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GEOHERITAGE POTENTIAL AS GEOTOURISM SPOT BASED ON QUANTITATIVE AND QUALITATIVE ANALYSIS IN BANDUNG, WEST JAVA

Hana Nur Aini [1] Hilfi Taufiqul Rahman[2] Achmad Djunarma Wirakusumah [3] Rachmat Heryadi [4]
[1] Master Student at Gadjahmada University Bulaksumur, Sleman, Daerah Istimewa Yogyakarta, 55281, Indonesia
[2] Undergraduate Student at Faculty of Geological Engineering Padjadjaran University, Jatinangor, Sumedang 45363, Indonesia
[3] Bandung Polytechnic of Mining and Engineering Sudirman St., No.63., Bandung Kulon, Kota Bandung, Jawa Barat, Indonesia
[4] Indonesia Geotourism Society, Lasut VII Building, 4th Floor, Diponegoro St., No. 57 Bandung, Jawa Barat 40122, Indonesia

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ABSTRACT
Bandung is one of area with abundant geodiversity which also indicates high geotourism potential. One of Bandung geodiversity attractive aspect is the high scientific value related to Tectono-Volcanic History of Bandung which have a good Geoheritage potential. This research intends to assess the Geoheritage potential for Geotourism purposes in Ban-dung City. Research methods such as field observation, literature study, quantitative and qualitative analysis aimed toward at seven geoheritage potentials: Sunda Ignimbrite at Goa Jepang, Sunda Ignimbrite at Goa Belanda, Lava Tube at Cikapundung River, Pahoehoe Lava at Cikapundung River, Ropy Lava at Curug Lalay, Columnar Joint Lava at Curug Omas and Lembang Fault Scarp at Keraton Cliff. Quantita-tive Analysis is based on classification for geotourism pur-poses which includes Intrinsic and Scientific Value, Educa-tional Value, Economic Value, Conservation Value, etc. Quantitative analysis indicates that Geoheritages in Bandung City have a good potential for Geotourism purposes with mean percentage score of >59%.

Corresponding Author:
Hana Nur Aini
Gadjahmada University Bulaksumur, Sleman, Daerah Istimewa Yogyakarta, 55281, Indonesia
Email:

1. INTRODUCTION

Indonesia is a nation with high geodiversity potential from its nature, rock and soil, mineral, fossil, geological structure and geological process. This diversity is both a charm of Indonesia and has high scientific significance that has to be conserved and deserve to be recognized as geoheritage potential.

Geoheritage is geodiversity which contain significance as a heritage due to the on-going or already completed geological record that happened on earth which is scientifically significant, rare, unique, and visually appealing that it has its own educational use (Ministry of Mineral Resource and Energy of Indonesia, Article 1 number 2, 2020). Bandung is one of area in Indoensia with abundant geodiversity which also has geoheritage potential. The tectono-volcanic history of Bandung basin forming has produced geological features that are proof of that very process. One of area which shows such various geological features is located at Ir H Djuanda Bandung Grand Forest Park and is represented by the existence of 7 geological sites which are the main object of this research.

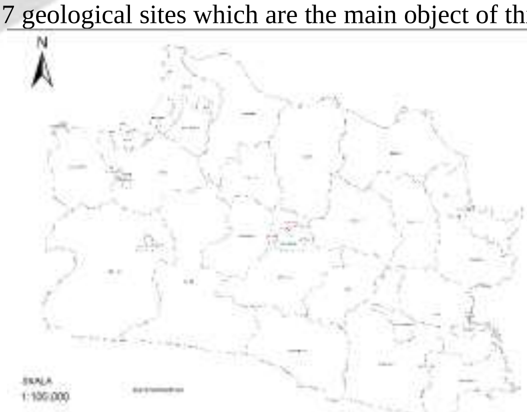

Figure 1. Study Area Map

Sites that become the object of this research is a potential geotourism location. These locations are geologically based, which means that they are formed as a product of natural geological process hence, information about the locations such as the geological history of each location become crucial. In geotourism concept, informations related to geological aspects of each sites should be widespread so that the value of such geological sites will increase as an attractive educational scientific product. Geotourism is a way to socialize natural science, environmental knowledge, and conservational awareness in hope of instilling the importance in conserving the geological heritage that will lead to sustainable local community-based tourism development.

