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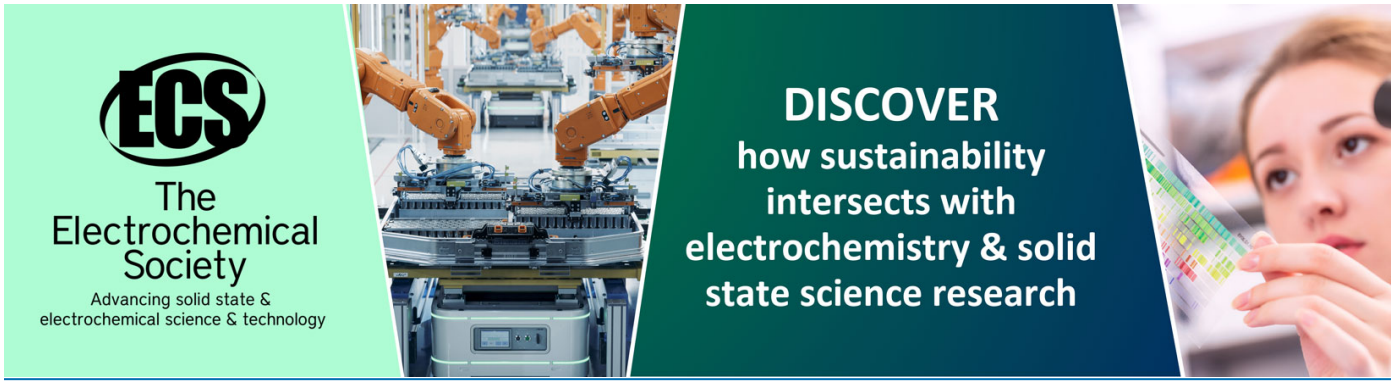

Assessment of the values of science, education, tourism and the risk degradation of Pentadio geothermal areas to developing geotourism in the Limboto Lake Plain, Gorontalo

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Abstract. Geothermal areas are unique. Therefore, it can be developed to become a geotourism destination. Limboto Lake plain has geothermal potential which is indicated by the appearance of several points of manifestation. This study aims to assess the value of science, education, tourism and the risk of degradation in the geothermal area of the Limboto Lake plain unit. The method used is the assessment of the value of science, education, tourism and the risk degradation issued by the Geological Agency. The assessment was carried out in two geothermal areas located on the plain of Lake Limboto, namely Geothermal Pentadio. The research results showed that the weighting of the criteria for the values of science, education, tourism and the risk degradation in the Pentadio geothermal area were 73.75%, 73.75%, 75%, 65%, respectively.

1. Introduction

Geotourism is a form of nature tourism that particularly focuses on both landforms and geology [1–3]. Geology is an important aspect of the tourism development of an area. One of the factors in natural tourism locations is very much controlled by the geological setting in the area. The natural beauty of an area cannot be separated from the existing geological elements in terms of beauty, constituent materials, and the process of its formation.

Based on the Kotamobagu Regional Geologic Map by Apandi & Bachri [4], the research area consists of four rock formations, namely Limestone (Ql), Lake Sediment (Qpl), Bilungala Volcanic rock Formation (Tmbv), and Bone Diorite (Tmb) (Fig 1). The regional geological structure that occurs in the study area is northwest-southeast. The regional geological structure is interpreted to cross the Lake Deposits (Qpl). Geological events that occur in Indonesia [5–11], specifically the North-Arm of Sulawesi have implications for the potential of energy and mineral resources, one of which is the source of geothermal resources. The research area is the western segment of the Gorontalo fault zone and has a geothermal potential that is interesting to visit (see figure 1).

