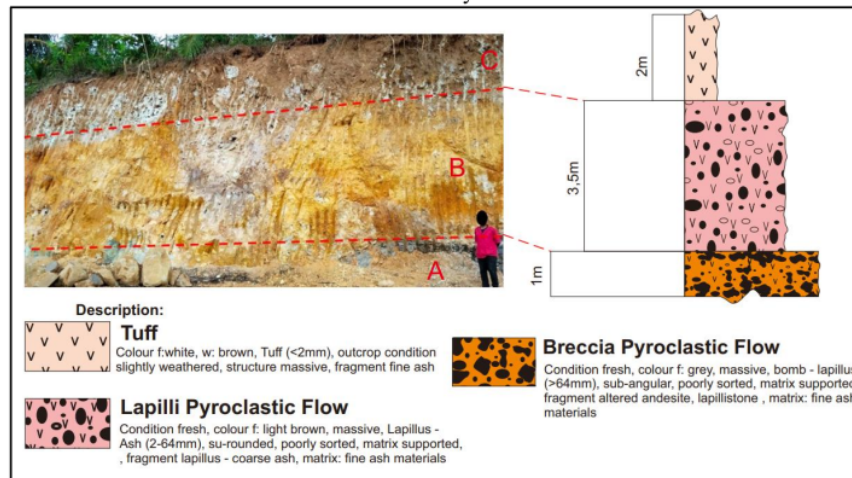


Figure 8. Exposure of pyroclastic deposit, top composed of tuff, middle composed of pyroclastic flow, bottom composed of altered phreato-magmatic.

The geotourism assessment at this location based on the parameter in (table 1) are such as following: scientific and intrinsic values are 63% and educational values 25% because this location need higher knowledge in order to interpret the exposure, so not everyone can understand the important of this place. Conservation value 13% and economical value 33% are low because this location could be used as housing for the local residential. There is no added value as this place not very long ago excavated with an excavator.

4.3. Gumuk Reco

The Gumuk Reco are extreme tourist and extreme rides located at Sepakung Village, Banyubiru Subdistrict or at the coordinate at Lat -7.341853°, Long 110.427211°. The exact location of the Gumuk Reco is inside of the Gajah Old Volcano's crater, exactly at the cliff of the crater (figure 9). This location has a distinctive and unique characteristic, namely that it is located on the crater wall of Mount Gajah which experienced an explosive eruption which then became inactive and left a crater. Visitors can approach using bridge at the cliff and of course using safety equipment. Other attraction in this location is the swing above the cliff, bridge made of glass and many spot photo around the cliff. The inside of the crater shows igneous rock with the appearance of columnar joints resulting from solidification of lava near surface.



Figure 9. Gumuk reco tourist attraction, visitors can walk on the bridge at the cliff.

4.4. Baladewa Twin Waterfalls

Located in Wirogomo Village, Banyubiru Subdistrict, or in coordinate at Lat -7.342328, Long 110.390019. The Baladewa twin waterfalls is the only waterfalls located at the crater of Kelir Old Volcano where at the location there are two waterfalls from different water sources. The Waterfalls consist of two different lithologies, the blocky lava at the top and unconsolidated pyroclastic flow at the bottom (figure 10). To be able to reach the waterfalls, visitors have to walk 800m through residents agricultural field, near the waterfalls visitors also can found warm spring 200m before the waterfalls.

The warm spring manifestation located on the slope of a mountain, make it hard to found. The water in this location has temperature around 32°C, pH-6 and have yellow colour, also smells like sulphur (figure 11). Even though it's not likely had a tourism value, but it has a high value to study because it's the only warm spring manifestation can be found on the crater of Kelir Old Volcano. The warm spring manifestation has a small discharge, it is feared that the manifestation will disappear if its heavily exploited.

The Bolodewo waterfalls, based on geotourism assessment are as follow scientific and intrinsic value 63% and educational value 50% because this location show variety lithologies and warm spring manifestation which have high educational value. Economical value 33% and conservation value 38% are because this location quite remote and not known to public, also this place very far from tourist infrastructure. But this location still natural and less disturbance from human activity.

