Geoheritage of Labuan Island

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Abstract: The Labuan Island in East Malaysia possesses some geological features with geoheritage values. A study on the new list of potential geoheritage sites has been carried out in the island through some systematic steps includingidentification, characterization, classification, assessment, and evaluation of eight (8) geosites: Tanjung Punei Beach, turbidite outcrops in Kampung Bebuloh, Tanjung Batu Beach, Labuan mud volcanoes in Kampung Layang-layangan, Tanjung Layang-layangan Beach, coal-bearing strata and oil seepages in Kampung Ganggarak, historical coal mining sites in Tanjung Kubong, and Tanjung Kubong Beach (Bethune Head – Kubong Bluff). These potential geoheritage sites have their own unique characteristics such as distinctive rocks (lithological/petrological sites), landform/landscape features (geomorphological sites), and fossil occurrences (paleontological sites). Other sites exhibit some unique processes/phenomena such as mud volcanoes and oil seepages. In term of scale, they range between small to medium sizes. These geological resources have been assessed based on some geodiversity/geoheritage values including scientific (and educational), aesthetic, recreational, cultural, and some other values, with the local level of significance. SWOT analysis has been conducted to evaluate these potential geoheritage resources. All these geoheritage resources are expected to be utilized properly, such as for research and educational activities as well as geotourism development.

Keywords: Geoheritage, geoheritage values, geosite, geotourism, Labuan Island, East Malaysia.

INTRODUCTION

There are distinctive rocks and other valuable Earth materials, wonderful geological landforms/landscapes, and amazing geological processes/phenomena everywhere on the Earth. These features make our Earth become more attractive and can be potential geological heritage. Geological heritage or geoheritage is a geological concept which focuses on unique, special, and representative geological features (ProGEO, 2011) that have several values such as scientific, educational, aesthetic, recreational, cultural, and other values (Gray, 2004, 2005; GSA, 2012).

As one of countries that actively conserve and develop the geoheritage resources, according to Komoo (2004), Malaysia has started the efforts on the conservation and development of its geosites since the Third Malaysian Plan (1976-80) through some policies to protect geological monuments and landscapes. Meanwhile, systematic efforts toward promoting geoheritage have been initiated in 1996 through the establishment of the Malaysian Geological Heritage Group. Thereafter, a lot of research works have been conducted to explore and expose many geoheritage sites entire the country. The term 'geosite' was proposed by Wimbledon (1996) to refer "any site that contains significant geodiversity". This concept was then introduced in Malaysia by Komoo (2004) by defining the term as "any geological site with the feature or landform which contains a significant geodiversity component that indicates high geodiversity value". Besides, ProGEO (2011) also defined 'geosite' as "a key locality or area showing geological features with intrinsic scientific interest which allow us to understand the evolution of the Earth".

The Labuan Island (Figure 1) is a federal territory of Malaysia which is strategically located in offshore Sabah. It

is located around 8 km off the northwest coast of mainland Sabah, just slightly to the north of Brunei Bay and faces South China Sea. It is bordered by longitude line 05° 15'N to 05°20'N and latitude line 115° 10'E to 115° 20'E. The name of Labuan was derived from the Malay word "labuhan" meaning "harbour". The island consists of some outstanding geological and geomorphological features that make the island important in term of geoheritage. This article contains the systematic study of potential geoheritage sites of the island. The authors proposed some steps which are important to study these selected sites: identification, characterization, classification, assessment as well as evaluation. Some geoheritage studies in some regions can be good examples for this study, such as a systematic geoheritage study in Jeli district, Kelantan (Nazaruddin, 2015) and a case study of geoheritage at the equatorial in Central Africa (Henriques & Neto, 2015).