Study Area

This study Is located at Ir. H. Djuanda Grand National Forest Park which administratively situated at Ciburial Village, Cimenyan, Bandung (Figure 1).

Bandung Geological Setting

Bandung is located at a volcanic range that extent from West-East in accordance to Java Island. This volcanic range is a magmatic/volcanic arc included in Sunda Island Arc. This island arc consisted of multiple arc system which include the inner arc of non-volcanic origin and outer arc which is located under the southern sea of Java Island.
Bandung basin is constructed of volcanic deposits, quarter sediments, and late Neogen sediments. Sardjono and Simandjuntak (2004) in Marjiyono, et al. (2008) shows that the geometry and composition which construct the plate structure that cuts through Bandung, formed two sedimentary layers which are expected to be volcanic sediment and late Neogen sediment (Figure 2).

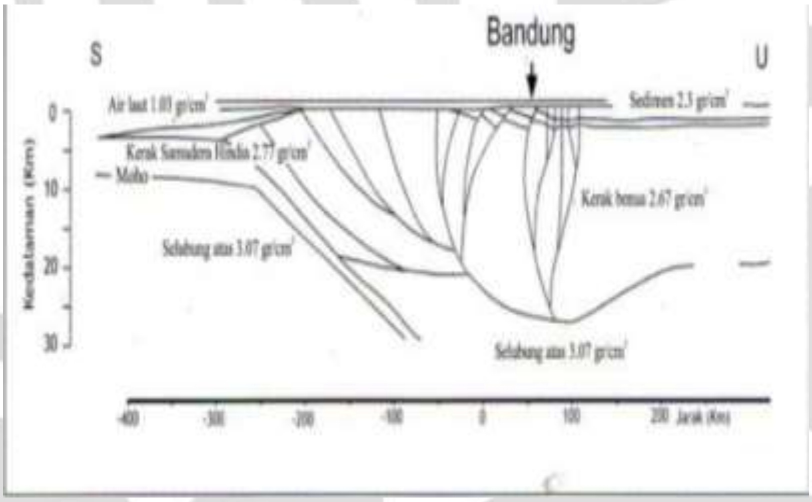

Figure 2. Western Part of West Java's Basin Structure
(Marjiyono. et al., 2008 after Sardjono dan Simanjuntak, 2004)

Geological structure such as folds and faults is expressed through the topography due to the continuity of these structures all the way to the surface. Structural patterns in West Java can be analyzed through satellite imaging. There are 4 structural pattern in West Java and their respective orientation: Meratus Pattern (NE – SW), Sunda Pattern (N – S), Java Pattern (NW – SE & W – E).

Subduction activity of Indo-Australia oceanic plate toward Eurasia plate under Java Island has produced magma intrusions and rising magma chambers under Java Island which leads to the construction of range of active volcanoes which elongated from West to East. Volcanoes are distributed more in West Java that it is believed that West Java is the dwelling place of gods, or also locally known as 'Parahyangan' which then turn to 'Tatar Priangan'.

2. DATA AND METHOD

This study utilizes the systematic study about geoheritage through several main points: inventory, characterization, classification, and assessment. To support those main points, three methods are used to as a base in understanding the geoheritage potential for geotourism. The first method is data acquisition and study through previous literatures to find the geological condition information of each site. The second method is field data acquisition, checking, and inventory in the form of description in order to understand the real geological condition. Lastly, analysis of each site through quantative (Table. 1, Attachment) means (Kubalikova, 2013) and qualitative.