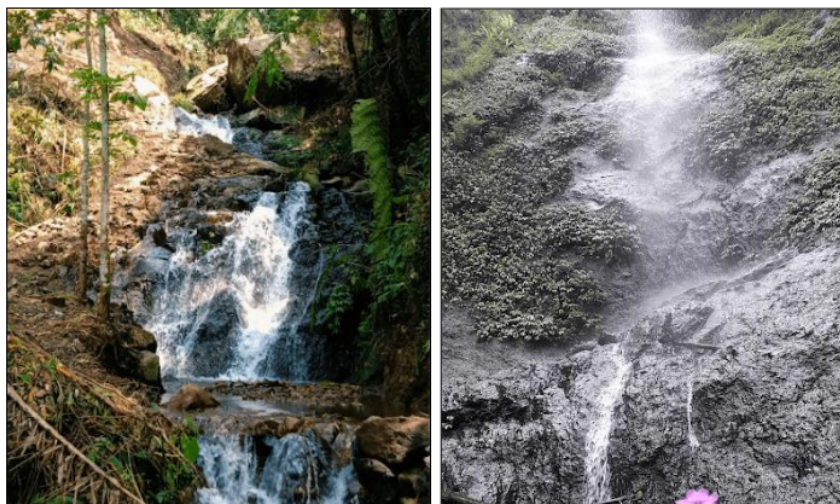


Figure 10. Two waterfalls are located close to each other namely Twin Waterfalls.



Figure 11. Warm spring manifestation located near the Twin Waterfalls.

4.5. Gunung Watu Parasitic Cone

This tourism located in coordinate Lat -7.322880° and Long 110.357173° or administratively at the Gemawang Village, Jambu Subdistrict, Semarang Regency. The name Gunung Watu comes from the

words *gunung* and *batu* in Javanese which are used by local people to refer to a place that is a mountain but is made only of stone (figure 12). The mountain is very unique where visitors can see the parasitic cone up close, even climb to the top of it. The mountain composed of only the blocky lava that show this parasitic cone has eroded until the parasitic neck can be seen. Around this location blocky-boulder fragment can be found as the parasitic eruption product which composed of andesite rock (figure 13). The parasitic cone is estimated to be a byproduct of Kelir Old Volcano, as it is located at the Kelir Old Volcano's slope. Lava sample at this location identified as andesite pyroxene (figure 14) where there is major appearance of pyroxene and hornblende does not appear. The rock composed of: plagioclase (40%), pyroxene (20%), quartz (5%), opa (10%), volcanic glass (25%).

Based on the parameter (table 1), this location has potential for geotourism and tourist attraction as it is located at a parasitic cone. The parameter scientific and intrinsic value 50% and educational value 25% as this location there are no journals that discuss the discovery of this parasitic cone. Economical value 25% and conservation value 38% the percentages are low because this location recently abandoned because of the lockdown effect the recent years.



Figure 12. Mountain top show "Gunung Watu" words sign.



Figure 13. Blocky-boulder as byproduct of the parasitic cone's eruption.

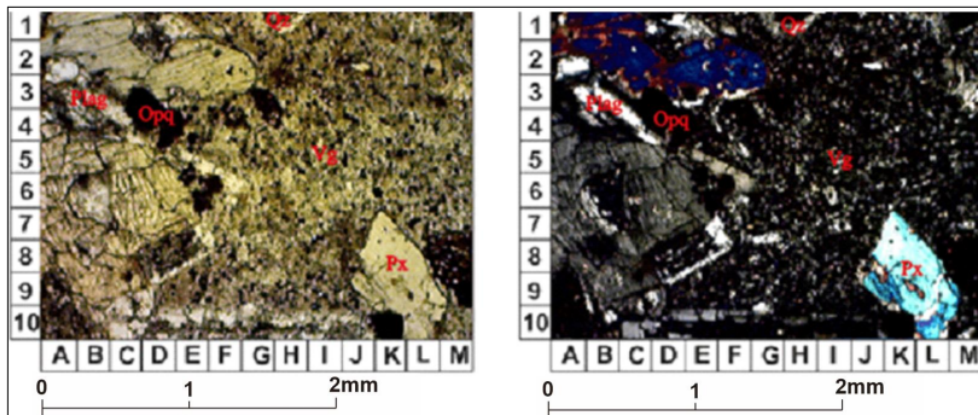


Figure 14. Petrography analysis of the andesite pyroxene from lava sample. Parallel nicol (left) and cross nicol (right).

4.6. Mount Telomoyo

Mount Telomoyo located in coordinate Lat. -7.361340° , Long 110.399785° or administratively in Pandean Village, Ngablak Subdistrict, Magelang, Central Java. The Telomoyo Volcano can be climbed by motorbike or by foot with different path (figure 15). Along the way to the top, there is many indications of volcanic activity, such as Andesite Lava Flow on the mountain slope, Pyroclastic flow around the mountain and unconsolidated pyroclastic at the top of the mountain (figure 16). Beside volcanological signs, there are also many beautiful photos spot along the way to the top. To enter the mountain, visitor have to pay IDR 15.000/pax that include insurance and ticket.

