Inventory and identification of geodiversity to support geotourism in the Lenggoksono bay area of South Malang, Indonesia

A Susilo\(^1\), A T S Haji\(^2\), B Suharto\(^2\), Sunaryo\(^1\), I W Suyadnya\(^3\), C W Pramais\(^2\), and A H Rahman\(^2\)

\(^1\)Department of Geophysical Engineering, Faculty of Mathematics and Natural Sciences, University of Brawijaya Jl. Veteran – Malang 65145, Indonesia
\(^2\)Department of Environmental Engineering, Faculty of Agricultural Technology, University of Brawijaya, Jl. Veteran – Malang 65145, Indonesia
\(^3\)Department of Sociology, Faculty of Social and Political Science, University of Brawijaya Jl. Veteran – Malang 65145, Indonesia

E-mail: adisusilo@ub.ac.id

**Abstract.** Lenggoksono Beach Area which is a geomorphological region in the form of karst mountain located in the south of Malang Regency. This beach has beautiful scenery and presents unique and an interesting geosite conditions to be enjoyed. The purpose of this study is to inventory geodiversity data to fulfill the geotourism criteria and assess geodiversity data in the Lenggoksono Bay Area. The research method used was a survey and data collection method with 5 stages: data collection, criteria, assessment, interpretation, and clustering. The Lenggoksono Bay area has 5 landscapes, 4 beaches, islands, hills, and a river estuary. From the survey results, 6 types of rocks were found. Lenggoksono Bay was formed through the process of lifting the seabed containing limestone and coral reefs and igneous rock deposits over millions of years ago. These processes form the morphology and structure that has developed until present. The Lenggoksono Bay area has high value (4.4), where it contains scientific records, specific geological settings or landscapes. This is very meaningful, as an evidence of important geological events, and has special ecological functions that can be utilized for research, education, understanding of geological processes, and conservation. This area includes areas that comply the criteria to become geotourism.

1. Introduction

Geotourism is a branch of cognitive tourism or adventure tourism that emphasizes geological features, including geological objects (geosites) and recognition of geological processes [1, 2]. Geotourism under the umbrella of ecotourism is tourism linked to the geological character in a place or region that has a principle of sustainability [3, 4]. Thus Geotourism can be used as a concept of development of the South Malang Karst Area or it can be used as a bridge of development without abandoning the principles of sustainability. Lenggoksono Beach Area which is a geomorphological region in the form of mountains which composed of limestone and karst and located in the South of Malang Regency. It has beautiful scenery and presents unique and interesting geosite conditions to be enjoyed. The Lenggoksono Beach area is one of the seven potential geosites to be developed as a tourism...
destination in the Karst area of South Malang. The potential of Geotourism contained in the Lenggoksono Coastal Region can be developed into a Geopark if it can develop in the agricultural, fisheries, cultural or cultural sectors. Development of local products as commercial items that can be obtained by visitors when visiting, which is equipped with experience and knowledge, is very important. With the development of geotourism in the Lenggoksono Coastal Region, Geopark which has several benefits will be obtained both for regional development and economic improvement. To be able to develop the existing Geotourism in Lenggoksono Bay, it is necessary to inventory and identify the existing Geodiversity in the area.

2. Method

2.1. Research Location and Date
The implementation of research was conducted from April 2019 to May 2019. The final project will be carried out at Lenggoksono Beach, Purwodadi, Tirtoyudo, Malang, East Java.

2.2. Research Method
The implementation of this final project uses the method of literature study, survey and data collection approach. The stages of the study are divided into 5 stages:

2.2.1 Data Collection: Data sources in this research are primary and secondary data.

2.2.2 Criteria. The criteria for assessing geodiversity are described as in Table 1:

| No. | Criteria | Score |
|-----|----------|-------|
| 1   | Landscape | (1): mountains (embankment, plateau), (2): hill, (3): plains (beaches and rivers), (4): islands (clusters, single or isolated islands), karst (5): volcano |
| 2   | Rock Domain | Igneous, Sedimentary, Metamorphic |
| 3   | Internal Process | (1): lifting (due to tectonics, plutonism, diapirism, isostatic), (2): compression (accumulated at the tectonic plate boundary), (3): enlargement, (4): rifting (occurs at the tectonic plate boundary), (5): volcanism (eruption, volcanic material flow) |
| 4   | External Process | (1): weathering, (2): sedimentation (on slopes, rivers, lakes, swamps, beaches, sea), (3): rock / land mass movement (fall, landslide, creep), (4): objects falling from space / extra-terrestrial (meteorites, tectites), (5): tectonic can be still active (unstable) or no longer active (stable) |
| 5   | Temporary Evolution | |
| 5.1 | Geological age | (1): Precambrian, (2): Paleozoic, (3): Mesozoic, (4): Tertiary, (5): Quaternary |
| 5.2 | Degree of evolution | (1): Very old, (2): Old, (3): Middle, (4): Young, (5): Very Young |
| 5.3 | Evolution type | (1): Very static, (2): Static, (3): Middle, (4): Active, (5): Very active |