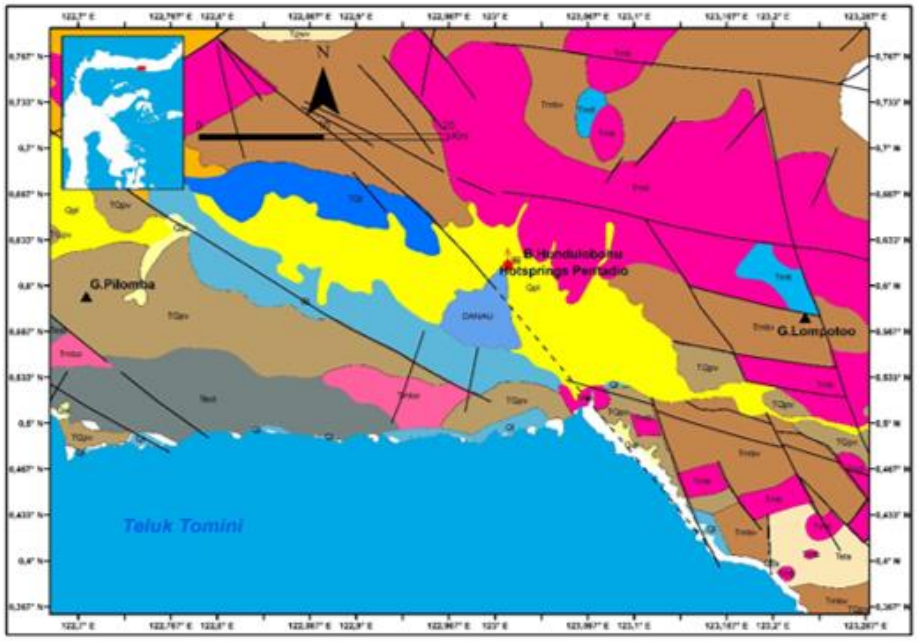

Figure 1. Regional geology of research area.

Gorontalo has the potential for geothermal resources [12]. Previous research which has been done in the Pentadio geothermal area includes geological, geochemical and geophysical research [13]. Previous studies in the research area have not discussed about geotourism. Based on the description above, it is necessary to conduct a review or an assessment of the geological features in the study area. Previous studies in the research area have not discussed geotourism and detailed geotourism assessments [14]. This study aims to assess the value of science, education, tourism and the risk degradation in the geothermal area of the Limboto Lake.

2. Methods

The assessment method uses the Geological Survey Center method [15]. The assessment method is carried out on the Pentadio's geothermal geosite. The Pentadio geothermal geosite has five manifestations located on the Limboto Lake. Before conducting the assessment, geological observations are made of the geological features in the field. The assessment is based on four aspects of assessment, namely aspects of scientific value, educational value, tourism value and potential degradation value. Each scoring point has a value that is converted into a percentage which is added up to classify geosites scientifically.

Science scores include location criteria representing geological framework (30%), key research locations (20%), scientific understanding (5%), current geological site conditions (15%), geological diversity (5%), presences of geological heritage sites (15 %), barriers to use of location (10%). Educational values include the criteria for vulnerability (10%), location attainment (10%), barriers to location utilization (5%), security facilities (10%), supporting facilities (5%), population density (5%), relationships with other values. (5%), location status (5%), specificity (5%), observation conditions for geological elements (10%), potential for educational / research information (20%), geological diversity (10%).

The tourism value includes the criteria of vulnerability (10%), location attainment (10%), barriers to location utilization (5%), security facilities (10%), supporting facilities (5%), population density (5%), relationships with other values. (5%), location status (15%), peculiarities (10%), conditions on the observation of geological elements (5%), interpretive potential (10%), economic level (5%), proximity to recreation areas (5%). The value of the risk of degradation includes parameters of damage to

geological elements (35%), adjacent areas/activities that have the potential for degradation (20%), legal protection (20%), accessibility (15%), and population density (10%).

Based on the final result of the summation of the quantitative assessment of the value of science, education value, tourism value, and degradation risk value, it can be categorized into 3 (three) category classes. The three-class categories are the low scientific value category (grades <200), the medium scientific value category (grades 201 - 300), and the good scientific value category (grades 301 - 400).