After each parameter in (Table. 1, Attachment) of each geological is assessed, we then calculate the mean total from each value of the assessment to further classifiy the geotourism potential of each geological site (Table 2)

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Table 2. Mean Total Classification For Geoheritage Potential For Geotourism Purpose

Score interval (Mean Total %)	Class
0 – 25	Poor
26 – 50	Fair
51 - 100	Good

3. RESULT AND DISCUSSION

Invertory

Geoheritage potential inventory of the study area includes identification and mapping of selected geological sites which is based on literatures such as Abdurrachman, M. et al. (2016), Wirakusumah, A., et al, (2021), Bandung geological map (Silitonga, 1973), Geodiversity Inventory Report of Bandung Basin (IAGI-MAGI) and completed through discussion with other geologists that have the comprehensive understanding of the study area. Sites identification for geoheritage potential needs to consider several criterias such as uniqueness, occurrence, rarity, and representativeness of geological features (Predrag and Mirela, 2010; Brocx and Semeniuk 2011). Location map and geoheritage potential list (Figure 3, table 3)

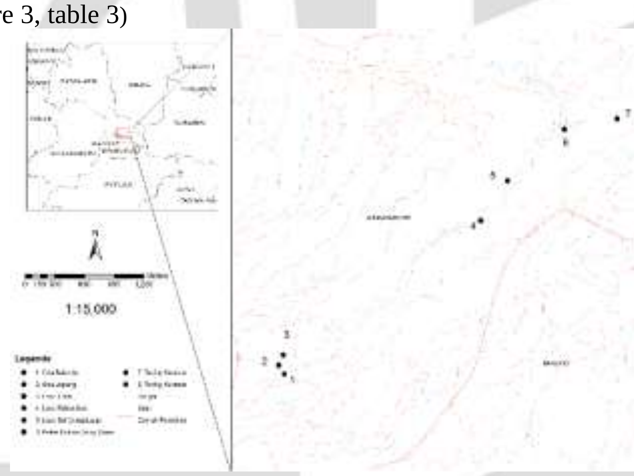

Figure 3. Study Area Detailed Location and Geological Sites Locations in the Area

Table 3. Geoheritage Potential of Study Area

No	Geolocal Site	Location	Main Geological Feature
1	Sunda Ignimbrite at Goa Jepang	Ir. H. Djuanda Grand National Forest Park (S 6°51,379' E 107°37,943')	Pyroclastic Flow (Ignimbrite)
2	Sunda Ignimbrite at Goa Belanda	Ir. H. Djuanda Grand National Forest Park (S 06º51'25,54'' E 107º37'58,33'')	Pyroclastic Flow (Ignimbrite)
3	Lava Tube at Cikapundung River	Ir. H. Djuanda Grand National Forest Park (S 6° 51' 19.41" E 107° 37' 58")	Rocks, Igneous Primary Structure
4	Pahoehoe Lava at Cikapundung River	Ir. H. Djuanda Grand National Forest Park (S 06º50'35,6" E 107º39'2,4")	Rocks and Igneous Primary Structure
5	Ropy Lava at Curug Lalay	Ir. H. Djuanda Grand National Forest Park (S 06º50'22.6" E 107º39'11.1")	Rocks and Igneous Primary Structure

6	Columnar Joint Lava at Curug Omas	Ir. H. Djuanda Grand National Forest Park (S 6° 50' 5.87" E 107° 39' 29.65")	Rocks and Igneous Primary Structure
7	Lembang Fault Scarp at Keraton Cliff	Ir. H. Djuanda Grand National Forest Park (S 6°50'2,479" E 107°39' 46,861")	Landscape and Geological Structure (Fault)

Characterization

In characterizing the geoheritage potential, field observation and literature study in crucial. Main value concerned in this characterization is the scientific and education significance of each geological site. However, there are several sites that were chosen based on their aesthetic value potential for recreational purpose and other added values.