GENERAL GEOLOGY

Labuan Island is a northeastward plunging asymmetrical anticline where the major geological structure controls the topography of the island. Topographically, the island is largely flat and undulating with the highest point is only 85 meters. The island is a part of Neogene sedimentary rocks in the South China Sea which produce oil and gas (Tongkul, 2002). Stratigraphically, the island consists of some lithostratigraphic units (in younging order): Crocker Formation and Temburong Formation (aged Late Eocene to Oligocene), Setap Shale Formation (Early to Middle Miocene), Belait Formation (Late Miocene), and covered by the Quaternary alluvium mainly around the coastal areas (Hafzan Eva Mansor *et al.*, 2010; Sanudin Tahir *et al.*, 2011). Figure 2 shows the geological map and some



Figure 1: Location map of Labuan Island, East Malaysia (source: Google Earth 2016).

geological cross sections of Labuan Island, meanwhile the lithostratigraphy of the island is shown in Figure 3.

IDENTIFICATION

Labuan Island offers excellent rock exposures on some of its beaches and road/hill cuts which are potentials as geoheritage resources. The identification involved the process of listingand mapping of selected geological sites, which were based on the previous listings (by previous researchers) e.g. Lee (1977), Tongkul (2001; 2002; 2005), and Rapi (2012), published literatures, discussion with other geologists, and fieldworks (in 2014 and 2015) in the area. Identification of potential geoheritage sites needs also to consider the following criteria: uniqueness, rarity, and representativeness of some geological features (Predrag & Mirela, 2010; Brocx & Semeniuk, 2011). The new list and geosite map (map of the potential geoheritage sites) of Labuan Island were proposed in this study (Table 1; Figure 4). The numbering of the sites for this study was arranged from south to north of the island. This study has managed to identify two sites of the Crocker Formation, five sites of the Belait Formation, and one site of the Setap Shale Formation.

CHARACTERISATION

Potential geoheritage sites were characterized by observing and describing the sites in details, and supported by information from the previous literatures. This step was conducted to give substantial geological information to each site. The scientific (and educational) values (providing opportunities for research and education purposes) of the sites get a special attention, but a few sites were also selected due to their aesthetic (the visual appeals provided by the physical environments) and recreational values (using the physical landscapes for recreational activities). Several sites on the other hands exhibit cultural/ historical (physical environments with social or community significance in both past and present societies), economic (financial values depending on the nature of the materials involved), and functional values (important functional roles in environmental system including to human society) (Gray, 2004; 2005). The following paragraphs are descriptions of each geological site:

Tanjung Punei Beach

Tanjung Punei Beachis located behind the Labuan Crude Oil Terminal (Shell), in the southwestern tip of Labuan (in Kiansam Peninsular). This beach contains associated slump and turbidite deposits of Crocker Formation with the almost vertical dip (N170°E/57°W) outcropped in the rocky and sandy beach (Figure 5). The outcrop can be observed clearly during the low tide. According to Hafzan Eva Mansor (2012), this succession consists of thick interbedded sequence of flysch conglomerate, sandstone, siltstone, and silty shale together with some thick (more than 12 meters), massive and strongly folded slumped shales and mudstone with big guartzite and slumpballs. Several sandstone beds containing coal clasts and coaly organic, and Nereites trace fossils. Tongkul (2002) stated that this site is composed of two sedimentary facies: bedded sandstone-mudstone facies and disturbed sandstone-mudstone facies. These sedimentary facies show slumping process on continental slope and turbidite depositional process in deepwater environment. Nereites is one of ichnofacies which is characteristic of deep water and is apparently restricted to turbidite deposits (Boggs, 2006).

Turbidite Outcrops in Kampung Bebuloh

Kampung Bebuloh, which is situated on the way to Tanjung Punei in Kiansam Peninsular, exhibits a broad and excellent turbidite deposits and Bouma sequence of Crocker Formation with some interesting geological features (Figure 6). These beds (N42°E/59°SE) are often, but not always, show several types of sedimentary structures such as flysch sole markings (e.g. groove moulds), ripple cross lamination, very small flute moulds, and trace fossils. A trace fossil





Figure 3: Lithostratigraphic column of Labuan Island (after Hafzan Eva Mansor, 2012)

Figure 2: Geological map and some geological cross sections of Labuan Island (after Hafzan Eva Mansor, 2012)

specimen of *Spirorhaphe* has been found and preserved in positive relief on the sole of fine- to medium- grained sandstone layer. It forms a spiral coil with incomplete whorls. Due to the finding of this *Spirorhaphe* specimen, which is one of *Nereites* ichnofacies, the sedimentary rocks of this area are interpreted to have been deposited in deepwater environment(Boggs, 2006).

