Assessment of Limestone Caves in Dabong, Kelantan using Systematic Studies for Potential Geoheritage Sites

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Abstract. The systematic studies for potential geoheritage sites have been conducted in Dabong area which focus at Pagar Cave, Gelap Cave and Keris Cave. Five approaches of systematic studies phases which are inventory, characterisation, classification, assessment and evaluation had been implemented to evaluate these three caves for potential geoheritage site. Based on overall systematic studies, there are five values of geoheritage observed in these three caves, which are scientific, educational, aesthetic, recreational and economic values. The level of significance is only local where these natural features are only important for the local community only. The quantitative assessment shows that the rank is about right to be as potential area for geoheritage sites.

1. Introduction
In recent years, geoheritage has gain recognition around the world as an essential part of the history of the abiotic world. Geoheritage is described as the selection of abiotic element which has significant values in geological conservation. The assessment of geological conservation of a geological features geological site depends on several geological potential values such as scientific, aesthetic, educational, economical and functional value. These geological and geomorphological features made our earth more exciting and can become an attraction of an area, a district, a state or a country.

For the benefit of all humankind and future generations, there are alternative concepts of conservation such as Geopark Concept Of the United Nations Educational, Scientific And Cultural Organization (UNESCO). The concepts can be used in order to protect our precious earth heritage without disturbing the local communities for their socio-economic benefits and promoting the geoheritage resources for tourism, research and education. Hence, this smart concept showed that conservation could increase their living standards. In Malaysia, the recent launch of Langkawi Geopark can be seen as a giant leap forward to sustain the sustainability development of geoheritage in Malaysia. On 1st June 2017, Langkawi Geopark was nominated as the 52nd member of Global Geopark Network (GGN) supported by UNESCO. The place was declared as geopark because of its geodiversity of the rock succession, mineral, structural geology, fossils evidence, landscape, history of the earth processes. For example of finding are ancient fossils preserved in sedimentary rock of Langkawi provides crucial information for the geologist to interpret the rock of Machinchang range as the oldest formation in Malaysia [1].

Geotourism is defined as tourism that sustains or enhances the distinctive geographical character of a place—its environment, heritage, aesthetics, culture, and the well-being of its residents [2]. The
geosite was introduced in Malaysia as any geological site with the feature or landform which contains a significant geodiversity component that indicates high geodiversity value [3].

There are 22 geological heritage sites with high-value landscape, 19 of them are potential geosites with landscape diversity and another three are potential geosites with geological diversity identified in Kelantan state [4]. Dabong area was not included but with several geoheritage aspects that we found, the Dabong area has the potential to classify as one of the potential geoheritage sites in Kelantan state. This study presents the systematic studies for potential geoheritage resources of the Dabong area which need to be conserved and developed. Based on [1], there were some phases that needed to study be evaluated includes inventory, characterization, classification, assessment as well as evaluation.

2. Study Area
Dabong is a sub-district of Kuala Krai which is located at the south part of Kuala Krai District, Kelantan, Malaysia. The district is mainly of hilly land and was a tropical rain forest before the 20th century. Kuala Krai District has an area of 2329 km² and comprises three sub-district including Manek Urai, Kuala Krai town and Dabong.

Dabong is about 155 km away from Kota Bahru, the capital of Kelantan. Pagar Cave, Gelap Cave and Keris Cave are located at Dabong near to the Gua Ikan which is a cave complex of 5 km south of Dabong (Figure 1). Other than that, it is near the Gunung Stong State Park, Dabong which is 9 km away from those three caves. The distance between those three caves is less than 0.5 km. The river that flow through Dabong is named after Sungai Galas. Sungai Galas is one of the tributaries of Sungai Kelantan, which is the main river of Kelantan state.