The lava flow on the volcano slope, wich can be found at elevation 1487 masl that can be interpret the magma composition in this volcanic complex. This lava shows the flow structure and still fresh, means this lava is the latest lava formed in the surface of Mount Telomoyo (figure 17). Based on petrological analysis, the lava consists of Andesite Pyroxene Rock.

Petrological of the Andesite pyroxene rock shown lava flow structure with slightly weathered rock condition, grayyellow color, porphyritic texture (phenocrysts embedded within fine grain or glass groundmass), mineral composition consisting of plagioclase (45%), quartz (10%), pyroxene (25%), opaque minerals (5%), and volcanic glass (15%). The Pyroxene Andesite Petrographic shown by (figure 18).



Figure 15. Top of the Mount Telomoyo overlook Mount Andong.



Figure 16. Unconsolidated Pyroclastic near top of the mountain.

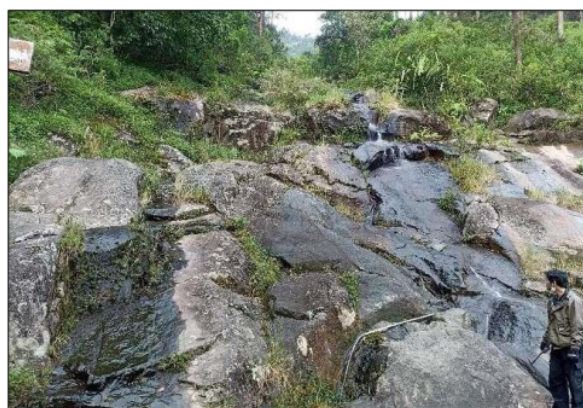


Figure 17. Andesite lava outcrop with lava flow structure at the Telomoyo Volcano slope.

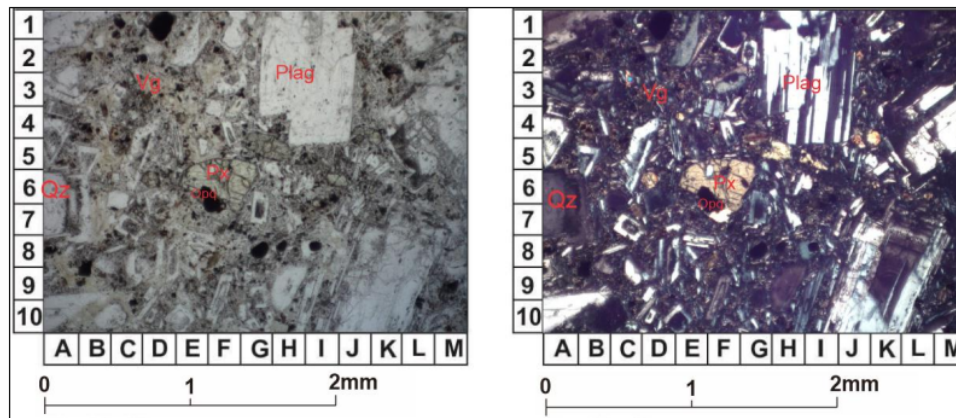


Figure 18. Pyroxene Andesite Petrographic Section. Parallel nicol (left), cross nicol (right).

Mount Telomoyo has many tourists potential, based on the parameter from the table 1. Scientific and intrinsic value 63% and educational value 63% as this inactive volcano have many subjects to unearth. Economical value 83% and conservation value 75% as this place are unique because the only mount can be hiked using motorcycle and have many photos spot also its natural is maintained.

4.7. Keditan Pines Village

The Keditan Pinus Village is an area of protected forest nature reserve under the PERHUTANI Corp. located in coordinate Lat -7.368372° , Long 110.389102° or administratively in Keditan Village, Ngablak Subdistrict so, in this area visitors prohibited to chop the tree or bring harm to the environment. In this location visitors can camp or glamping with the mountain's foot experience, or simply doing outbond activities (figure 19). The exposure shown the fresh intrusion rock and its altered intrusion side-by-side, its separated by fracture (figure 20). The altered rock appertains to propylitic alteration indicated by red appearance of the rock, the fresh rock classified as andesite. Fracture can be found in this exposure as a path for hydrothermal fluids. The altered rock interpreted as the propylitic alteration by the red maroon colour of the rock (Further analysis needed to determine the altered rock).



Figure 19. Keditan Pines Village, where visitors can camp at the pines forest.



Figure 20. Andesite intrusion exposure shows adjacent location, fracture also found in this exposure.

Based on the parameter (table 1), this location has become tourist location where people can camping and doing outside activity and this location also have geological object. The parameters and the scoring are as follows scientific & intrinsic values 50% and educational values 38% the only uniqueness of this area are the appearance of the intrusion adjacent to its altered rock. Economical value 83% and conservation 100% are because this place is forest reserve protected by law, and this forest only used for camping and outdoor activity. Added values 50% because it's have ecological values as the pines and rubber reserve forest.