Tanjung Batu Beach

Tanjung Batu Beach in the SE of the island is dominated by sandstone lithology which was characterized by very light grey sandstone at the base overlain by intercalation of very thin siltstone or claystone (0.03m to 0.07m thick), with the interbedded of sandstone and claystone of Belait Formation. Sedimentary structures and features include tafoni, hummocky and trough cross stratification, and sea caves (Figure 7). This coastal exposure consists of moderately dipping to the northeast (strike/dip: N311°E/20°NE).

| No. | Geological site | Geological site Location Main geological feature | | Other features | |
|-----|---|---|---|---|--|
| 1 | Tanjung Punei Beach | In the southwestern tip of Labuan (in Kiansam Peninsular) (05º15'25.8" N, 115º09'30.0" E) | Slump and turbidite deposits of Crocker Fm. (deepwater deposits) | Beach morphology | |
| 2 | Turbidite outcrops in Kampung Bebuloh | In the SW of Labuan (in Kiansam Peninsular), near Tanjung Punei Beach (05°17'08.8" N, 115°11'24.3" E) | Broad turbidite outcrops of Crocker Fm. | Sedimentary structures, trace fossils | |
| 3 | Tanjung Batu Beach | In the SE of Labuan (05º17'06.1" N, 115º15'54.2" E) | Sandstone of Belait Fm. with many sedimentary structures | Beach morphology | |
| 4 | Labuan mud volcanoes in Kampung Layang-layangan | In the W of Labuan (05º20'04.5″ N, 115º11'51.4″ E) | An active mud volcano (of Setap Shale Fm.) with cone-shaped (dome) morphology | A dormant mud volcano nearby the active one | |
| 5 | Tanjung Layang- layangan Beach | In the W of Labuan (05º20'44.9" N, 115º11'58.8" E) | Sedimentary sequences of Belait Fm. with a variety of sedimentary structures | Coal seams, beach morphology | |
| 6 | Former coal mining sites in Tanjung Kubong | In the N of Labuan (05º22'57.81" N, 115º14'25.18" E) | A shaft and a tunnel as evidences of an ex-mining site (a part of Belait Fm.) | - | |
| 7 | Coal-bearing strata and oil seepages in Kampung Ganggarak | In the centernorth of Labuan (05°22'06.3" N, 115°13'30.2" E) | Coal seam and coal clasts in the sandstone of Belait Fm. and two oil seeps | Sedimentary beds of Belait Fm. | |
| 8. | Tanjung Kubong Beach (Bethune Head – Kubong Bluff) | In the northern tip of Labuan (05º23'40.0" N, 115º15'10.7" E) | Sedimentary sequences of Belait Fm. with a variety of beach morphology and sedimentary structures | Trace fossils | |

Table 1: List of potential geoheritage sites in Labuan Island.

Labuan Mud Volcanoes in Kampung Layanglayangan

Kampung Layang-layangan, near Tanjung Layanglayangan, is the location of Labuan mud volcanoes, an evidence of petroleum occurrence in the subsurface of the island. These mud volcanoes were formed as a result of the emission of argillaceous rock of Setap Shale Formation when the fine-grained rock combines with the groundwater and gas (methane) in the subsurface. There are at least two domes (cone-shaped morphology) formed by the extruded materials which can be found in the location, where one of them is still active and another one is in dormant (Figure 8).

Tanjung Layang-layangan Beach

Another beach in Labuan Island that shows potential geoheritage features is Tanjung Layang-layangan Beach in the west of the island (Figure 9). This succession consists of rapid alternations of lignitic or pebbly sandstone and dark reddish brown claystone. The outcrop shows thickening and fining upward sequences and the main internal sedimentary structures observed in sandstone beds are planar, trough, and hummocky, and current ripple with some climbing ripple

cross-stratified sandstone representing the delta deposits (N224°E/72°NW).Coal seams can be observed in sandstone lithology at this location. This area is affected significantly by the wave erosion forming a sea arc.