3. Results and discussion

Pentadio Geothermal is a geosite located on the plain of Lake Limboto. The Pentadio geothermal is located at coordinates 0.6139 - 0.6180 N and 123.0048 - 123.0096 E. Administratively it is located in Pentadio Barat Village, Telaga Biru District, Gorontalo Regency.

Pentadio geothermal manifestation type is hotspring (Fig 2a). There are 5 (five) hot springs at Pentadio. Surface temperature ranges from 62.1 to 80 °C while the subsurface temperature is based on geothermometer calculations by the Geological Survey Center [15] ranges from 122° to 153 °C. All hot springs have a pH of 6, are colorless and tasteless. Some hot springs have no smell, some smell of sulfur.

Pentadio geothermal is located in fluvial landforms with lake plain landforms. Lake plains are formed from the deposition of sedimentary material as the area of a lake decreases. Limboto Lake is having a degradation and leaves a large plain around the lake.

The lake plain is at an elevation of 7 - 27 masl. The materials for the lake plain are alluvial deposits in the form of clay, sand and gravel (Fig 2b). Land use on the lake plain unit is a settlement, a place to build public facilities, agricultural and fishery activities, and tourism. The lake plains are located in the center part of Gorontalo Province, stretching from east to west of Gorontalo. To the north of the lake plain there are volcanic mountains. To the south of the lake plain there are volcanic hills (see figure 2).

Figure 2. a) Pentadio hotspring; b) Lake plain.

The volcanic mountains is at an elevation of 474 - 1430 masl (Fig 3). The material that makes up volcanic mountains is volcanic and plutonic rocks. Volcanic rock is a product of Bilungala Volcanic Rocks (Tmbv) which was formed during the Miocene and is composed of breccias, tuffs, andesite lava and rhyolite. Plutonic rock is a product of Diorite Bone (Tmb) which was formed during the Miocene and is composed of quartz diorite, diorite, granodiorite and granite (see figure 3).

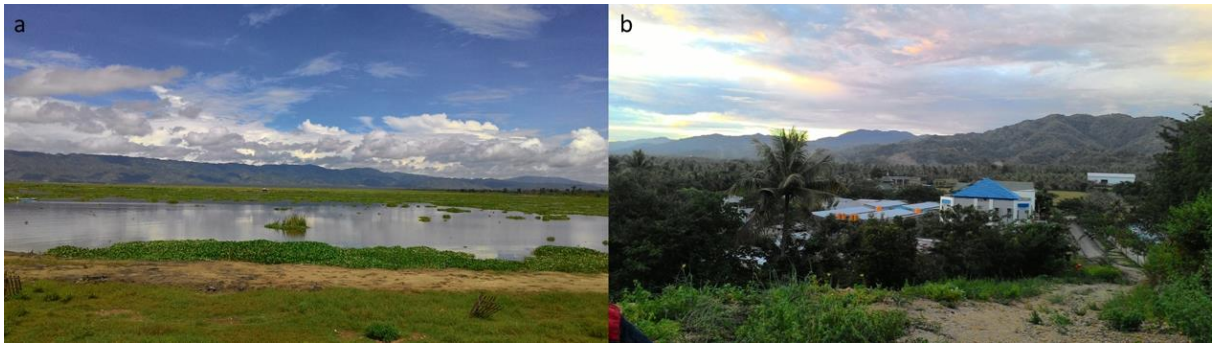

Figure 3. a) The northern volcanic mountains; b) The southern volcanic mountains.

In the northern segment of the Pentadio geothermal manifestation, there are isolated hill forms. An isolated hill known as Hundulobohu Hill is composed of tuff lithology, limestone and non-compact materials such as clay (Fig 4). The highest elevation of Hundulobohu Hill is 24 masl with land use in the form of settlements and construction of educational facilities (see figure 4).

Figure 4. a) tuff lithology on Hundulobohu Hill; b) Limestone in Hundulobohu Hill.

