proposals, strategies or even general guidelines for the use and development of land. The important purpose of planning policies is to guide the development approving authority when undertaking controls over development activities.

To move forward in the sustainable development process, there are many challenges and issues that must be dealt with. Where planning is concerned it will always be a challenge to produce a plan that is fully effective and implementable. To plan for sustainability also means focusing on planning issues and subject matters that are central to the creation of sustainability. Beyond the traditional environment-oriented concerns, e.g. protection of natural features and environmentally-sensitive areas, land use planners must consider issues at the very core of physical planning which have a major implication on sustainability. Among the great planning challenges is the need to put the principle of good governance into practice, which as noted by Ibrahim (2007), is a pre-requisite for sustainable development. In terms of public participation alone, there are many issues that need to be addressed. Firstly, it is essential to be able to assess the effectiveness of each public participation exercise so that there can be a more systematic way of improving such involvement. Secondly, there is the need to educate the public. Thirdly, there is a need to understand the complexity of the underlying interactive processes in a community and to bring together the diverse views of different groups of people. And finally, the greatest challenge is to make planning a collaborative effort by all involved in development.

THE CONSERVATION CONCEPT

The term ‘conservation’ from publications by Badan Warisan (Malaysia Heritage Trust) and the International Council on Monument and Sites (ICOMOS) as mentioned by Ibrahim (2007), is in accord with the Burra Charter. Ibrahim further stressed that the fundamental conservation processes derived from the international charters can be summarised to involve four major physical activities, these being: preservation, restoration, reconstruction and adaptation as follows: *Preservation* stresses the maintenance of heritage in its existing state and in retarding deterioration; *Restoration* indicates a process of returning the existing heritage to an earlier known state by removing accretions or by reassembling existing components without the introduction of new material; *Reconstruction* relates to the process of re-creating a non-surviving heritage or conservation area as nearly as possible to a known earlier state; and *Adaptation* signifies modification to a place to suit a proposed compatible use.

The future role of conservation is seen through the opportunities for land-use planning to integrate heritage policies in relation to the wider demands of sustainability (Barker 2006). According to Green (1996), there are three main types of conservation. Firstly, conservation is essentially the preservation and protection of environmental features, beautiful sceneries or landscapes, wildlife, clean air and water. However, if the pollution of air and water reaches levels where our very existence is threatened, the maintenance of environmental quality is much more a necessity than an amenity. Secondly, there is the control of pollution and the maintenance of an environment fit for living, as well as the need for it to be pleasant to live in; and thirdly, conservation means the planned use of resources to ensure their continuing supply until sustainable substitutes can be found. Thus, conservation involves a compromise between conflicting interests and its definitions, where the formulation of scientific management of natural environments and resources for the purpose of maximising their aesthetic, educational, recreational and economic value, is done to bring benefits to society.

One of the essential tasks for government, local authorities and all public agencies concerned with the use of land and natural resources, is to make adequate provision for development and economic growth, whilst at the same time ensuring effective conservation of wildlife and natural features as an important element of a clean and healthy natural environment. The conservation of nature is important for attractive environments, and hence, attention to nature conservation is essential to social and economic well-being. With careful planning and control, conservation and development can be compatible.

LAND USE PLANNING AND MANAGEMENT OF PROTECTED AREAS

The designation of a protected area is often only the first step in a continuing, and sometimes unsuccessful, process of protection, and this gives rise to the phenomenon of ‘paper parks’, in which protected areas are designated but where there has never been any real attempt to manage their conservation (Dudley et al. 1999). In such situations, threats from illegal incursions, poaching and fire are being matched by more subtle impacts from trans-boundary air pollution and climate change (Phillips et al. 2001). Clearly, serious threats to protected areas cannot, by their very nature, be stopped by fences or guards, and processes of economic integration and the growing economic influence of corporations are creating new challenges to protect the lifestyles and habitats of high value to the public. Therefore, protected areas should be seen as more relevant to the development plans and to the needs of local people. Otherwise, many protected areas will, sooner or later, be overwhelmed.

Most large protected areas have people living inside their boundaries and many more have local populations just outside the protected area limits. Consequently, a key challenge for protected areas according is to find ways in which human needs can be better integrated with the needs of wildlife, biodiversity and the wider environment (Oviedo and Brown 1999). This includes both the needs of local or indigenous people and the needs of people living far away from protected areas in towns and cities, but who nonetheless, have a stake in their future, such as for nature or ecotourism, or for sustainable use of environmental resources e.g. medicinal plants in the forests.