Former Coal Mining Sitesin Tanjung Kubong

A historical coal mining site in Tanjung Kubong area is a potential geoheritage site in the north of Labuan Island. There is a shaft and a tunnel as evidences of mining activities in the past (Figure 10). According to Tongkul (2002), Tanjung Kubong area consists of three sedimentary facies: pebbly sandstone facies, sandstone-mudstone facies, and mudstone facies of the Belait Formation.

Coal-bearing Strataand Oil Seepages in Kampung Ganggarak

An outcrop in Kampung Ganggarak exposes coalbearing strata of Belait Formation and oil seepages (Figure 11). Entirely, this succession consists of several lithologies such as claystone (0.02 m to 1.78 m thick), coal seams (0.31 m to 1.72 m thick), trace of shale, conglomeratic sandstones, and dominated by medium to coarse-grained sandstone(0.02



Figure 4. Geosite map showing the location of potential geoheritage sites in Labuan Island

m to 0.31 m thick) with the general strike and dip of the strata is N235°E/54°NW.Coals can be found as coal seams in the sandstone and as clasts of conglomerate from Belait Formation. These strata were interpreted as shallow marine deposits. Two oils seeps can be observed at the location indicating active petroleum system in the subsurface.

Tanjung Kubong Beach (Buthene Head – Kubong Bluff)

Tanjung Kubong Beach is located in the northern tip of Labuan Island, between the Bethune Head and Kubong Bluff. This beach landform displays excellent outcrops of interbedded sandstone - mudstone sequences of the Late Miocene Belait Formation with the general strike/dip of the strata: N235ºE/20ºNW (Figure 12). According to Sanudin Tahir et al. (2011), the clastic sequences were interpreted to have been deposited within the shoreface and equivalent environment. Somegeomorphological features of the coastline can be observed here such as beautiful beaches, several sea caves, and rocky cliffs. Some sedimentary structures also occurred in the area e.g. hummocky crossstratification, swaley cross-stratification, scours, etc. These can be interpreted for the transport mechanisms of the sediments, which are a combination of both bed load and suspension. Trace fossils can be observed in some parts of the area. Coal seams can also be found in some parts of this outcrop.



Figure 5. Geological features in Tanjung Punei Beach: (a)Associated slump and turbidite deposits are located in the Tanjung Punei beach; (b) Parallel-laminated sandstones; (c) Open-matrix clast supported conglomerate, with abundant siltstone mega-clasts; (d) *Nereites* trace fossils in sandstone; (e) Coal clasts in sandstone; and (f) Mini fault

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Figure 6. Important features from Kampung Bebuloh: (a) A fresh and clear outcrop of turbidite deposits characterized by thinbedded sandstone interbedded with shale; (b) A close-up view of the interbedded of sandstone and shale; (c) Cross-ripple lamination and climbing ripple developed within fine-grained sandstone; (d) Slump structure; (e) Mini fault; and (f) Trace fossil of *Spirorhaphe*



Figure 7. Potential geoheritage features in Tanjung Batu Beach are outcropped: (a) Sandstone outcrops of Belait Fm. in the beach; (b) Tafoni structure; (c) Cross bedding; and (d) Sea cave

CLASSIFICATION

The classification of potential geoheritage resources of Labuan Island was based on some categories: geodiversity (Gray, 2005), class (Brocx and Semeniuk, 2007; Predrag and Mirela, 2010), and scale (Brocx and Semeniuk, 2007). Geodiversity was divided into eight elements: rock, mineral, fossil, landform, landscape, process, soil, and other georesources (Gray, 2005). Some classes of potential geoheritage sites are mineralogical site, lithological/petrological site, geomorphological site, speleological site, structural site, stratigraphic site, hydrological/hydrogeological site, and so on (Brocx and Semeniuk, 2007; Predrag and Mirela, 2010). Meanwhile, Brocx and Semeniuk (2007) classified the sites as regional scale (or megascale; coverage of around 100 km x 100 km), large scale (or macroscale; coverage of around 10 km x 10 km), medium scale (or mesoscale; coverage of around 1 km x 1 km), small scale (or microscale; coverage of around 10-100 m x 10-100 m), fine scale (or leptoscale; coverage of around 1 m x 1 m), and very fine scale (coverage of around 1 mm x 1 mm).