4.8. Mount Andong

Mount Andong located at Girirejo Village, Ngablak Subdistrict, in geographic position at coordinate Lat -7.391844° and Long 110.371402° . Mount Andong can be accessed by 3 hiking routes they are Sawit route with ETA 3 hours, Gogik route with ETA 2 hours and Pendem route with ETA 1.5 hours. Along the way to the top, there are many altered rocks and few water spring scattered around the hiking routes. The Andong Mountain has formed the lava dome, it's a circular, mound-shaped protrusion resulting from the slow extrusion of viscous lava from a volcano. From the top of the Andong Mountain, there are 6 volcanoes can be seen namely Ungaran, Sindoro, Sumbing, Telomoyo, Merbabu, and Merapi. The morphography of Mount Andong (figure 21) are such as follow, the lava dome (V1) at the center shown by red line, its created as the last phase of volcanic construction period where it composed of agglomerates and auto-breccia lithology. The volcanic crater (V2) shown by orange line is created as the final phase of the volcanic destruction period where there are no more volcanic activity from this mountain.

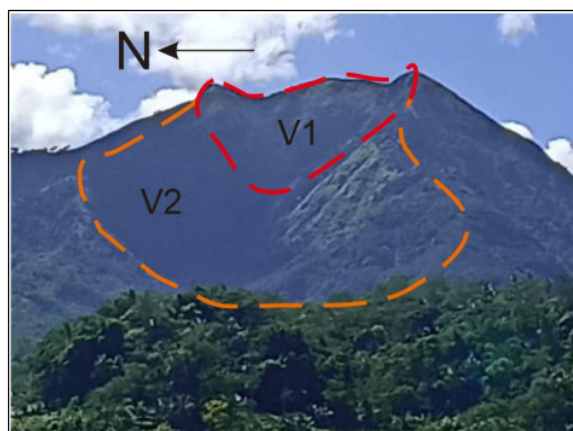


Figure 21. Morphography Mount Andong seen from west, the lava dome (V1) at the center, shown by red line, volcanic crater (V2) shown by orange line.

This exposure shows argillic alteration and there is indication of baking effect shown as a black spout (figure 22). The argillic alteration shows the hydrous-rich process where clay minerals formed, the baking effect can be interpreted as intrusion penetrated the alteration. The Andong Mountain has formed the lava dome, it's a circular, mound-shaped protrusion resulting from the slow extrusion of viscous lava from a volcano. The lava dome can be seen from distance, but the sign of lava dome can be seen up-close such as auto-breccia and boulder-blocky fragment near the top of the mountain.



Figure 22. Argillic alteration in Andong Mountain, the black spouts indicate the baking effects.

The Mount Andong are the smallest mountain in Java, based on the parameters on the (table 1), the scoring is: Scientific and intrinsic value 63% and educational value 63% because this location have high value for post volcano activity such as lava dome and argillic alteration appearances. Economical value 83% and conservation value 100% as this location has lots of visitors who hiked to the top of the mountain or either visiting Sunan's grave and its already known where climbers must maintain the cleanliness and attitude when climbing a mountain. Added value 25% are from the existence of the Sunan' Tomb, where many grave pilgrimage hiked only to visit this tomb.

4.9. Sekarlangit Waterfall

The waterfall located in Tlogorejo Village, Grabag Subdistrict, Magelang, in geographic position at coordinate Lat -7.366754° and Long 110.357377° , the waterfalls (figure 23) can be accessed only by tracking around 600m on a footpath. Along the way to the waterfall presenting rows of rock such as scoria, agglomerates, and diorite intrusion which all show the process of volcanic eruption. The diorites intrusion has columnar joint structure that show magma solidified as it ascends (figure 24).

By the petrographic thin section (figure 25), the rock identified as micro-diorite with mineral composition are Plagioklas (55%), Hornblende (20%), Pyroxene (10%), Quartz (5%) and Opaque Minerals (10%). Where Micro-diorit can be determined where the vulcanic glass not appear and the minerals interlocking with each other. The Micro-diorite can only be found on the near surface intrusion.

The assessment gave score as the following result scientific and intrinsic value 38% and educational value 63% because this location shows varieties of lithology and uniqueness that only geologist can comprehend. Economical value 67% and conservation value 38% are because this place has abandoned and shown detoriate day by day.



Figure 23. Sekarlangit waterfalls, show blocky lava flow.



Figure 24. Diorite intrusion with columnar joint structure.