The need for a large network of well protected areas connected by buffers, corridors and linkages with adjacent lands, and for an approach that takes into account the whole landscape or bioregion, should be addressed within a larger portfolio of sustainable resource use (Figgis 2004). Protected areas are graded from strictly protected core reserves, through a range of relatively soft or low impact development uses, to areas where human needs predominate and where there is relatively little emphasis on protecting wildlife. Although the concept of buffer zones and support zones around protected areas has been recognised for some time, a range of other soft options is now becoming available, such as sustainable forest management, leisure fishing, organic agriculture, low-level collection of non-timber forest products, and nature or eco-tourism (Sayer 1999).

It is important to link heritage conservation plans with other national and state plans, and national strategies for sustainable development; defining priority species, sites, habitats and preparing action plans with clearly specified objectives and targets. In sustainable development context, heritage areas cannot be protected and conserved in isolation, and a big challenge is to reconcile or break down the borders that lead to the isolation of such places from living environments. New partnerships with local people, non-governmental organisations (NGOs), private initiatives, tourism operators, resource users, development agencies, human rights groups, religious organisations, local governments and the general public are all increasingly important in this mission, especially so because protected areas exist in a world where institutions and political structures are rapidly changing.

STRATEGY FOR PROTECTED AREA PLANNING

Natural areas may be managed either to maintain their geodiversity and biodiversity, to provide physical environmental and resource protection, or because they constitute scenic features that have high amenity value. In many cultures, amenity values are not particularly associated with natural, undisturbed habitat but are treasured landscapes that have been drastically modified by human activities. These have to be rationalised with natural areas.

On a bio-regional scale, people and protected areas can co-exist, both through the judicious use of categories that can consistently combine biodiversity conservation with human habitation and managed sustainable resource extraction, and by developing region-wide co-operative programmes along protected areas and neighbouring activities (Miller 1999). Successful use of bio-regional planning represents an exciting approach with considerable potential to strengthen efforts to integrate parks and protected areas into the larger landscape. This approach seeks to maintain biological diversity across entire landscape regions while meeting people's needs. Cases in all continents already demonstrate that such options are viable and tend to foster social, economic and sustainable environmental management.

A comprehensive and planned approach to conservation for bio-regional planning involves three critical requirements: (1) *Prioritisation*: there is a need to prioritise within global conservation, in order to focus most attention on areas that have the greatest biodiversity richness, intactness or which are under most threat; (2) *Broad-scale conservation*: there is a need to develop larger scale approaches to conservation, which consciously plan conservation interventions over a large area, such as an eco-region or bio-region, based around an agreed biodiversity vision and involving a mosaic of protected areas and other forms of sustainable land use; and (3) *Integration*: there is a need for conservation and development objectives in land-use planning and regional development strategies, based on an ecosystem approach aiming to build a mixture of protected areas of various categories, linked and buffered by various other types of sustainable land uses.

Protected areas can be incorporated as a viable land use along with other types of development. Maps that illustrate areas with physical, biological, or social constraints to development can be over-layed on top of land use maps to show exactly what pieces of land require protection, conservation, or management and mitigation (RCEP 1999). Reasons for development constraints and the need for additional protection may include habitats of rare or endangered flora or fauna, unique geological features, scenic areas, high erodable areas, vital groundwater recharge areas, wetlands, historical or cultural landmarks, existing recreation areas and watershed protection areas. Therefore, it is important that the planning and management of protected areas be incorporated and integrated into a regional development scheme or expressed in special area plans or master plans, since such schemes or plans provide a framework or structure by which the role of protected areas can be defined, thereby enabling more effective integration of conservation and management to be made in a more refined, detailed and specific action plan.

Most protected areas are managed for multiple, yet compatible uses (Stolton and Dudley 1999). They can have many management objectives beyond biodiversity conservation, including outdoor recreation, tourism, watershed protection, sustainable forestry, hunting or fishing, scientific research, and environmental education. Establishing a protected area requires more than simply setting aside a track of land for protection, and a management plan is crucial to ensure that geodiversity biodiversity and cultural heritage are protected (UNEP 2004). To be effective, the plan must address the various threats to the area and the biodiversity that it supports. Threats to any given protected area might include the conversion of natural habitats to agriculture, incompatible land uses of neighbouring land, unsustainable extraction of environmental resources, illegal logging and poaching, the introduction of invasive or alien species, pollution and effects of climate change, lack of enforcement of rules and regulations and inefficient and ineffective management.

The IUCN emphasises that protected areas should not be seen as isolated entities, but must be treated as parts of broader conservation landscapes, including both protected area systems and wider ecosystem approaches to conservation that are implemented across the landscapes or seascape.The over-riding purpose of a system of protected areas is to increase the effectiveness of *in-situ* nature conservation, and the long-term success of *in-situ* conservation requires that the global system of protected areas comprise a representative sample of each of the world's different ecosystems.