Potential geoheritage sites in Labuan Island are dominated by rock and landform/landscape diversity, fossil occurrences as well as some unique processes/phenomena



Figure 8: Mud volcanoesin Labuan are a rare and unique geological feature: (a) The flow of the mud extruded from an active mud volcano; (b) The main vent of the active mud volcano; and (c) A dormant mud volcano in the site

such as mud volcanoes and oil seepages. The scale of the sites ranges between small to medium. The classification of potential geoheritage sites in the island in the basis of their geodiversity, class, and scale can be seen in Table 2.

ASSESSMENT

Assessment of potential geoheritage sites was conducted through two approaches: the qualitative and quantitative methods. The qualitative method focuses on some geodiversity (and geoheritage) values, mainly scientific (and educational), aesthetic, recreational, and cultural value, plus some additional values such as economic and functional values, and so on (Komoo, 2003; Gray, 2004, 2005). Moreover, each site should be assigned with the level of significance (Brocx & Semeniuk, 2007), such as international (one of, or a few of, or the best of a feature globally), national (one of, or a few of, or the best of a feature nationally, though globally relatively common), statewide/regional (one of, or a few of, or the best of a feature state-wide or regionally, though globally and nationally relatively common), and local (especially important to local communities, though globally, nationally, and regionally relatively common). The level of importance attributed to a given geoheritage resource is related to one of two factors: 1. How common is the feature with a certain scale; and 2. How important is the feature based on the geoheritage values. The qualitative assessment of potential geoheritage sites in Labuan Island on the basis of geoheritage values and levels of significance (ranking) is summarized in Table 3.

The second approach, i.e. the quantitative method, is the numerical assessment (valuing) of the geological sites or the scoring of the sites (Kubalikova, 2013). This approach was carried out in this study by assessing these potential geoheritage sites based on their geodiversity and geoheritage values. Six classes of values have been simply established for this purpose: 0 = none; 1 = very poor; 2 = very poor



Figure 9: Interesting geological features with outstanding geoheritage values in Tanjung Layang-layangan Beach: (a) An outcrop of sedimentary sequence (dominated by sandstone) of Belait Fm.; (b) Wave ripple; (c) Cross bedding; (d) Sea arch; and (e) Coal seam



Figure 10: The historical coal mining site in Tanjung Kubong area: (a) The location of the former mining site; (b) The shaft; (c) The tunnel as the passage of underground mining activity; and (d) The close-up of the tunnel.

Figure 11: Some characteristic features of Kampung Ganggarak outcrop: (a) A coal seam in the area; (b) Coal clasts in conglomerate of Belait Fm.; (c) One of the oil seeps in the location; and (d) Another oil seep.



Figure 12: Tanjung Kubong Beach shows some potential geoheritage features: (a) The view of the beach with very thick sedimentary sequences, fractures and sea caves; (b) Interbedded sandstone and mudstone sequences; (c) Very thick-bedded, medium-fine grained, hummocky-swalley cross-bedded sandstone; (d) Interbedded of pebbly sandstone and bleached, white, fine-grained sandstone exhibiting large scale tabular-planar crossstratification (measuring tape shows 1 m length); (e) Coal seams are associated in sandstone.

Table 2: Classification of potential geoheritage sites in Labuan Island.