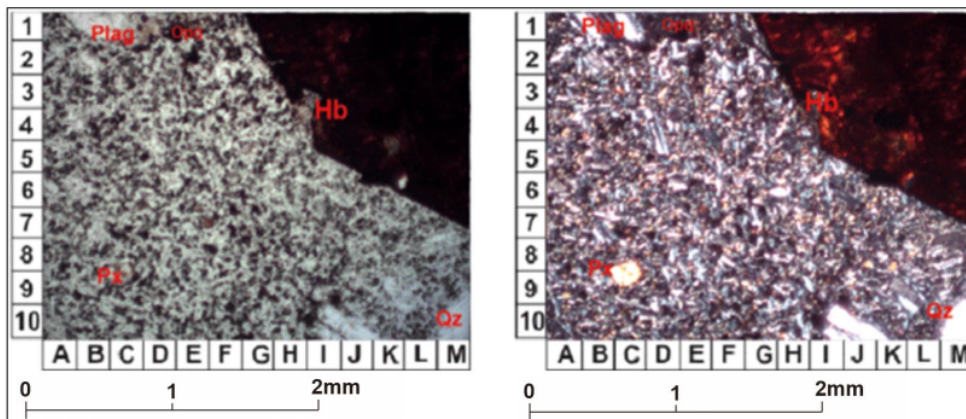


Figure 25. Micro-diorite petrographic thin section of the Intrusion located at Sekarlangit Waterfalls. Parallel nicol (left), cross nicol (right).

4.10. Sumuran Waterfall

Located at foot of Telomoyo Mountain, administratively at the Seloprojo Village, Ngablak Subdistrict in geographic position at coordinate Lat-7.361417°, Long 107.0380416°. This is one of the waterfalls around the TVC which shows andesite with sheeting joint, sheeting joints are extensive fractures that typically develop parallel to natural slopes (figure 26). The Sumuran Waterfall is very popular tourist destination because its accessible with tracking following the foothpath.



Figure 26. Andesite lava exposure with sheeting joint lava structure at Sumuran Waterfalls.

By the petrographic thin section (figure 27), the rock identified as Andesite Pyroxene rock shown sheeting lava flow structure with slightly weathered rock condition, grey-brown colour, porphyritic texture (phenocrysts embedded within fine grain or glass groundmass), mineral composition consisting of plagioclase (45%), quartz (5%), pyroxene (20%), opaque minerals (5%), and volcanic glass (25%).

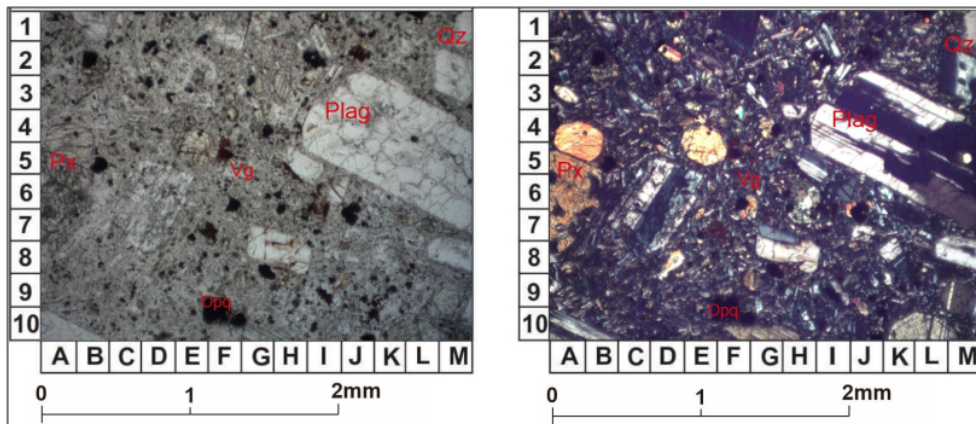


Figure 27. Pyroxene Andesite Petrographic Section. Parallel nicol (left), cross nicol (right).

The assessment implemented gives the following results scientific and intrinsic value 38% and educational value 63% because this location shows varieties of lithology and that can only be understood by geologist. Economical value 67% and conservation value 38% are because this place has a lot of visitors and the guard of this location gave less attention about conservation.

4.11. Rawa Pening Lake.

The lake located in Semarang Regency and have become bread and butter for local residents. The lake has area about 2670 hectares, and became ponds for cultivating fish, and shellfish, moreover the water from the lake used for field irrigation. One of the popular tourisms is Banyubiru's Bukit Cinta (figure 28), it's dockyard for small boat where visitors can take picture around the dockyard or hire a boatman to tour around the Rawa Pening Lake. Moreover, another charm in this area is the floating restaurant (figure 29), where there is restaurant built on the lake and the customer have to take a boat to visit the restaurant. Some research say the Rawa Pening Lake was an old volcano that became a caldera, based on the lithologies founded, but there is still more questioned to be unearth.