Sunda Ignimbrite at Goa Jepang

This geological site is located in Ir. H. Djuanda Grand Forest Park Bandung, at coordinate 6°51,379' S 107°37,943' E (Figure 4). This site is an explosive eruption product of ancient Sunda Volcano which occurred during phase 2 volcanism of Bandung plain forming. This ignimbrite consisted of pyroclastic materials ranging from lapilli to blocky size with scoria structure (Figure 4). Fragments are andesitic and basaltic with a matrix of coarse tuff. This site contains a historical value which correlated to Japan's colonial age in Indonesia. This is because this site has witnessed the cruelty of Japanese colonialists toward the indigenous local due to *romusha* system which is also the cause of the fall and defeat of Japanese army to the allied powers of World War II in this cave signaled by the massacre of Japanese army in this site. The originality of this site becomes necessary, because the existence of a ver original site such as this one is very rare in Indonesia. Aside from that, materials constructing this site can be a good study material for scientists to further comprehend the volcanic evolution in Bandung plain.

Figure 4. Sunda Ignimbrite at Goa Jepang
(Documentary by IAGI – MAGI, 2020)

Sunda Ignimbrite at Goa Belanda

This geological site is a geological site in Ir. H. Djuanda Grand Forest Park located at coordinate 06º51'25,54'' S 107º37'58,33'' E (Figure 5). This site is situated southeast and not very far from Goa Jepang. This site is also a product of explosive eruption product of ancient Sunda Volcano and the material constructing this site is also not too different from Goa Jepang except that the Ignimbrite is of more grain-supported fabric here than the Goa Jepang. This ignimbrite consisted of pyroclastic materials ranging from lapilli to blocky size with scoria structure. This site records historical evidence that is related to Dutch's colonialism in Indonesia in the past. This site used to be utilized for supporting hydroelectric power generation business (Kusliansjah, K. et al, 2013). However, as it got renovated in 1918, this site function is shifted toward supporting military affairs. This site is located in the middle of forest which makes its rarity value clear, because not all cave or grotto in Indonesia located in the middle of a forest, especially conservation area. The material constructing this site also hold intrinsic and education meaning for volcanic evolution study of Bandung Plain.

Figure 5. Sunda Ignimbrite at Goa Belanda (Documentary by IAGI – MAGI, 2021)

Lava Tube at Cikapundung River

This geological site is located in Ir. H. Djuanda Grand Forest Park located at coordinate 6° 51' 19.41" S and 107° 37' 58"E around the Cikapundung River. Lava tube is consisted of igneous basaltic-andesitic rocks with autobreccia and tube structure (Figure 6). Generally, Lava tube is a lava that was formed during pahoe-hoe lava transiting to Aa Lava and formed a tube-like structure. Lava tube is a product of Mt. Tangkubanparahu lava that is constructed of andesitic-basaltic rocks with porphyritic texture (Silitonga, 1973). Lava tube holds a significant intrinsic and scientific value due to its rarity in Indonesia, deserving as a geoheritage.

Figure 6. Lava Tube at Cikapundung River (Documentary by IAGI – MAGI, 2021)

Pahoehoe Lava at Cikapundung River

Pahoehoe Lava is located in Ir. H. Djuanda Grand Forest Park located at coordinate 06º50'35,6" S and 107º39'2,4" E. This lava flow originated from Mt. Tangkubanparahu, estimated to have occurred around 50.000 years ago. This lava consisted of basaltic rocks (Mirzam, et al., 2016) with pahoehoe structure (Figure 7) and has the characterized by low-viscosity lava flow with smooth or undulated surface which is an evidence of elastic transition in its flow (Mirza, et al., 2016). The uniqueness of this lava is is structure that resembles that of 'batik' (Indonesian textile pattern) and occurred naturally that it is even dubbed as 'Batik Rock' by the locals (Figure 7). The existence of this lava is very important as geological evidence of the occurrence of lava flow similar to the one that happened in Hawaii.