![Figure 1. Location of study area in Dabong, Kelantan (the yellow circle) (adapted from [5])](image-url)
3. General Geology of Dabong
Kelantan state is located between longitude from 101°20’ to 102°41’ E and latitude from 04°33’ to 06°14’ N. It borders with Thailand and share some similar geological setting with Thailand. Kelantan are consisting of ten districts namely Tumpat, Kota Bahru, Pasir Mas, Bachok, Tanah Merah, Machang, Pasir Puteh, Jeli, Kuala Krai, and Gua Musang which made a total of 15,022 km² area of land.

Dabong is a town that located at the southern part of the Kelantan state. Dabong is a part of Gua Musang Group which consisted of Permian to Triassic rocks.

The Gua Musang Group is the newly proposed of stratigraphic unit in central belt of Peninsular Malaysia [6]. Under this group, it was reported that the formation consisted predominantly of calcareous and argillaceous rocks together with the subordinates of arenite, pyroclastic and lava flow [7]. Koh Formation overlies the upper boundary of Gua Musang Formation, however the lower boundary still remains unknown. Gua Musang Group is further divided into two formations, which are the Gua Musang Formation and Gunung Rabong Formation.

4. Methodology
The methods for this study is following the systematic studies of potential geoheritage sites [4] which are inventory, characterisation, classification, assessment and evaluation. Inventory is the identification of the potential geoheritage sites in the study area. The inventory was done based on the previous literature review, and fieldwork in the area.

On the other hand, characterisation was done on the study area by observing and evaluating the site in detail. The characterisation and inventory are synchronised together as the inventory is for identifying and characterisation is more into portraying the sites that had been identified based on the geological features that exist.

The next phase is classification, which is focus on the geodiversity’s scope, as well as the size of the site. In classification, the geodiversity features had been classified based into several categories in geology which then reflect the subdisciplines (process and product-oriented) of Geology and can be considered as the scope of geoheritage inventory and assessment [8].

In the assessment, two methods were implemented which are a qualitative and a quantitative method. The qualitative method was conducted to determine the geodiversity values (scientific and educational, aesthetic, recreational and economical values) and the level of its significance ranking (local/ regional/ state-wide/ national/ international) [8]. For the quantitative method, the usage of numerical assessment evaluation (valuing) to rank the geological features [9] which the number reflected accordingly: 0 = none; 1 = very bad; 2 = bad; 3 = fair; 4 = good; and 5 =very good ) [4]. We proposed the total values of 0-7 represent much too low, 8-14 represent a little too low, 15-21 represent about right, 22-28 represent a little too high and 29-35 represent much too high. These values show the ranking of potential area to be a geoheritage site.

The last phase was the evaluation. The potential value of geoheritage in Pagar Cave, Gelap Cave and Keris Cave were evaluate using SWOT analysis that comprises the strength, weakness, opportunities and threats towards geoheritage conservation and development in Dabong area. By doing the evaluation, the type of geoheritage conservation can be evaluate.

5. Results and Discussion

5.1 Inventory
The inventory of potential geoheritage resources in the study area includes the identification and field observation at the Pagar Cave, Gelap Cave and Keris Cave were identified as shown in Figure 2. Some criteria that cover the geoheritage aspect were selected to identify the potential geoheritage sites in study area. The Pagar Cave, Gelap Cave and Keris Cave were chosen based on rarity, unique occurrence, and specialty at Dabong.
Pagar Cave, Gelap Cave and Keris Cave is located near to each other. It is approximately 95 km from the Kuala Krai Town and 7 km from Dabong Town. It is near to Gua Ikan, which is about 5 km south of Dabong. The accessibility is only through the Jalan Sungai Sam-Dabong. In these three caves, the uniqueness of million years old artitic limestone can be identify.

Figure 2. The inventory mapping of location for Pagar Cave, Gelap Cave and Keris Cave. All these three caves are located at Dabong, Kelantan, and it is a part of Ikan Cave Complex.