Pentadio geothermal fluid appears to the surface in the form of hot springs through geological structures that form fractures in the Gorontalo graben zone [15]. This geological structure provides a path for the geothermal fluid from the reservoir to the surface. Based on the Geothermal Directorate's research [15], the heat source of the Pentadio geothermal area is the dyke system. The dyke system was formed due to young volcanic activity that produced Pilomba and Lompotoo Volcanoes around Gorontalo.

The factors used in conducting quantitative scientific values assessment include location that represents a geological framework, the main research location, scientific understanding, geosite/site conditions, geodiversity, the existence of a geological heritage site in an area, and location usage problems.

The percentage for various criteria or standards used for the assessment of a geological heritage site based on scientific values on the Pentadio's geothermal geosite reach a weight of 73.75%. The location criteria that represent a geological framework are 30%, The main research location is 5%, Scientific understanding 2.5%, Geosite / site conditions 11.25%, Geodiversity 2.5%, The existence of a geological heritage site in an area 15%, and location usage problems 7.5%.

The factors used in assessing the value of education include vulnerability, location reach, site utilization problems, security facility, supporting facilities, population density, relationship with other values, location status, peculiarity (unique), conditions in the geological element observation, potential of educational / research information, and geodiversity.

Weights for the various criteria or standards used for the assessment of a geological heritage site based on educational values on the Pentadio's geothermal geosite are 73.75%. The criteria for vulnerability are 7.5%, location reach is 10%, site utilization problems are 2.5%, security facilities are

10%, supporting facilities are 5% and population density is 2.5%. The relationship with other values is 5%, the location status is 2.5%, the peculiarity (unique) is 3.75%, the conditions in the geological element observation are 7.5%, the potential for educational / research information is 10% and the geological diversity is 7.5%.

The factors used in conducting a quantitative assessment of tourism values include the vulnerability of a geological heritage site, location reach, Site utilization problems, security facilities, supporting facilities, population density, relations with other elements, location status, peculiarities, conditions in the observation of geological elements, interpretive potential, economic level and near to recreation areas.

Weights for the various criteria or standards used for the assessment of a geological heritage site based on tourism values in the Pentadio's geothermal geosite reach a weight of 75%. Vulnerability criteria are 7.5%, location reach is 10%, site utilization problems are 2.5%, security facilities are 10%, supporting facilities are 5% and population density is 2.5%. The relationship with other values is 5%, the location status is 2.5%, the Peculiarity is 3.75%, the conditions on the observation of geological elements are 7.5%, the interpretive potential is 7.5%, the economic level is 1.25% and the weight close to the recreation area is 5%.

The factors used in the quantitative assessment of the risk of degradation include damage to geological elements, adjacent areas/activities that have a probability to cause degradation, legal protection, accessibility and population density.

The weights for various criteria used for the assessment of a geological heritage site based on the values of the risk of degradation in the Pentadio's geothermal geosite reach a weight of 65%. The criteria for damage to geological elements are 17.5%, adjacent to areas/activities that have a probability to cause degradation by 20%, legal protection 5%, accessibility 15%, and population density with a weight of 7.5%. The Pentadio geothermal area is in the graben zone and the Gorontalo fault zone which are prone to disasters.

Table 1. Assessment criteria.

No.	Assessment Criteria	Geosite Geothermal Pentadio (%)
1	Scientific	73.75
2	Education	73.75
3	Tourism	75
4	Risk Degradation	65
	Total	287.5
	Assessment	Moderate

Assessment criteria for Pentadio's geothermal geosite in scientific values, education, tourism, and risk degradation show a moderate level (Table 1). The weight of the scientific value is 73.75%, education 73.75%, tourism 75 and risk degradation 65.

4. Conclusions

An assessment of the values of science, education, tourism and the risk degradation of Pentadio geothermal areas has been carried out. The highest score is on tourism, scientific and educational assessments because the Pentadio area has been managed as a tourist location. Pentadio geothermal area is already a potential site from a geological perspective and can be used for education/research. The lowest value is the risk of degradation because the Pentadio geothermal area is prone to disasters but has good accessibility.

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