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Figure 7. Pahoehoe Lava at Cikapundung River (Documentary by IAGI – MAGI, 2020)

Ropy Lava at Curug Lalay

Lalay Waterfall Tangkubanparahu Rope Lava is located in Ir. H. Djuanda Grand Forest Park located at coordinate 06º50'22.6" S and 107º39'11.1" E.. This lava is estimated to have originated from Tangkubanparahu eruption around 50.000 years ago and consisted of basaltic-andesitic rocks (Wirakusumah, A., et al, 2021). According to Abdurrahman, et al. (2016) the occurrence of the ropy-like structure happened when lava formed under non-viscous condition, this non-viscousness is caused by the contribution of wet java sediment in the magma that erupted in this area (Figure 8). This lava flow has the characteristing of containing a phenocryst pyroxene and plagioclase mineral embedded in light gray ground mass.


Figure 8. Ropy Lava at Curug Lalay (Documentary by IAGI – MAGI, 2014)

Columnar Joint Lava at Curug Omas

This geological is in Ir. H. Djuanda Grand Forest Park located at coordinate 6° 50' 5.87" S and 107° 39' 29.65" E (Figure 9). Lava in this site is a product of Tangkubanparahu eruption that is of andesitic-basaltic origin with columnar joint structure. Omas waterfall has the height of 30 meters and depth of 10 meters located on Cikawari River. This waterfall formed due to basaltic lavaflow. Joint morphology on this waterfall occurred due to gravity release during lava eruption to the surface.

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Figure 9. Columnar Joint Lava at Curug Omas (Documentary by IAGI – MAGI, 2020)

Lembang Fault Scarp at Keraton Cliff

Keraton Cliff is located in Dago Pakar Area, in Ciharegem Puncak, Ciburial Village at coordinate 6°50’2,479” S and 107°39’ 46,861” E (Figure 10). This cliff is a landscape formed as a product of Lembang Fault. This cliff is a very clear proof of geological and geomorphological expression occurred due to Neotectonic in Bandung Basin. Aside from neotectonics, this fault slip movement is also affected by volcanism. According to Van bemmelen (1949) in Hidayat (2010), the beginning of Lembang Faulting is related to Sunda volcanism. This geological site becomes very important as an evidence of tectono-volcanic activities that occurred in Bandung.

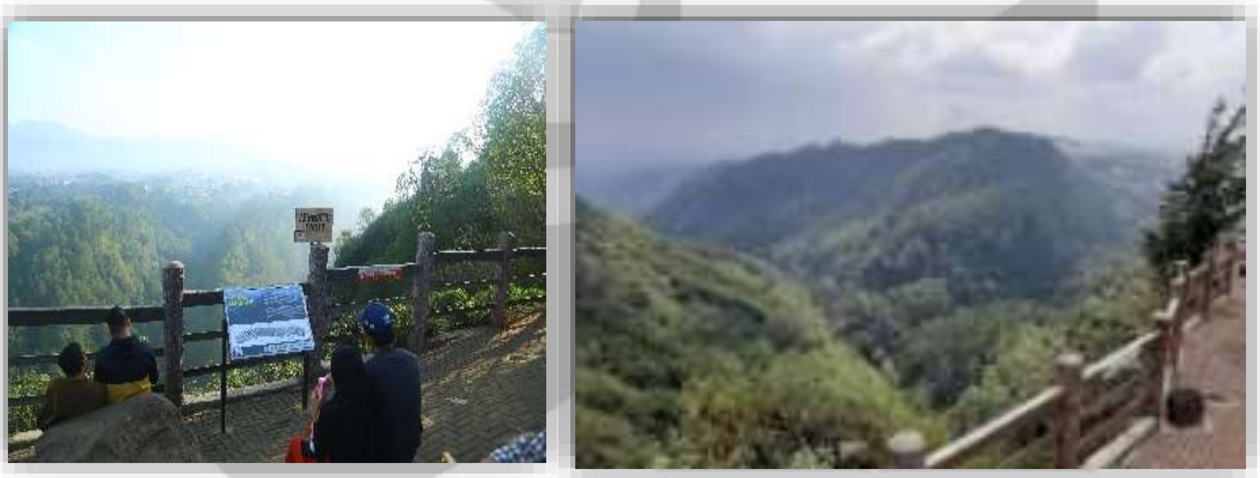

Figure 10. Lembang Fault Scarp at Keraton Cliff (Documentary by IAGI – MAGI, 2020)