2.2.2 Interpretation: Interpretation aims to determine the meaning of Geodiversity from several aspects [5]:
1. Geodiversity is scientific, if it is a record and evidence of the evolution of the earth
2. Geodiversity means aesthetics, if it has a uniqueness and natural beauty
3. Geodiversity means recreation, if it has the potential to support tourism
4. Geodiversity means culture, if it has historical and cultural aspects

2.2.3 Clustering
Clustering aims to establish the function of Geodiversity. There are 4 clusters in geodiversity [5]:
1. As an artifact of earth's history, where geological diversity has the ability to explain the history of the earth, whose information can be used as a basis for geological resource management activities, including predictions of upcoming geological events
2. As a key record of a geological event, where geological diversity has the ability to provide information about the origin and development of various components forming geological diversity, so it can be concluded if geological diversity is scarce.

3. As a special landscape, which based on its aesthetic value can be determined if the geological diversity is unique.

4. As a supporter of ecology, where geological diversity has an influence on biological life and diversity so that the close relationship between geology and biology can be determined.

2.2.4 Assessment: Assessment aims to determine the value of Geodiversity according to its benefits. Rating is divided into 4 values [5]:

1. Geodiversity is of low value, if it only contains scientific records that can be utilized for the development of earth science and research.

2. Geodiversity is of medium value, if it contains important scientific records which can be utilized for research and education.

3. High value geodiversity, if it contains scientific records, geological order or specific landscape, is meaningful as evidence of important geological events, and has special ecological functions that can be utilized for research, education, understanding of nature, and conservation.

4. Geodiversity is of high value, if it contains: a scientific record, a specific geological order or landscape, meaningful as evidence of important geological events, and has more or more prominent ecological functions that can be utilized for research, education, understanding of nature and culture, conservation, and sustainable tourism that can trigger growth in the value of local and national economies.

3. Results and Discussion

3.1. Landscape Criteria

Landscape criteria are geotourism criteria of a location consisting of mountains, hills, plains, islands and volcanoes.

Figure 1. Lenggoksono Bay Topographic Map
According to the data on the Topographic Map (Figure 1) in the Lenggoksono Bay area there are mountains shown on the map namely Cengger and Butak Mountain on the west side of Lenggoksono Beach. For the hilly criteria, it can be seen on the map, the contour shape shows that there are hills in the Lenggoksono Bay Area. One of the hills located between Wedi Awu Beach and Lenggoksono Beach is Bukit Tumpak Wi. There are 2 small islands in the south, i.e. Simun and Kalong Island. In the volcanic landscape criteria, according to the Purwodadi Village Geotourism Map [6], there is a geomorphological type of the Mandalika Formation formed from andesite, basalt, trachs, and andesite breccias as a result of magmatic activity taking place from the age of Eocene to recent of ~45 Ma [7]. There are 4 beaches at Lenggoksono Bay:

3.1.1 Lenggoksono Beach
This beach is included in the Mandalika formation. Lenggoksono Beach Tourism can be used to do activities such as swimming, surfing and snorkeling. Lenggoksono Beach has a beautiful beach length of ± 60 meters surrounded by high cliffs and lush and green trees (Figure 2).

3.1.2 Wedi Awu Beach
Known as one of the good surfing spots in Malang Regency. When entering the dry season or when the full moon the waves at Wedi Awu Beach are quite good and the height can reach 3 meters. For beginner surfers, they can surf at Lenggoksono Beach because the bottom of the beach is sand, so it is relatively safer compared to Wedi Awu Beach which has a rock (Figure 3).

3.1.3 Bolu-Bolu Beach
Bolu-Bolu Beach has white sand and clear sea water. Bolu-Bolu Beach is also a sunrise attraction. Visitors can also enjoy snorkeling tours underwater beauty of Bolu-Bolu Beach. There have been many tourists who admire going to this beach; local and overseas tourists. Generally, foreign tourists also tour camping here to see the sunrise (Figure 4).

3.1.4 Banyu Anjlok Beach
Banyu Anjlok Beach is a freshwater pool above the beach which can be seen in Figure 6.
3.1.4 Banyu Anjlok Beach
Basin-shaped like a bay that is actually part of a cluster of beaches from a larger bay. Banyu Anjlok Beach has a beach with calm waves so it is safe as a swimming destination on Banyu Anjlok Beach. The main destination of this beach is a waterfront beach facing the sea (Figure 5). Above the waterfall, there is also a freshwater pool. This freshwater pool can also be used as a tourist destination for swimming and diving (Figure 6).

So, from the above data it can be concluded that the landscape criteria, get a score of 5.