Figure 28. Bukit Cinta located in Banyubiru where visitors can hire boatman to tour around lake.



Figure 29. Floating restaurant, gives visitors the experience eating on the lake.

Based on the assessment scoring, Scientific and intrinsic value 63% and educational value 25% are mainly because there are almost no papers that discuss this area specifically and There is a lot of debate about the geological conditions. Economical Value 100% and Conservation value 13% are because this place used for tourism and livelihood for local residents, where no one cares about its current status of the lake and almost no legal law that protect the cleanliness of the lake.

5. Discussion

The geotourism potential location can be scored using Kubalikova [3], to analyse and find out its tourism, educational and conservation's score to facilitate the assessment. Few criteria in the assessment are scientific and intrinsic values, educational values, economical values, conservation value, added values and aesthetic values. The distribution of the points is the higher get 1 point, middle get 0.5 point and the lowest 0 point as shown in Kubalikova's assessment table (table 1).

1: Scoria Mountain (Brawijaya V Dukuh Temple)
 2: Proclastic Deposit
 3: Gumuk Reco
 4: Bolodewo Twin Waterfalls
 5: Watu Gunung Parasitic Cone

6: Mount Telomoyo
 7: Keditan Pines Forest Village
 8: Sumuran Waterfalls
 9: Sekarlangit Waterfalls
 10: Mount Andong
 11: Rawa Pening Lake

Table 2. Assessment feasibility value of geotourism and geoheritage purposes in Telomoyo Volcanic Complex based on Kubalikova [3].

Parameters	1	2	3	4	5	6	7	8	9	10	11
Scientific and Intrinsic Values											
Integrity	1,0	0,5	1,0	1,0	0,5	1,0	1,0	1,0	0,5	0,5	1,0
Rareness	1,0	1,0	1,0	0,5	1,0	0,5	0,5	0,5	0,5	0,5	1,0
Diversity (numbers of different partial features and processes within the site)	0,5	1,0	0,5	0,5	0,5	1,0	0,5	1,0	0,5	0,5	0,5
Scientific Knowledge	0,5	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Percentage	75%	63%	63%	63%	50%	63%	50%	63%	38%	38%	63%
Educational Values											
Representativeness/ visibility/ clarity of the features/ processes	1,0	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
Exemplarity/ pedagogical use	1,0	0,5	0,5	1,0	0,5	1,0	1,0	1,0	1,0	1,0	0,0
Existing of educational products	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Actual use of the site for educational processes (excursion, guided tours)	0,5	0,0	0,0	0,5	0,0	1,0	0,0	1,0	1,0	1,0	0,5
Percentage	63%	25%	25%	50%	25%	63%	38%	63%	63%	63%	25%
Economical Values											
Accessibility	0,5	0,5	1,0	0,5	0,5	0,5	0,5	0,5	0,5	0,5	1,0
Presence of tourist infrastructure	0,5	0,5	1,0	0,5	0,5	1,0	1,0	1,0	1,0	1,0	1,0
Local products	0,0	0,0	0,0	0,0	0,0	1,0	1,0	1,0	0,5	0,5	1,0
Percentage	33%	33%	67%	33%	33%	83%	83%	83%	67%	67%	100%
Conservation Value											
Actual threats and risks	1,0	0,0	0,5	0,5	0,5	1,0	1,0	1,0	0,5	0,5	0,0
Potential threats and risks	1,0	0,5	0,5	0,5	0,5	0,5	1,0	1,0	0,5	0,5	0,0
Current status of the site	1,0	0,0	1,0	0,5	0,5	1,0	1,0	1,0	0,5	0,5	0,5
Legal protection	1,0	0,0	0,0	0,0	0,0	0,5	1,0	1,0	0,0	0,0	0,0
Percentage	100%	13%	50%	38%	38%	75%	100%	100%	38%	38%	13%
Added values											
Cultural values; presence of historical/ archeological/ religious aspect related to the site	1,0	0,0	0,0	0,0	0,0	0,5	0,0	0,5	0,0	0,0	0,0
Ecological values	0,5	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0
Percentage	75%	0%	0%	0%	0%	25%	50%	25%	0%	0%	0%
Total Percentage	69%	27%	41%	37%	29%	62%	64%	67%	41%	41%	40%

5.1. Scientific and Intrinsic Value

Parameter used based on table 1, the criterions are: integrity where well reserved area gets 1 point and destroyed site get 0 point, rareness is the more unique a location is the higher its point, diversity count as visible geological process in one location, and scientific knowledge count as how much paper has been made at the location. Telomoyo Volcanic Complex is a location where there are many volcanoes present either in the form of a mountain or the remains of a volcano.