5.2 Characterisation
The characterisation was done in the study area by supported information from the literature review of the geoheritage potential and relatable to study area. These three caves were described based on their locations, main geological features and other features. The characterisation was done to observe the available geological features in selected sites based on selection during the inventory. The characterisation of the study area was shown in Table 1.

Table 1. List of potential geoheritage resources in Dabong, Kelantan, Malaysia.

| No | Geological site | Location | Main Geological features | Other features |
|----|-----------------|----------|--------------------------|----------------|
| 1  | Pagar Cave      | Dabong, Kuala Krai (5°21’14.7"N, 102°01’40.7"E) | Cave complex with beautiful cave morphology | Column, stalagmate, flowstone, plant fossil, monkey face structure, sinkhole |
| 2  | Gelap Cave      | Dabong, Kuala Krai (5°21’21.3"N, 102°01’43.2"E) | Cave morphology | Column |
| 3  | Keris Cave      | Dabong, Kuala Krai (5°21’19.7"N, 102°01’44.4"E) | Cave complex with beautiful cave morphology | Column of calcite mineral, notch, keris like structure, window, flowstone |

5.2.1 Pagar Cave
Pagar Cave is located at coordinate 5°21’14.7"N, 102°01’40.7"E. The entrance to Gua Pagar is so tight that visitors have to crawl through a small opening. The estimate terrain elevation above sea level is 47 metres. This cave composed of limestone. Pagar cave about 100-200m in height and the length inside the cave is about 200m. There are typical speleothem features such as stalactites, stalagmites and
The exciting features in most of the caves are flowstone. This feature formed in a thin layer which at first, it only takes on the shape of the underlying floor or wall bedrock but over time, it tends to become rounded as it gets thicker. Flowstone can be variation colour due to calcite composition. However, the flowstone in Pagar Cave is white colour. Flowstone build from actively flowing water which rather than water squeezed through cracks in which carbon dioxide is lost and carbonate material is deposited.

Some unique and imaginative geological features (mimetoliths) is a monkey face structure at the side of the Pagar cave entrance. In theory, the area is exposed to the surface because of the tectonic uplift. Then the solution process occurred mainly because of rain water seeping into the main fractures which dissolving the limestone and widening the fractures. This occurs rainwater is slightly acidic where it is already dissolved with some carbon dioxide (CO₂) in the atmosphere. The result, the weak carbonic acid (H₂CO₃) reacts with the limestone (CaCO₃) to produce soluble calcium bicarbonate (CaHCO₃), a solution process might relate to other chemical reactions [10].

5.2.2 Gelap Cave
Gelap Cave is located at the 5°21'21.3"N 102°01'43.2"E. Gelap Cave is literally means “dark” which in Malay language it is reflected the darkness inside the cave. The inside of Gelap Cave was very dark and comparatively smaller than the other two caves. The only accessible path is through the small opening in the cave which required a person to crawl. This path is only about 20 cm tall, however it was possible to pass this way for any human size. This cave has a small stream that might accumulate from dissolved limestone and river from outside the cave.

5.2.3 Keris Cave
Keris Cave (Figure 4) is located at the coordinate 5°21'19.7"N 102°01'44.4"E and it is one of the Ikan Cave Complex. The special feature of Keris Cave was shown by the Karst landform affected by medium chemical weathering (rock contact with atmosphere- weathering effectively). This process occurred when water continually seeps into cracks and expands, eventually breaking the rocks apart. When the rain water reacting with the mineral grains in rocks to form soluble salts. Hydrolysis, mainly when the water is slightly acidic.
Figure 3. Erosion processes resulting: a) shows white flowstone, b) Monkey like structure morphology (red circle), c) Stalactite features (red circle), and d) Notch that shows few layers of pre river level (red circle).

Figure 4. The Keris Cave; a) The column that resemble a Keris shape where the cave gets its name, b) The flowstone that resemble like an elephant and c) The column that formed from the erosion of stalagtite and stalacmite.