IMPLEMENTING LANGKAWI GEOPARK

A geopark is an area that contains unique rock formations dated back millions of years. Apart from that, there are biological diversities of flora and fauna, rich cultural heritage and socio-economic activities of the local communities amongst the elements that contribute towards the creation of a geopark. Due to its rich natural and cultural heritage that Langkawi is well known for, in 2007 the whole Langkawi archipelago of 99 islands was bestowed the status of a global geopark by the Global Geopark Network (GGN), endorsed by UNESCO – the first in South East Asia and 52nd in the world. This placed the Langkawi archipelago as a protected and conservation area with the global geopark functions of conservation, education and sustainable development (Shafeea et al 2007). This is different from Malaysian National and State Parks gazetted under the National Parks Act, National Forestry Act or under specific enactments. Langkawi Geopark is not about total nature protection and conservation because there are other development land uses on the islands, the main island of Langkawi in particular. It does not restrict developments, as long as they are compatible and complementary to the natural areas and support sustainable development.

The definition of geopark by GGN, and endorsed by UNESCO, describes its multi-faceted nature. It has all the elements of environmental and cultural conservation areas but at the same time explains that sustainable development components and elements are necessary for the economic well being of the local communities. The GGN definition is as below:

> "A geographical area where geological heritage sites are part of a holistic concept of protection, education and sustainable development. The geopark should take into account the whole geographical setting of the region, and shall not solely include sites of geological significance. The synergy between geodiversity, biodiversity and culture, in addition to both tangible and non-tangible heritage are such that non-geological themes must be highlighted as an integral part of

each geopark, especially when their importance in relation to landscape and geology can be demonstrated to the visitors. For this reason, it is necessary to also include and highlight sites of ecological, archaelogical, historical and cultural value within each geopark. In many societies, natural, cultural and social history are inextricably linked and cannot be separated (GGN 2010).

MAJOR CONSERVATION AND DEVELOPMENT AREAS IN LANGKAWI GEOPARK

The national Land use planning policy and strategy which affects Langkawi Geopark are stipulated in the National Physical Plan. The state strategic land use policies and strategies which affect the Langkawi Geopark are framed in the gazetted Kedah State Structure Plan, while the land use zonings and development guidelines for the archipelago are outlined in the recently gazetted Langkawi District Local Plan. In planning and implementing Langkawi Geopark, sustainable development, conservation and education shall be the main criteria and thrusts. Sustainable development is to ensure that while natural and cultural heritages are protected and conserved to become sustainable tourism resources for local and foreign tourists, other development and activities will support the conservation areas and sustainable socio-economic development of the local population is ensured.

Currently, Langkawi Geopark's major protected areas are in the form of forest reserves, mainly the three geoforest parks of Kilim Karsts Geoforest, Machincang Cambrian Geoforest and Dayang Bunting Marble Geoforest that cover 16,889 hectares, comprising 13,772 hectares of diptrocarp forests and 3.117 hectares of mangrove forests. Other smaller forest reserves are scattered all over the archipelago. A total of 97 geosites have been identified but no biosites or cultural sites have been declared, although there are several areas which are known for their rich biodiversity and cultural values. Only a few sites such as Pulau Anak Tikus Pulau Ular, Pulau Tepur and Pulau Jemuru – 'pulau' is a Malay word for island - are promoted and open to visitors. Development within these areas are controlled and only trails for public paths are provided. In Kilim Karsts Geoforest, only Jetties and Information Centre are provided. For Machincang Cambrian Geoforest, Cable Car and recreation facilities are provided while at Dayang Bunting Marble Geoforest only jetties and recreation facilities are provided. This concept indicates that land use planning does not reject development within these three areas, but sustainable development is greatly emphasised within Geoforest Parks.

For other areas in Langkawi Geopark, developments are strictly in compliance with the zonings stipulated in the Langkawi District Local Plan Development zones. Even though some of geosites are located within the development zones, new development within its vicinity are avoided or will be strictly controlled. Nevertheless, there are some geosites of lesser importance, or of lower heritage value, which may need to be sacrificed to make way for development, such as Gua Pinang due to the economic returns that the nearby activity generates, that is the LARFAGE Cement Industry.

FUTURE PLANNING OF LANGKAWI GEOPARK THROUGH DEVELOPMENT PROJECTS

Langkawi is one of the tourism islands which are competing with other island destinations in the tourism industry. After being proclaimed a geopark, its economic and tourism market has been broadened through rebranding and creating new attractions to boost local tourism activities. For the 10th Malaysia Plan, all LADA's development projects will focus on the enhancement of tourism products and the promotion of Langkawi Geopark. The main tourism assets in Langkawi are the invaluable million years old geological formations, pristine beaches, forests, water falls and rivers. These natural resources will be protected and carefully managed as they form the heart of tourism activities for Langkawi and degradation of the natural environment will have direct effect on Langkawi's tourism. In this respect, the current planning approaches focus on information dissemination and understanding of matters pertaining to Geopark. The projects to be implemented are those related to the enhancement of infrastructures and accessibility to the geosites.