5.1.1. Integrity. In the Telomoyo Volcanic Complex many tourisms location has been abandoned because of the Corona Virus effect, where there are less visitors which make less profit for the local residential. At the moment, few place which open to public are the Gumuk Reco, Baladewa Waterfalls, Mount Telomoyo, Mount Andong, Pines Forest and Sumuran Waterfalls. The places shown above either need reparation or still in revitalization after the closing effect for many months.

5.1.2. Rareness. The tourism location is unique in their own ways, Scoria Mountain is unique because it's the only mountain formed from scoria, gumuk reco is the only one place that can show innerside of the crater which consist of fresh igneous rock. Baladewa Waterfalls which located inside of the crater had warm spring manifestation and the only manifestation located inside of the crater, the other warm spring located near the scoria mountain. Watu gunung are very unique where it is parasitic cone which can climbed to the top and the only parasitic cone who shows its volcanic neck. Mount Telomoyo and Mount Andong are the quarternary volcanic cone, where Mount Andong show alteration and lava dome

formation and the Mount Telomoyo which show fresh andesitic lava. Sumuran Waterfall and Sekarlangit Waterfall have lava intrusion which in Sumuran have sheeting joint while in the Sekarlangit show columnar joint.

5.1.3. Diversity. Almost all the location above has volcanic process the creation of the volcano can be seen in Scoria Mountain, Mount Telomoyo and Mount Andong. Where the syn volcano event shown by the intrusion in waterfall locations and the appearance of the parasitic cone at the Watu Gunung. Devastation event of volcano can be seen in the gumuk reco which show inner side of the crater and appearance of the warm spring located in Scoria Mountain and Baladewa Twin Waterfalls.

5.1.4. Scientific Knowledge. Scientific research at the location focused only on the geothermal activity simply research the geochemical components of the warm spring. There are still few papers which discuss about geological properties of the TVC.

5.2. Educational Value.

This criterion used following parameter:

5.2.1. Representativeness/ visibility/ clarity of the features/ process. All location shown above, almost composed of geological hint which show the pre-volcano, syn-volcano and post-volcano event. Moreover, only geologist can decipher and comprehend how the volcanic evolution in TVC, where public can hardly recognize these hints.

5.2.2. Exemplarity/ Pedagogical Use. The TVC are very rich about knowledge from volcanology, but only few scientific disciplines can use the knowledge, such as geologist and volcanologist. Where these two study rocks and volcano evolution, furthermore the magma located deep below the TVC.

5.2.3. Existing of educational products. This location only has few educational products in result of the little research conducted in this area. Where research in this area only focused in geochemical of the warm spring manifestation, cause many locations in this place not much known. Moreover, the known warm spring in the TVC is the one adjacent to Scoria Mountain, while the warm spring adjacent to baladewa waterfalls not yet known of its existence.

5.2.4. Actual use for educational. The TVC only has few guided tours, only at the Mount Andong, Mount Telomoyo, and Pines Forest. It is because the other location not known yet or the location have little attractiveness for the tourist. Moreover, the guide tours only show place close to each other and gave little knowledge about the science event happened in the TVC.

5.3. Economical Value

As tourist detination the TVC need to have infrastructure and accessibility to facilitate visitors and give good experience to them.

5.3.1. Accessibility. The TVC was once a tourist attraction, but after the Covid Lockdown, today many locations have been abandoned because there are almost none visit those location. The road in TVC most of it is asphalted road, but quite a few asphalt roads are damaged such as road to Pines Forest and road to top of Mount Telomoyo where there is road made by rocks. The asphalted road is the result of local resident mutual self-help, it is shown the little government attention to tourist locations especially in TVC.

5.3.2. *Infrastructure*. Infrastructure in many locations needs to be revitalized due to its poor condition, otherwise need more improvement to make things easier and more attractive for the tourist. The abandoned location such as Bolodewa Waterfalls, Scoria Mountain (Brawijaya V Dukuh Temple), Sekarlangit Waterfall, Watu Gunung and Pines Forest are still having infrastructure but deteriorate day by day because no one take cares of it. Where the Mount Andong, Mount Telomoyo, Sumuran Waterfall still active, but need to improved.

5.3.3. *Local Products*. The local product in this TVC are mainly the coffee beans, because the temperature and soil accommodate for it. Aside it, also many rice fields and barn in this location because the fertile soil, moreover there are Rawa Pening Lake which can be used to cultivate freshwater fish and clam.