Classification

In this study, the geoheritage potential for geotourism in the study area is classified based on several categories including geodiversity (Gray, 2005), Coverage (Brocx and Semeniuk 2007; Predrag and Mirela 2010) and Scale (Brocx and Semeniuk, 2007). Gray (2005) divides geodiversity into 8 elements: rocks, minerals, fossils, landforms, landscapes, soils, processes and other georesources. Geoheritage potential for geotourism can also be classified based on the scope or field such as mineralogical site, petrological site, structural site, stratigraphic site, geomorphological site, speleological site, hydrological / hydrogeological site and others (Brocx and Semeniuk 2007; Predrag and Mirela 2010). The geological feature scale consists of regional scale (covering 100 km x 100 km or more), large scale (covering 10 km x 10 km or more), medium scale (covering 1 km x 1 km or more), small scale (covering 10 – 100 mx 10 – 100 m or more), fine scale (includes 1 m x 1 m or more) and finer scale (covers 1 mm x 1 mm or less). (Brocx and Semeniuk 2007).

Geoheritage potential for geotourism in the research area is dominated by rocks, minerals, geological processes and landform/landscape forms such as fault scarp, grottos, waterfalls and rivers. The site has a size between small - large scale. Table 4 shows the classification of geoheritage potential for geotourism in the study area.

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Table 5 represents a qualitative assessment of the geoheritage potential in the study area based on the general geoheritage value. The quantitative approach used for the need to numerically assess geological sites related to their potential as geoheritage for geotourism, uses the assessment aspect of Kubalikova (2013). The assessment aspect consisted of several values contained such as Scientific and Intrinsic, Education, Economics, Conservation and Additional Value. In this quantitative approach, it also involves calculating the total average of each aspect of the assessment to classify it according to the class of geotourism potential which is divided into 3, namely 0 – 25% = Poor; 26 – 50 % = Fair; and 51 – 100% = Good. Table 6 shows the scores obtained for each site in relation to the values in the Kubalikova (2013) assessment.

Table 4. Classification of Geoheritage Potential For Geotourism in the Study Area

Geological Site	Geodiversity (Gray, 2005)	Scope (Brocx and Semeniuk, 2007; Predrag and Mirela 2010)	Scale (Brocx and Semeniuk, 2007)
Sunda Ignimbrite at Goa Jepang	Rocks, mineral, Geological Process, landform	Gemorphological Site, Petrological Site, Historical-Geological Site	Small – medium Scale
Sunda Ignimbrite at Goa Belanda	Rocks, mineral, Geological Process, landform	Petrological Site, Geomorphological Site, Historical-Geological Site	Small - medium Scale
Lava Tube at Cikapundung River	Rocks, Geological Process	Petrological Site, Historical-Geological Site	Small Scale
Pahoehoe Lava at Cikapundung River	Rocks, Geological Process	Petrological Site, Historical-Geological Site	Small Scale
Ropy Lava at Curug Lalay	Rocks, Landform/Landscape, Geological Process	Petrological Site, Geomorphological Site, Historical-Geological Site	Small Scale
Columnar Joint Lava at Curug Omas	Rocks, Landform/Landscape, Geological Process	Petrological Site, Geomorphological Site, Historical-Geological Site	Medium Scale
Lembang Fault Scarp at Keraton Cliff	Rocks, Landform/Landscape, Geological Process	Petrological Site, Geomorphological Site, Historical-Geological Site	Large scale