A Malaysian Geopark Resource Centre will be constructed within the Kilim Jetty area as added value to present activities and tourism products within the area. The centre will function as the main reference centre to other countries as the geological formation in Langkawi are the oldest in Malaysia and South East Asia and the Palaeozoic rock sediment formation dated 550 to 220 million years are also present. The centre will not only house geological heritage, flora and fauna and cultural diversity but also as attraction to tourists, students, researchers, scientists and the general public. The present facilities at other well known tourist attraction products such as Laman Padi, Telaga Tujuh and Tasik Dayang Bunting should be enhanced in terms of quality, safety and comfort.

To ensure the sustainability of Langkawi, the planning of tourism development and protecting the environment should be supplementing and complementing each other at every level. The integration and co-operation of all stakeholders as a team from Federal Agencies, State and NGOs should be realised in Committees to formulate well informed decision making on matters pertaining to geopark development.

CONCLUSION

In the process of developing an effective implementation system, any management plan must reflect upon needs and priorities and must be owned by those who will have to implement it. Therefore, adopting a plan should mainly be the task of the people responsible for protected area matters, although many other stakeholders will need to contribute to its initiation, development and implementation. There should be direct links between the system plan as a rational tool and the local action plan required to give effect to it, such as a clear connection between the system plan and site-based management plans.

Land use planning can apply to spatial physical arrangements of land uses of a town or city, or countryside, region, nation and even international zones, or to national, regional and local policies which determine the spatial arrangement of the use and development of land. A successful planning system will promote economic prosperity by delivering land for development in the right place and at the right time. It will encourage urban regeneration by ensuring that new development is channelled towards existing urban or service centres rather than adding to urban sprawl.

Development Plans are intended to set the main considerations on which planning applications are decided and to guide other responsibilities of local government and other agencies. They are also intended to contain the local planning authority's policies and proposals for the development and use of land, Plan-making has been generally regarded as a central component of the planning process, and a key means of devising and delivering planning policies for the improvement of the environment, the management and conservation of natural beauty and amenities of the land. The plan can be a means of setting long-term strategies to provide a more sustainable pattern of development.

A Development Plan is a potentially powerful instrument for environmentally sustainable development. The approach starts from an assessment of the current state of the physical environment, and attempts to qualify what effect the plan will have on this state. Development control operates within a plan-led system which is the most effective way to contribute to more sustainable development through development control to ensure environmental appraisal and to screen development control decisions for their conformity with the plan. It is only through the physical land use planning system that protected areas can be considered within the broader context of the surrounding region. This enables planning to integrate protected areas into their regional environments and to effectively address adjacent land use issues that influence protected area resources.

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THE IMPORTANCE OF GEOLOGICAL HERITAGE RESOURCES IN LAND USE PLANNING: EXPERIENCE FROM LANGKAWI GEOPARK

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Abstract
Being an oldest landmass with the most complete Paleozoic rock sequence Langkawi archipelago hosts the richest geological diversity and heritage resources in the country. As a popular tourist destination, the scenic beauty has attracted tourists to Langkawi without them realising that the beauty has been created by the islands' rich geological heritage diversity. To date more than 90 geoheritage sites of highly significant scientific, aesthetic, social or recreational value have been identified. Some of these geoheritage sites have become popular tourist sites. To ensure the sustainability of the tourism industry Langkawi needs to have a comprehensive and practical conservation strategy and mechanism. Without a good conservation policy the geoheritage sites are constantly under threat and under stress due to the need of space for development. To ensure the sustainability of these natural resources it is timely to include geoheritage sites in future land use planning.

INTRODUCTION

Geology is the basis for the lives on earth. In general it underpins the societal need for natural resources and raw materials that support our day-to-day existence (Prosser et al. 2006). The understanding of the importance of geology as a prime natural resource is