| No. | Geological site | Geodiversity (Gray, 2005) | Class (Brocx & Semeniuk, 2007; Predrag & Mirela, 2010) | Scale (Brocx & Semeniuk, 2007) |
|-----|---|---|--|---|
| 1 | Tanjung Punei Beach | Rock: slump and turbidite deposits, sedimentary structures (vertical bedding, folded slumps); landform: beach landforms | Petrological site, stratigraphic site, geomorphological site | Medium scale |
| 2 | Turbidite outcrops in Kampung Bebuloh | Rock: turbidite deposits, sedimentary structures (flysch sole marking, ripple cross lamination, flute moulds); trace fossil: Spirorhaphe | Petrological site, stratigraphic site, paleontological site | Small scale |
| 3 | Tanjung Batu Beach | Rock: sandstone and intercalation of thin siltsone or claystone, sedimentary structures (tafoni, hummocky and trough cross stratification, seacaves); landform: beach landforms | Petrological site, stratigraphic site, geomorphological site | Medium scale |
| 4 | Labuan mud volcanoes in Kampung Layang- layangan | Rock: argillaceous rocks (mudstone); process: mud volcanoes | Petrological site, mud volcano site | Small scale |
| 5 | Tanjung Layang- layangan Beach | Rock: sandstone and claystone, sedimentary structures (planar, trough, and hummocky stratification, sea arc, etc.); landform: beach landforms | Petrological site, stratigraphic site, geomorphological site | Small scale |
| 6 | Former coal mining sites in Tanjung Kubong | Rock: sandstone, mudstone, coal | Petrological site | Small scale |
| 7 | Coal-bearing strata and oil seepages in Kampung Ganggarak | Rock: sandstone, conglomeratic sandstone, shale, claystone, coal seams; process: oil seeps | Petrological site, stratigraphic site, petroleum site | Small scale |
| 8 | Tanjung Kubong Beach | Rock: sandstone, mudstone, sedimentary structures (hummocky and swaley cross stratification, scours, etc.); landform: beach landforms | Petrological site, stratigraphic site, geomorphological site | Small scale |

| | Level of significance | Local | Local | Local | Local | Local | Local | Local | Local |
|----------------------|---------------------------------------|--|---|---|---|--|---|---|--|
| | Functional value | As the site of Labuan Crude Oil Terminal, and as a tourism and recreational site | | As a tourism and recreational site | Skin therapy using mud | As a tourism and recreational site | As a historical site | | As a tourism and recreational site |
| Auto Diutiu. | Economic value | Potential to generate income from tourism and recreational activities | Potential to generate income if they are extracted as rock aggregates (should be controlled and limited) | Potential to generate income from tourism and recreational activities | Potential to generate income from tourism and recreational activities (especially for mud bathing) | Potential to generate income from tourism and recreational activities | Potential to generate income from tourism and recreational activities | Potential to generate income if they are extracted as rock aggregates (should be controlled and limited) | Potential to generate income from tourism and recreational activities |
| me in conto agmi | Cultural (and historical) value | 1 | I | I | | 1 | Ex-mining site since the British colonial time | | |
| and a powning source | Recreational value | Sightseeing, swimming, and camping | | Sightseeing, swimming, and camping | Mud bathing | Sightseeing, swimming, | Recreational visit or study tour to ex- mining sites | | Sightseeing, swimming, and camping |
| meescen summin h su | Aesthetic value | Attractive beach landform | A fresh and clear outcrop | Interesting landscape of beach area | Interesting mud volcano activity | Attractive beach area with some unique geomorphological features | Interesting ex- mining site has been developed become a historical site | | Attractive beach landform |
| T IC MONT | Scientific (and educational) value | Deepwater deposits (slump and turbidite deposits), geological and sedimentary structures, trace fossils | Turbidite deposits, sedimentary structures, trace fossil assemblages | Sandstone with many sedimentary structures | The formation of mud volcances, their composition and relationship with petroleum occurrence | Sedimentary sequences, a variety of sedimentary structures | The formation of coal, coal mining activity | The formation of coal, the formation of oil seepages, structure controlled the oil seeps | Sedimentary sequences with a variety of beach morphology, sedimentary structures, and trace fossils |
| | Geological site | Tanjung Punei Beach | Turbidite outcrops in Kampung Bebuloh | Tanjung Batu Beach | Labuan mud volcanoes in Kampung Layang- layangan | Tanjung Layang- layangan Beach | Former coal mining sites in Tanjung Kubong | Coal-bearing strata and oil seepages in Kampung Ganggarak | Tanjung Kubong Beach |
| | No. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | <u>%</u> |