3.2 Rock Domain Criteria
Rocks found in the hills, valleys and beaches of Lenggoksono Bay are listed as in Figure 7.

![Rock Types](image)

**Figure 7.** Identification of Lenggoksono Bay’s Rock

3.3 Internal and External Process Criteria
Internal processes are shown by the existence of plate activity that has influenced the shape of the island of Java since the Mesozoic age to Cenozoic (~65 Ma). The basement in East Java is part of the crust originating from Western Australia or Gondwana who joined the Sundaland at the end of the Cretaceous [7]. The next tectonic phase is subduction which results in a magmatic arc from Eocene to the present [7, 8, 9]. Mandalika formation in south of Malang are the result of Miocene magmatic arcs [10]. The Mandalika formation also intruded by diorite, dacite, andesite, and basalt units. The Mandalika tuff formation is deposited unconformably. It was also deposited breccia and lava whose expanse was quite extensive [10].

External processes that occur are shown by the emergence of a phase of transgression that causes sediment associated with deltaic environment, characterized by the formation of Nampol. After the formation of the Nampol, Wonosari formation was also deposited associated with limestone [10]. This limestone can be a clue that the southern part of Malang is a shallow or neritic marine environment in Miocene [11, 12]. After that, erosion took place forming a morphology and structure that has developed to present research area. In addition, the alluvium formation was cut off by the presence of a dendritic river [10]. From the above inventory, in this criterion, 4 criteria are met, and the score is 4.

3.4 Temporary Evolution Criteria
The Lenggoksono Bay Area is composed of the Mandalika Formation [10]. The andesite lava consists of andesite pyroxene, andesite hornblende, which in some places undergoes hydrothermal alteration in the form of kaolin. Basalt lava generally consists of amygdaloidal basaltic pyroxene whose cavities are filled with secondary minerals of calcite and zeolite. Dacite lava is found in many mineral-pyrite as well as tantrums of iron oxide. Andesite breccias have andesite fragments with scoria. The formation in the study area can be drawn from the age of the Late Oligocene Mandalika Formation to the beginning of the Middle Miocene [10].

Based on the criteria determined in the description above, the geodiversity status of the Lenggoksono Bay Tourism Area can be determined as shown in Table 2.
Table 2. Results of determining the status of the Geodiversity of the Lenggoksono Bay Tourism Area for each criterion

| No. | Criteria          | Assessment | Status     |
|-----|------------------|------------|------------|
| 1.  | Landscape        | v v v v v  | leading    |
| 2.  | Rocks Domain     | v v v v v  | leading    |
| 3.  | Internal Process | v v v v v  | very high  |
| 4.  | External Process | v v v v v  | very high  |
| 5.  | Temporary Evolution | v v v v v | very high  |

Based on the geodiversity status (Table 3), the Geodiversity Status of the Lenggoksono Bay Region gets a value (5+5+4+4+4)/5=4.4. Thus, the Lenggoksono Bay Area has High Value status.

4. Conclusion
Based on the research results above, The Lenggoksono Bay area has a high value where it contains scientific records, specific geological settings or landscapes, is meaningful as evidence of important geological events, and has special ecological functions that can be utilized for research, education, understanding of nature, and conservation. This area includes areas that have met the criteria to become geotourism because they have 5 geological destinations that have the potential to become geotourism and can be further developed after this research.

References
[1] Słomka T, and Kicińska-Świderska A 2004 Geotourism - Basic Concepts Geotourism 1 (1): 5-7
[2] Dowling R and Newsome D 2018 Geotourism: Definition, characteristics and international perspectives. Handbook of geotourism (Cheltenham: Edward Elgar Publishers)
[3] Farsani N T, Coelho C, and Costa C 2012 Geoparks and geotourism: New approaches to sustainability for the 21st century Universal-Publishers
[4] Štrba I, Kršák B, and Sidor C 2018 Some comments to geosite assessment, visitors, and geotourism sustainability Sustainability 10 (8) 2589
[5] Samodra H 2016 Pemahaman Dan Korelasi Antara Geodiveristy-Geoheritage dan Cagar Alam Geologi Jakarta: Kementerian Energi dan Sumberdaya Mineral
[6] Susilo A 2017 Peta Geowisata Teluk Lenggoksono Pusat Studi Kebumian dan Mitigasi Bencana (Malang: Universitas Brawijaya)
[7] Smyth R I 2007 The Deep Crush Beneath Island Arcs: Inherited Zircons reveal a Gondwana continental fragment beneath East Java, Indonesia Earth and Planetary Science Letters 258 pp.269-82
[8] Soeria-Atmadja R, Maury R C, Bellon H, Pringgoprawiro H, Polve M, and Priadi B 1994 Tertiary magmatic belts in Java Journal of southeast asian earth sci. 9 (1-2) pp.13-27
[9] Smyth H R, Hall R, and Nichols G J 2008 Cenozoic volcanic arc history of East Java, Indonesia: The stratigraphic record of eruptions on an active continental margin. Special Papers-Geological Society of America, 436, 199
[10] Sujianto 1992 Peta Geologi Lembar Turen (Bandung: Pusat Penelitian dan Pengembangan Geologi)
[11] Hall R, Clements B, Smyth H R, and Cottam M A 2007 A new interpretation of Java’s structure
[12] Satyana A H and Purwaningsih M E 2003 Oligo-Miocene carbonates of Java: tectonic setting and effects of volcanism Proc. of Joint Convention Jakarta pp. 1-27