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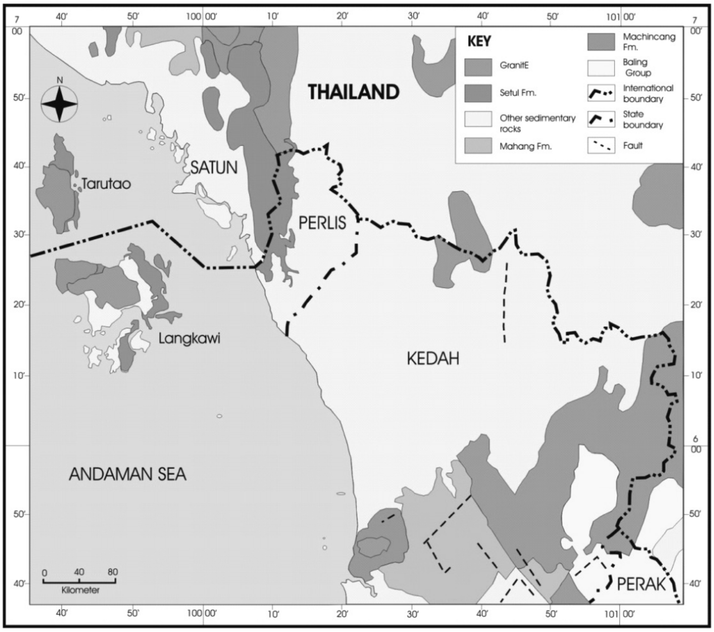
shared by many and among them are planners. Knowledge of geology plays a fundamental role in land use planning and in understanding the site suitability for development and residents. This is through the study on soil types and habitat that determine the land use of an area. Besides the study of geology the understanding of the dynamic of the natural environment such as the geological evidence on the last climate change, the changes of sea levels and the extinct as well as evolved species, would enable us to better understand and plan for current and future environmental changes and associated hazards. The dynamics of natural environment includes the present day natural system such as rivers and coastlines. This is the most common contribution of geology to the land use planning in the country. This is because it is associated with better prediction and management of flood events, coastal erosion and other potential hazards (Pereira & Komoo 1999; James Bachat et al. 2007; Nur Fazzillah Muhamed Noordin et al. 2007)

Another area of geology knowledge that is important for the land use planning has emerged in the last 20 years known as geological heritage or geoheritage (Joint Nature Conservation Committee 2002). The relationship between geoheritage and planning in Malaysia has been highlighted through the work by Halimaton Saadiah Hashim et al. (2007), who had includedgeological and landscape heritage as one of Environmentally Sensitive Area (ESA) within integrated work of identification and management of area. The integrated ESAs approach that includes the geoheritage is still confined to Selangor and has yet to be adopted by other planners in the country . Geoheritage can simply be seen as a significant geology, landform and landscape that carry the identity or signature of a place such as Author Seat, an extinct volcano system to Edinburgh, Table Mountain to Cape Town and limestone Hill to Ipoh. The heritage values are not limited cultural based but are also important for scientific, research and educational purposes particularly in understanding the Earth. This paper highlights Langkawi Geopark, the land that hosts the oldest continent in the country, and the importance of land use planning to protect the natural heritage within it.

LANGKAWI GEOPARK

Langkawi archipelago lies in the Northwestern corner of the Malaysian Peninsular (Figure 1). It is famous for its myths, idyllic natural scenery, picturesque landscapes and dramatic and beautiful coastlines as well as endemic fauna and flora. This natural and beautiful island has inevitably become one of the top tourist destinations in Malaysia. The landscapes reflect a rich geological diversity that made up the archipelago. The geological diversity of Langkawi has been widely studied by members of the Geological Heritage Group of Malaysia and results of the studies are published in Geological Heritage of Langkawi book and also in Malaysian Geological Heritage book series.

FIGURE 1 : Location Map of Langkawi Island and Its Geological Element in Relation to the Main Land.



The rich geological diversity has in turn created wide habitats and ecosystem diversities including biological and cultural diversities. These habitats are influenced by the underlying geology therefore raising the awareness regarding the importance of geological diversity in order to preserve this fragile island environment. This has made the area a perfect place not only for nature lovers, but also for scientists who want to study the geological and natural resources of the area. Every year large numbers of scientists including geoscientists, biologists, natural scientists and social scientists visit the place and use the natural and cultural resources for teaching, research and recreation. Up to now more than 90 geological sites of high heritage value have been identified in Langkawi and most of which are located in geoforest parks, that is areas designated for protection in the Langkawi geopark. For the time being those geosites are quite safe provided the parks are not converted into development areas in the near future. Some other geosites still remain vulnerable and can be wiped out at anytime to give way to development. With ever increasing population and tourism as well as development activities, the geological resources in Langkawi are always under pressure. The present population of Langkawi is about 93,000 living within an area of about 48,000 hectares. On top of that Langkawi attracts about 1.5 million visitors a year. A study by Narimah Samat (2010) showed that between 1974 and 2005 the built-up area of Langkawi has increased 23 folds. This enormous development rate will somehow put pressure on the natural resources of Langkawi if it is not taken into account in the land use planning.

However, at the same time everybody realises that those geosites together with other natural resources are the main attractions that bring tourist money to Langkawi. Realising the importance of preserving the geoheritage resources and the great potential of eco-geotourism that the resources can offer in future, the Geological Heritage Group of Malaysia is doing intensive promotion and public awareness programmes to ensure the sustainability of the resources through the global geopark initiative.