poor; 3 = fair; 4 = good; and 5 = very good. These scores were created by considering some criteria. For scientific (and educational) value, the score was determined by assessing unique and distinctive geodiversity, such as rock, mineral, fossil, landform, landscape, and other geologic characteristics that are significant to scientific/research and educational purposes. This value should also consider how important is the features for geological records and Earth's history. Aesthetic value was scored by considering the visual appeal of geological features or processes. Recreational value emphasizes on potential recreational and tourism activities that can be conducted in the site. Cultural value will assess the interactions between geologic (or geomorphologic) features and cultural (or historical) events. For economic value, the score is based on the financial value of the resources depending on their nature and their potentials to generate income. Meanwhile, functional value considers the uses of resources (Komoo, 2003; Gray, 2004; GSA, 2012). The score which was given to each geoheritage value was based on perceptions of these criteria, where the score 0 ('none') means that the site is not related to the value (has no values) and the score 5 ('very good') means that the site has very good quality in this certain value.

Table 4 presents the scores obtained for all sites. Former coal mining sites in Tanjung Kubong has the highest mark (24) in the quantitative assessment, since they have more complete and higher geoheritage values: scientific (and educational), aesthetic, recreational, historical, economic, and functional values. Meanwhile, even though the site of coal-bearing strata and oil seepages in Kampung Ganggarak is an important site in geology and geoheritage, however, it has the lowest mark (8) since it possesses only scientific (and educational) and economic values.

EVALUATION

The SWOT analysis is used in this study to evaluate the strengths, weaknesses, opportunities, and threatsof potential geoheritage resources in Labuan Island. Table 5 summarizes the SWOTanalysis to evaluate the study area in term of geoheritage potentials.

GEOTOURISM DEVELOPMENT

Geoheritage sites can be utilized for the development of tourism sector, mainly geotourism (Adriansyah *et al.*, 2015). Labuan Island possesses some geoheritage sites which can be utilized to stimulate the geotourism development of the area. However, based on the recent condition, those sites and features should be provided with the proper system and some facilities and infrastructures to support the tourism and recreational programs and activities in the island such as study/educational tour, sightseeing, swimming, and camping (in the beaches) as well as mud bathing (in the mud volcano site) (Table 6).

Due to its richness in geoheritage resources and potential geotourism development, a geotrail of Labuan Island should be provided as an alternative and attractive approach to support the tourism sector in the island. According to Campbell and Jones (2013), a geotrail is a trail links geological significant sites and creates an educational journey for people to follow. Scientific information, including geological map and photographs, should be provided in the panels in each geoheritage and geotourism site as well as in the field guide brochure. Geotrail is intended to showcase all geoheritage resources of the island, so that visitors can take the unique opportunity to travel and enjoy to the whole Labuan, and in the same time to get the geological knowledge. For this, a geotrail map (such as in Figure 13) should be created and provided for visitors.

CONCLUSION

A systematic geoheritage study has been conducted in Labuan Island, a federal territory in the East Malaysia. Identification of some geological sites has been conducted to record the potential geoheritage resourcesof the island. Exploring the island from the south to the north, there are eight sites or localities which have been identified as potential geoheritage sites: Tanjung Punei Beach, turbidite outcrops in Kampung Bebuloh, Tanjung Batu Beach, Labuan mud volcanoes in Kampung Layang-layangan, Tanjung Layanglayangan Beach, historical coal mining site in Tanjung Kubong, coal-bearing strata and oil seepages in Kampung Ganggarak, and Tanjung Kubong Beach.

Potential geoheritage sites in the island have been characterized in details and classified based on their distinctive rocks (petrological sites), beautiful landform/ landscape features (geomorphological sites), fossil occurrences (paleontological sites) as well as some unique processes/phenomena such as mud volcanoes and oil seepages. The scales of these sites are small to medium sizes. From the assessment, these sites indicated that they have some geoheritage values including scientific (and educational), aesthetic, recreational, cultural (historical), economic, and functional values, with the local levels of significance. Geoheritage evaluation of this area has been conducted by SWOT analysis to evaluate their strengths, weaknesses, opportunities, and threats. Therefore, it is suggested that research and scientific activities should always be conducted in the island for the establishment of all these potential geoheritage sites while supporting conservation and development of the area. All geoheritage resources of the island can also be utilized in geotourism development, where the geotrail can be one of the approaches to support this.