5.4. *Conservation Value*

For keeping the abiotics an biotics component from extinction and land overuse, the geoturism location should keep its nature. This criterion has few parameters such as:

5.4.1. *Actual and potensial threats and risks*. Every tourism location has potential and actual threat mainly from human activity wich disturbed the nature. But not every human activity has threat if it is made considering its effect to the environment. The Mount Andong and Mount Telomoyo are a good example where human and nature can exist side by side without the law supporting it, the Pines Forest are example where law supported the coexist of human and nature. Aside from human threats, there is also natural disaster that appears frequently such as landslide, human can conserve but nature can act without warnings.

5.4.2. *Current status of the location*. There are many locations has been abandoned because the effect of covid lockdown, such as Gumuk Reco, Gunung Watu, Bolodewo Twin Waterfalls, Sumuran Waterfalls and Sekarlangit waterfalls its mainly because almost no visitors came to the locations. The other location such as Brawijaya V Dukuh Temple, Mount Andong, Mount Telomoyo and Pines Forest still active because there are still visitors which grows in number until today.

5.4.3. *Legal Protection*. There are only two place which have legal protection by national law, which is the Brawijaya V Dukuh Temple mainly because it is national heritage and the other is Pines Forest which is the reserved forest. The other location which has protection are the Mount Telomoyo and Mount Andong, where unspoken law applies and all visitors are aware of it. The rest of the location not yet have active laws protecting it.

5.5. *Added Value*

This criterion only has two parameters which consist of cultural heritage and ecological values.

5.5.1. *Cultural values; presence of historical/ archeological/ religious aspect related to the site*. The location that has the cultural values are the Brawijaya V Dukuh Temple, because it is a national heritage and the Sunan's Tomb at the near top of the Mount Andong.

5.5.2. *Ecological Value*. For this parameter, only Pines Forest can fulfil the parameters. Because the pines forest held a various and natural forest reserve not only consist of pines, but also rubber, teak tree and many more.

6. Future Development

Based on this study where geosite and geotourism assessment in Telomoyo Volcanic Complex, there are no issues regarding scientific and educational criteria because geology are natural event. Aside from science value, there are many issues regarding management and conservation for the development at the TVC area.

6.1. Resource Conservation

A few places such as the warm springs, forests, and waterfalls law is a must to maintain the uniqueness and existence. Set warm spring visitor and extraction limit, verify visitors coming and leaving to avoid theft attempt and ensure the development did not damage the surrounding environment.

6.2. Local Resident Participation

Local resident may or might be not aware of the value of the tourist location both scientifically and economically. Give local people education and let them participate in the future developments in these locations. This could give them new livelihood and let them appreciate tourist locations which result in conservation at the tourist locations.

6.3. Educational and Awareness

Not only the local residential which have to educate but also the visitors to avoid the damage on the tourist location. Because there are many the unique geology of this area namely the parasitic cone, the intrusion, morphology and lithology of the inside of the crater, and geothermal manifestation such as warm spring and alteration in few tourist locations.

6.4. Environmental Management

To avoid destruction of the tourist location, there is needed environmental management which prioritizes environmental conditions. When develop a tourist location prioritize in protecting and maintaining the natural conditions. Maintain the cleanliness and sustainability of the existing location. Finally pay attention to surrounding environment to manage trash, energy used and environment friendly attraction.

6.5. Sustainable Marketing

TVC has many tourist locations but very few people visit these locations, so many tourist attractions are neglected. To overcome this, tourist locations need to promote tourism responsibly, focus on the positive values of the area and utilize social media, websites, etc. to expand and promote local tourist locations.

6.6. Stakeholder Engagement

The final step is to build partnerships with the tourism industry, local governments, educational institutions and interested companies. A good collaboration can give exponential result in developing, monitoring, and conserving the tourist location.

7. Conclusion

From the result above, the TVC have many geosite location and can be concluded that:

- Feasibility as a geotourism of the Scoria Mountain (Brawijaya V Dukuh Temple) are 69%, Pyroclastic Deposit are 27%, Gumuk Reco are 41%, Baladewa Twin Waterfalls are 37%, Watu Gunung are 29%, Mount Telomoyo are 62%, Keditan Pines Village are 64%, Mount Andong are 67%, Sekarlangit Waterfalls and Sumuran Waterfalls both are 41% and Rawa Pening Lake are 40%.
- In general, there are many geological phenomena can be found in TVC, such as two warm spring manifestations located in Wirogomo and Candi Dukuh, a few igneous alteration, parasitic cones

and igneous rocks with columnar joint in Sekarlangit Waterfall and sheeting joint structure in Sumuran Waterfall.

- The tourist location needs further development to conserve and monitoring these areas, moreover to improve its value by resource conservation, local villager participation, educational and awareness, environmental management, and stakeholder engagement.

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