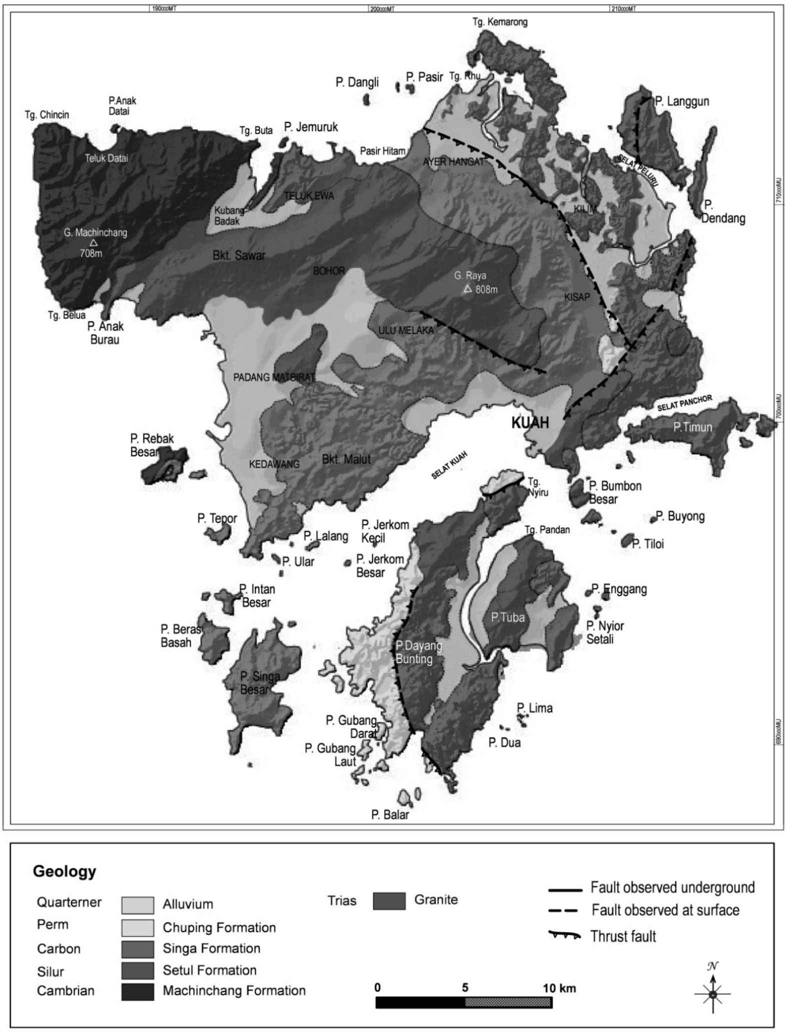
Since it was declared a member of the Global Geopark Network (GGN) under the auspice of UNESCO in 2007 Langkawi has witnessed a steady growth of tourist arrivals at the rate of about 5 to 7 percent a year. The increasing tourism activities also pose more threats to the geosites in particular and other natural resources in general. This paper highlights all the geological resources in Langkawi and the need to protect and conserve them for the sake of sustainability of geo-ecotourism of Langkawi.

BRIEF GEOLOGY OF LANGKAWI

The geology of Langkawi is mainly made up of sedimentary and granitic rocks, which have evolved since the Cambrian time until the latest part of the Paleozoic period. Scrivenor (1911) published the first document of the geology of Langkawi in the Royal Society Journal. In the early days most works were focused on the geological mapping in tandem with the needs in those days to look for the presence of economic minerals. Jones (1973) wrote a lengthy report on the Paleozoic sedimentary sequence and the granitic rock of Langkawi, but the most extensive report about the geology of Langkawi was published in 1981 complete with a geological map on one-inch scale. Since then a wealth of geological research has been undertaken by various local and international geoscientists covering a wide aspect of geology including stratigraphy (Jones 1981; Kamal Roslan Mohamed 2003), sedimentology (Ibrahim Abdullah et al., 2003; Kamal Roslan Mohamed 2003; Che Aziz Ali 2003), geochemistry and mineralogy (Wan Fuad Wan Hassan 2003 a & b), structural geology (Tjia 1989; Ibrahim Abdullah 2003), geomorphology (Zaitun Harun & Juhari Mat Akhir 2003; Juhari Mat Akhir, 2003; Pereira 2003; Ibrahim Komoo & Syafrina Ismail 2003), sea-level changes (Tjia, 1995; Zaitun et al 2003 a & b) ,and paleontology (Mohd Shafeea Leman 2003). Since the inception of the Geological Heritage Group of Malaysia (GHGM) in 1996 research programme has been geared more towards mapping and describing all the geosites in Langkawi. The first fruit of this effort by the GHGM was published a year later in 1997 (c.f. Ibrahim Komoo et al. 1997)