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| No. | Geological site | Scientific (and educa- tional) value | Aesthetic value | Recrea- tional value | Cultural (Histo- rical) value | Economic value | Func- tional value | Total |
|-----|---|--|--------------------|----------------------------|--|-------------------|--------------------------|-------|
| 1. | Tanjung Punei Beach | 5 | 4 | 5 | 0 | 3 | 5 | 22 |
| 2. | Turbidite outcrops in Kampung Bebuloh | 5 | 3 | 0 | 0 | 3 | 0 | 11 |
| 3. | Tanjung Batu Beach | 5 | 5 | 5 | 0 | 3 | 4 | 22 |
| 4. | Labuan mud volcanoes in Kampung Layang-layangan | 5 | 3 | 5 | 0 | 3 | 5 | 21 |
| 5. | Tanjung Layang- layangan Beach | 5 | 4 | 4 | 0 | 3 | 4 | 20 |
| 6. | Former coal mining sites in Tanjung Kubong | 5 | 3 | 3 | 5 | 3 | 5 | 24 |
| 7. | Coal-bearing strata and oil seepages in Kampung Ganggarak | 5 | 0 | 0 | 0 | 3 | 0 | 8 |
| 8. | Tanjung Kubong Beach | 5 | 4 | 5 | 0 | 3 | 4 | 21 |

Table 4: The quantitative assessment of potential geoheritage sites in Labuan Island.

Note: 0 = none; 1 = very poor; 2 = poor; 3 =fair; 4 = good; 5 =very good

| Table 5: SWOT | analysis to | evaluate the | potential | geoheritage | sites c | of Labuan | Island. |
|---------------|-------------|--------------|-----------|-------------|---------|-----------|---------|
| | 2 | | 1 | 0 0 | | | |

| No. | SWOT | Remark |
|-----|---------------|---|
| 1 | Strengths | Good place for research and education Some sites has high aesthetic value Suitable for recreational activities High historical value of coal mining activity in the island Most sites have potential economic and functional values Contains some elements of geodiversity Generally the study area has good accessibility |
| 2 | Weaknesses | Insufficient promotion of the area Poor management Lack of support from the authority |
| 3 | Opportunities | More research and educational programmes can be conducted in the area Geotrail and more panels of information are necessary to serve visitors Provide more facilities for recreational activities, such as sightseeing in the beaches, swimming, camping, etc. Potential for the empowerment of local community Good prospect for the cooperation or collaboration between many parties (stakeholders) such as local authorities, universities, and communities |
| 4 | Threats | Unmanaged waste Uncontrolled rock extration Oil contamination Vandalism |

| Table 6. Some | possible geotourism | programs and activities in | potential geoheritage sites | of Labuan Island |
|-----------------|----------------------|----------------------------|------------------------------|-------------------|
| THOIC OF DOILIG | possible geotoarisin | programs and detrifted in | potential geometricage sites | or Luouun ibiunu. |

| | | Study/educa- | Sightseeing | Swimming | Camping | Mud bathing | | |
|-------|---|--------------|--------------|--------------|--------------|--------------|--|--|
| No. | Geological site | tional tour | 88 | 28 | | | | |
| 1 | Tanjung Punei Beach | Р | \checkmark | Р | Р | - | | |
| 2 | Turbidite outcrops in Kampung Bebuloh | Р | - | - | - | - | | |
| 3 | Tanjung Batu Beach | \checkmark | Р | \checkmark | \checkmark | - | | |
| 4 | Labuan mud volcanoes in Kampung Layang- layangan | \checkmark | - | - | - | \checkmark | | |
| 5 | Tanjung Layang-layangan Beach | \checkmark | Р | \checkmark | - | - | | |
| 6 | Former coal mining sitesin Tanjung Kubong | Р | - | - | - | - | | |
| 7 | Coal-bearing strata and oil seepages in Kampung Ganggarak | Р | - | - | - | - | | |
| 8 | Tanjung Kubong Beach | Р | Р | \checkmark | \checkmark | - | | |
| Note: | Vote: P = possible; - = impossible | | | | | | | |



Figure 13: Geotrail map of Labuan Island was created (on the geological map) for geotourism development.

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