Tables 5. Qualitative Assessment of Geoheritage Potential in the Study Area

Geological Site	Scientific Value	Education Value	Economical Value	Conservation Value	Added Value	Level of Significance
Sunda Ignimbrite at Goa Jepang	Sundanese volcanic evolution history, material from process of large explosive eruptions (ignimbrite), not many research has been conducted in the area	High Clarity of Geological Features, easy access to affordable locations, good/high education infrastructure	High economic potential, local generate income by selling foods, and selling merchandise; some locals generate income as local guides easy accessibility from main tourism infrastructures	No destruction of site; potential threat from crowded tourism, managed by TAHURA Djuanda	Geometrically interesting, key evidence of the Sunda eruption, and its relation to the history of the Japanese colonial period	Local
Sunda Ignimbrite at Goa Belanda	Sundanese volcanic evolution history, material from process of large explosive eruptions (ignimbrite), not many research has been conducted in the area	High Clarity of Geological Features, easy access to affordable locations, good/high education infrastructure	High economic potential, local generate income by selling foods, and selling merchandise; some locals generate income as local guides easy accessibility from main tourism infrastructures	No destruction of site; potential threat from crowded tourism, managed by TAHURA Djuanda	Geometrically interesting, key evidence of the Sunda eruption, and its relation to the history of the Dutch colonial period	Local

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Lava Tube at Cikapundung River	The evolution history of the Tangkuban Parahu volcano, the primary rock structure that ilustrate the freezing process, not many research has been conducted in the area	High Clarity of Geological Features, low amount of actual use and infrastructure	High economic potential, site close to Goa Jepang, local generate income by selling foods, and selling merchandise	No destruction of site; Site is undeveloped but managed by TAHURA Djuanda	Geometrically interesting, key evidence of the history of the Tangkuban Parahu eruption, rock structures are rarely found	State
Pahoehoe Lava at Cikapundung River	The evolution history of the Tangkuban Parahu volcano, the primary rock structure that ilustrate the freezing process, not many research has been conducted in the area	High Clarity of Geological Features, easy access to affordable locations, good/high education infrastructure	High economic potential, local generate income by selling foods, and selling merchandise; some locals generate income as local guides; slightly far but easy accessibility from main tourism infrastructures	No destruction of site; potential threat from crowded tourism, managed by TAHURA Djuanda	Geometrically interesting, key evidence of the history of the Tangkuban Parahu eruption, folklore/legend that developed about the Dayang Sumbi's scarf, rock structures are rarely found	State
Ropy Lava at Curug Lalay	The evolution history of the Tangkuban Parahu volcano, the primary structure of the rope lava that ilustrate the freezing process, not many research has been conducted in the area	High Clarity of Geological Features, low amount of actual use and infrastructure	No impact on local community yet; very accessible from tourism infrastructures	No destruction of site; potential landslide risk, managed by TAHURA Djuanda	Geometrically interesting, rock structures are rarely found	Local
Columnar Joint Lava at Curug Omas	The evolution history of the Tangkuban Parahu volcano, the primary structure of the columnar joints that ilustrate the freezing process, not many research has been conducted in the area	High Clarity of Geological Features, easy access to affordable locations, good/high education infrastructure	Local generate income by selling foods, and selling merchandise; some locals generate income as local guides; slightly far but easy accessibility from main tourism infrastructures	No destruction of site; potential threat from crowded tourism, managed by TAHURA Djuanda	Geometrically interesting, suitable as a place of recreation with beautiful scenery and cool air	Local
Lembang Fault Scarp at Keraton Cliff	Evidence of the Lembang fault product, many research has been conducted in this area	High Clarity of Geological Features, easy access to affordable locations, good/high education infrastructure	Local generate income by selling foods, and selling merchandise; some locals generate income as local guides; easy accessibility from main tourism infrastructures	No destruction of site; potential threat from crowded tourism, managed by TAHURA Djuanda	Geometrically interesting, suitable as a place of recreation with beautiful scenery and cool air	Local