The structure that had been found in this area is Stalactites, stalagmites, dripstone, flowstone, joint, sinkhole, column and windows (with a texture crystalline of calcite). The caves are home to bats, so the guano can be seen scattered throughout the cave. There is a nearby, smaller, and isolated calcareous hill with the morphology of the cave, as shown in Figure 4.

5.3 Classification
In this study, Ikan Cave Complex's potential geo-heritage resource is based on specific categories of geodiversity, scope, and scale [1]. Geodiversity is divided into eight categories; rock, mineral, fossil, land, landscape, process, soil, and other geo-resources elements. Geoheritage also can be classified as mineralogical sites, petrological sites, natural sites, stratigraphic sites, geomorphological sites, speleological, and hydrological/ hydrogeological sites.[8][11]. The scale of geological features consists of a regional scale (coverage of 100 km x 100 km or larger. Large-scale (coverage of 10 km x 10 km or larger), medium-scale (coverage of 1 km x 1 km or larger), small scale (coverage of 10 – 100 m x 10 – 100 m or larger), fine-scale (coverage of 1 m x 1 m or smaller) and very fine (coverage of 1 mm x 1 mm or smaller) [8]. These three caves were classified to be in the small scales ranking and the scope were basically as petrological site due to the composition of limestone, geomorphological site based on the different landforms occurred there, speleological site- referring to the karst formation in the limestone. Table 2 illustrates the classification of potential geo-heritage resources in the Ikan Cave Complex based on their geodiversity, scope and scale.
Table 2. Classification of potential geoheritage resources in Dabong, Kelantan, Malaysia.

| No | Geological site | Geodiversity          | Scope                                             | Scale |
|----|-----------------|-----------------------|---------------------------------------------------|-------|
| 1  | Pagar Cave      | Rock, landform/landscape, process | Petrological site, geomorphological site, speleological site | Small |
| 2  | Gelap Cave      | Rock, landform/landscape, process | Petrological site, geomorphological site, speleological site | Small |
| 3  | Keris Cave      | Rock, landform/landscape, process | Petrological site, geomorphological site, speleological site | Small |

5.4 Assessment

The assessment method is divided into two approaches; qualitative and quantitative. The qualitative approach focused on certain values of geodiversity and geoheritage, mainly scientific (important for geological records and the history of Earth) and educational (training and educating professional geoscientists, university students, schools, and the general public) and any additional values such as aesthetic (features that are beautiful or unusual), recreational (suitable for various recreational activities of nature), cultural (historical and archeological values associated with beliefs), economic (financial value of resources by nature) and functional (resource use) [12][13][14]. Furthermore, the ranking of geo-heritage resources such as international, national, state-wide, regional and local [8] should also be assigned to levels of significance. Table 3 shows the qualitative assessment / evaluation of potential geo-heritage resources in the study area on the basis of geo-heritage values and ranking levels. Those three caves have a potential toward the scientific and educational values, recreational and economical values. However, the aesthetic value only implies to the Pagar Cave and Keris Cave. The level of significance is only small for all three caves.

Table 3. The qualitative assessment of potential geoheritage resources in Dabong, Kelantan, Malaysia.
The quantitative assessment on the other hand, was more discrete which based on the numerical evaluation to rank the geological sites [11]. This approach has been carried out to assess the potential geodiversity values based on six classes values. The six classes values have been set simply for this purpose which reflect: 0 = none; 1 = very bad; 2 = bad; 3 = fair; 4 = good; and 5 = very good (Table 4). The sum of the values for Pagar Cave, Gelap Cave and Keris Cave is 18, 13 and 17 respectively. These values reflected about right rank to be as potential area for geoheritage sites (Table 4).