The geology of Langkawi islands today is a result of a very long geological processes that took place under various conditions due to surface and subsurface processes including deposition, tectonic and magmatic events and finally by surface processes such as weathering and erosion that carved the present landscape. Basically the geology of Langkawi is dominated by sedimentary rocks that were deposited since Cambrian to the Permian time (Figure 2) before the deposition was interrupted by the granite intrusion in the Triassic period. The sedimentary formations are the Machinchang, Setul, Singa and Chuping formations.

FIGURE 2 : Geological Map of Langkawi (Modified after Jones 1981)



Machinchang Formation

The oldest rock outcrop in Langkawi is represented by the Machinchang Formation that forms the present day Gunung Machinchang (Ibrahim Abdullah et al. 2003). Patches of the formation outcrops are found at the northeastern corner of the main island, and on Pulau Jemuruk and Pulau Rebak. The rock was formed about 540 million years ago in different environments ranging from delta to shallow sea, when the earth was still barren during the late Cambrian time. Sediments from the hinterland was brought down to the river mouth and deposited in a terrestrial–marine transition environments forming a wide delta covering an area from Tarutao islands in Thailand to Langkawi, and Gunung Jerai and it extend southwards until Selangor where it formed the present day Dinding Schist. Deposition in different type of environments (Lee, 2006) had yielded a wide variety rock types in this formation ranging from the largest grain conglomerate to sandstone and siltstone with minor amounts of shale. In Langkawi most of the sediments that formed the Machinchang Formation were initially deposited in channels with minor presence of inter-channel muddy facies. These channelised facies were later superseded by shallow marine mouth bars and sand bar deposits, which eventually became deeper before the deposition of limestone took place.

This oldest rock in Malaysia and one of the oldest rock formations in Southeast Asia had undergone various types and phases of deformation and metamorphism, which resulted in the rock being invariably metamorphosed. However, owing to the competent nature of the thickly bedded sandstone and quartzite the deformation effects are much less apparent higher up the sequence where several hundreds of meters of totally non-deformed sedimentary rock successions can still be observed.

Setul Formation

Stratigraphically the Machinchang Formation is conformably overlain by the limestone of the Setul formation. The carbonate sediments that formed this rock was deposited in shallow to deep marine settings on a carbonate ramp during the early Ordovician time, about 480 million years ago. Deposition of this limestone began with accumulation of impure calcareous sediments comprising mud, peloidal grains, lime mud and very minor amounts of bioclastic grains (Che Aziz Ali et al. 2003 and 2005). Fossils such as *Hormotoma sp., Helicotoma jonesi, Paleomphalus giganteus, Lesueurilla zonata, Malayaspira rugosa, Endoceras sp., Ormoceras langkawiense, Discoceras chrysanthemum, D. laeviventrum,* and stromatoporoids (Jones 1981) can be found in this unit. This basal unit was later transgressed by a clastic interval consisting of siliceous mudstone and siltstone during the Hattengian transgression that marked the boundary between Ordovician and Silurian (Cocks et al. 2005). The rocks are now deformed and changed to slate, phyllite and quartzite due to tectonics. Graptolites *Monograptus* *sedgwecki, M. convolutes, Dimorphograptus malayensis, Orthograptus vesiculosus, Climacograptus rectangularis, Diplograptus modestus, trilobite Mucronaspis mucronata,* and gastropod *Lophospira* sp. are among the fossils that can be found in this unit (Leman et al. 2005). The deposition of this clastic sediment occurred in deeper marine conditions during high sea level which the carbonate was submerging and being smothered by the clastics.

The sea level dropped again during the Upper Silurian and witnessed the deposition of another calcareous sediments interval mainly consisting of peloidal and with less bioclastic components. The main facies in this unit comprises peloidal packstone, wackestone with minor amounts of peloidal grainstone. Only *Dentalium* sp., *Ormoceras* sp., trilobite and conodonts can be found in this unit (Jones 1981). Some tentaculites can also be seen in the thin section of rock taken from the lower part of this unit.

Early Devonian to Middle Devonian period had witnessed another episode of increasing clastic input due to the increase in sea level. This has brought the accumulation of a thick interval of clastic sediments consisting of mudstone, siltstone and sandstone which have been partly metamorphosed into phyllite and quartzite. *Monograptus langgunensis, Nowakia* sp. and *Styliolina* sp. are among common fossils in this unit. The deposition of this unit marked the end of a sedimentary formation named as the Setul Formation (Jones 1961). A brief break in deposition was postulated to have occurred after the deposition of the upper clastic unit of the Setul Formation but current data from the main land areas indicates that deposition continues with the deposition of a clastic sedimentary formation known as the Singa Formation in Langkawi and Kubang Pasu Formation in Perlis.