Tables 6. Quantitative Assessment of Geoheritage Potential for Geotourism in Study Area

Parameters	**Geosites**						
	Sunda Ignimbrite at Goa Jepang	**Sunda Ignimbrite at Goa Belanda**	**Lava Tube at Cikapundung River**	**Pahoehoe Lava at Cikapundung River**	**Ropy Lava at Curug Lalay**	**Columnar Joint Lava at Curug Omas**	**Lembang Fault Scarp at Keraton Cliff**
Scientific and Intrinsic Value							
Integrity	1	1	1	1	1	1	1
Rarity	0.5	0.5	1	1	1	1	1
Diversity	1	1	1	1	1	1	1
Scientific Knowledge	0.5	0.5	0.5	0.5	0.5	0.5	0.5

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Education Value							
Representativeness	1	1	0.5	1	0.5	0.5	1
Pedagogical Use	1	1	1	1	1	1	1
Existing educational products	1	1	0.5	1	0.5	0.5	1
Actual for educational purposes	1	1	1	1	1	1	1
Economical Value							
Accessibility	1	1	1	1	1	1	1
Presence of Tourist Infrastructure	1	1	0.5	0.5	0.5	0.5	0.5
Local Products	0	0	0	0	0	0	0
Conservation Value							
Actual threats and Risks	1	1	0.5	0.5	0.5	0.5	0.5
Potential threats and risks	1	1	0.5	0.5	0.5	0.5	0.5
Legislative protection	1	1	1	1	1	1	1
Current Status of a Site	1	1	1	1	1	1	1
Added Value							
Cultural Values	0.5	0.5	0	1	0	0	0
Ecological Values	1	1	0	0	0	0	0
Aesthetic Values	0.25	0.25	0.5	0.5	0.25	0.25	0.5
Total Mean (%)	80	80	60.83	72.5	59.16	59.16	64.16

Evaluation

Based on the research, it can be seen that the research area has 7 geological sites with respective feasibility values, including Sunda Ignimbrite at Goa Jepang (80%), Sunda Ignimbrite at Goa Belanda (80%), Lava Tube at Cikapundung River (60.83%), Pahoehoe Lava at Cikapundung River (72.5%), Ropy Lava at Curug Lalay (59.16%), Columnar Joint Lava at Curug Omas (59.16%) and Lembang Fault Scarp at Keraton Cliff (64.16%). (Tables 6). Overall, the research results from these seven areas have a value (> 59%) which indicates that the area has the potential to be used as geotourism. However, developments are needed to support this, including:

1. Development and Renovation of Infrastructures such as street name, information board, public toilet, and evacuation route
2. Promotion development about charms of geological sites in the area
3. Community development, especially about tourism, tourism management, and local product development.

4. CONCLUSIONS

Geological Heritage is a part of nature that need to be conserved and developed. For this reason, a study of the geoheritage system for geotourism has been carried out in the Ir Djuanda Forest Park area, Bandung. Several geological sites in the area, have been invested as potential geoheritage for geotourism, including Sunda Ignimbrite at Goa Jepang, Sunda Ignimbrite at Goa Belanda, Lava Tube at Cikapundung River, Pahoehoe Lava at Cikapundung River, Ropy Lava at Curug Lalay, Columnar Joint Lava at Curug Omas and Lembang Fault Scarp at Keraton Cliff. Details of characterization and classification show that the geo-heritage potential in this area is dominated by rocks, minerals, geological processes and landforms/landscapes such as fault scarps, grottos, waterfalls and rivers. This geological site has a small - large scale. The results of the qualitative analysis indicate that the site has geoheritage values including scientific, education, economical, conservation and added value with a level of significance. The results of quantitative analysis show that these sites support to be used as geotourism with the smallest percentage of 59.16%. However, there are several considerations to support these tourism activities, including the development and improvement of infrastructure, the development of the promotion of geotourism attractions and the development of community knowledge.

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