**Table 4.** The numerical assessment of potential geoheritage resources in Dabong, Kelantan, Malaysia (0 = none , 1 = very bad , 2 = bad , 3 = fair , 4 = good , 5 = very good).

| No | Geological site | Scientific and educational value | Aesthetic value | Recreational value | Cultural and Historical value | Economical value | Functional value | Level of Significance |
|----|-----------------|---------------------------------|----------------|-------------------|-------------------------------|------------------|-------------------|----------------------|
| 1  | Pagar Cave      | Karst landform                  | Monkey like structure | Cave exploration, rock climbing, camping, jungle trekking | - | Local community can generate income by: - selling foods and snacks, - camp business | - | Local |
| 2  | Gelap Cave      | Karst landform                  | -               | Cave exploration | - | Local community can generate income by: - do the cave exploration | - | Local |
| 3  | Keris Cave      | Karst landform                  | Column with Keris shape and flowstone which resemble an elephant | Cave exploration and camping | - | Local community can generate income by: - selling foods and snacks, - camp business | - | Local |

5.5 Evaluation
Evaluation of geoheritage can serve as a tool for geoconservation and management of geoheritage and geodiversity. This concept of the geodiversity was the first time developed in Australian Natural Heritage Charter (2002) and the principles of geoconservation were defined in the same document [14]. In this study, the SWOT analysis was used to evaluate the strength, weakness, opportunities, and threats of potential geoheritage resources in the area, as shown in Table 5. Based on the SWOT analysis; the strengths of this three caves are near to Gunung Stong which is very likely to accept tourists, suitable for all age range for cave exploration or other recreational activities, and have many imaginative features such as the mimetoliths in Pagar Cave which can be fascinating for tourists. The weakness are lack of promotion and less support from the community and authority. In order to establish a successful geoheritage site, the potential site need to be promoted and supported by the local community and authority. On the other hand, these three caves have few opportunities, which can be the one stop centre for geotourism nearby Gunung Stong and new job opportunity for local...
community once it is establish. The threat concerning these caves are vandalism and no proper management (Table 5)

**Table 5.** SWOT analysis to evaluate the potential geoheritage resources of the study area for conservation and development.

| No | SWOT       | Remarks                                                                                     |
|----|------------|----------------------------------------------------------------------------------------------|
| 1  | Strengths  | 1. Near Gunung Stong which is tourism places                                                 |
|    |            | 2. Suitable for all age range                                                               |
|    |            | 3. Have fossil and imaginative geological features (mimetoliths)                            |
| 2  | Weakness   | 1. Lack of promotion at the area                                                             |
|    |            | 2. Less support from the authority                                                           |
| 3  | Opportunities | 1. Develop the place to be the one stop center of geotourism as Gunung Stong will be geotourism at 2020 |
|    |            | 2. New job opportunity for the locals                                                       |
| 4  | Threats    | 1. No proper management of the caves                                                        |
|    |            | 2. Vandalism                                                                                 |

6. Conclusion

Geological resources can no longer be valued only on conventional economic value but should also be valued from their heritage aspects. The beauty and uniqueness of natural heritage need to be conserved and developed. Therefore, the systematic study has been conducted in three caves at Dabong, Kuala Kerai, Kelantan. These three caves are Pagar Cave, Gelap Cave and Keris Cave. These caves have been studied using the inventory, characterisation, classification, assessment and evaluation based on the systematic studies proposed in the previous literature. The three caves have different geological features which make it unique to be conserve. Each of the caves have scientific and educational values since it is providing the scientific knowledge and education for local community, professional geoscientist, students and other targeted groups.

Geoheritage evaluation of this area also has been conducted to evaluate their overall strengths, weaknesses, opportunities and threats. As these cave are near to Gunung Stong, it can develop to be one stop center of geotourism. However, this area is lack of promotion and support from authority which make it not famous among state. The threat for this study area is no proper management has been conduct for conserved it. Based on the geoheritage potential value, this site has potential for geotourism as it has interesting geological structure, and interesting place for speleologist. In this way, it will help to make geology meaningful to the people. This action will contribute to keeping geology relevant forever in the future.

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