Singa Formation

Deposition of the Singa Formation occurred mainly in shallow marine environment during which Langkawi was located within cooler climatic area in southern hemisphere from Late Devonian to Early Permian time. The total thickness of the formation is estimated at 2100m. Jones (1961) named the formation after Pulau Singa Besar for the predominantly dark coloured shale and siltstone widely distributed in the southwestern part of Langkawi Islands. In certain areas very thin alternations between very fine sands and silt appears like varve deposits. This type of deposit could have been deposited alternately during cold and warm seasons that took place in the protected shallow marine environments bringing about sediments similar to temperate lake deposits. The formation also contains various horizons of glacial marine diamictites (Stauffer & Mantajit 1981, Stauffer & Lee 1986, Leman 2000) represented by thickly bedded to massive dark grey to black siltstone and mudstone, containing sporadic clasts of various origin, size, shape and degree of roundness including a foreign one billion years old igneous rock named tronjehmite. The formation also yields various horizons of cold-water brachiopod fauna

(Shi et al. 1987, Leman 2003a). The Singa Formation can be divided into four members i.e. the Rebak, Kentut, Ular and Selang members, from oldest to youngest.

Chuping Formation

Towards the end of Early Permian time Langkawi has witnessed the end of clastic sediments deposition and at the same time the sea was again dominated by carbonate material. The clastic sediments that formed the Singa Formation were slowly replaced by carbonate sediments forming a thick sequence known as the Chuping Formation. Jones (1961) named the formation after Bukit Chuping in Perlis State for the thickly bedded to massive light grey crystalline dolomitic limestone exposed in Perlis and Langkawi Islands. However, in Langkawi Islands, a significant portion of the formation is composed of thinly bedded dark grey bioclastic limestone, particularly in the lower part of the formation (Leman 2003b). The age of the formation is late Early Permian to possibly late Triassic, but only Early to Middle Permian fossils are known in Langkawi Islands. The entire upper half of the formation had undergone a certain degree of metamorphism and is therefore devoid of fossils. The basal part of the formation shows transitional passage bed between siltstone of Singa Formation to limestone bed of Chuping Formation as can be seen on Pulau Singa Besar and Pulau Singa Kechil. The upper boundary of the Chuping Formation is not exposed but overthrusted by older Setul Formation in the eastern part of the Langkawi Island and also in Pulau Dayang Bunting.

Igneous rock

The Paleozoic geological history of Langkawi was terminated by an episode of major granite intrusion that occurred throughout the Malaysian Peninsula in the late Paleozoic to early Mesozoic era. In Langkawi, large and small igneous bodies can be found scattered, particularly in the central part of Langkawi Islands (Wan Fuad Wan Hassan 2003). The two largest igneous bodies are the Gunung Raya and Bukit Sawar granites, which extend out to the base of Gunung Machinchang at Telaga Tujuh. Other granite bodies include the Kuah, Tuba and Dayang Bunting stocks that are comparatively smaller than these two. All these granite bodies are interpreted to belong to the same stock. It has been named collectively as the Gunung Raya Granite and a radiometric dating by Bignell & Snelling (1977) had given a Late Triassic age to this intrusion episode.

GEOLOGICAL HERITAGE RESOURCES AND THE IMPORTANCE OF MANAGING AND CONSERVING GEOSITES IN LANGKAWI

Various geological processes that have taken place since 540 million years ago until now have produced a wide geological diversity in the Langkawi archipelago. The diversities, some of which can be considered as having high geoheritage values are present in many forms ranging from various rock types, geological structures, fossils, minerals, geomorphs, and landscapes. These geoheritage resources are scattered all over the Langkawi archipelago and the place where each of these geoheritage resource occurs is identified as a geosite. More than 90 geosites have been identified in Langkawi (Figure 3; Table 1), some of which have been developed as tourism sites (Tanot Unjah 2009). Each geosite possesses at least one or more special geological heritage feature that defines the geosite. For instance, Pulau Anak Tikus is a special geosite because it hosts the richest Paleozoic marine fossils in Langkawi, while Gua Kelawar is special because of its beautiful cave and also the presence of ancient shells attached to its roof that shows the sea level at about 6000 years ago. This shows that each geosite that had been identified carries important value and is very significant either at national level, regional level or even global level. Some of these geosites have been visited and studied by numerous researchers from all over the world.

FIGURE 3 : Stratigraphic Column of Langkawi (Modified after Kamal Roslan Mohamed 2003).

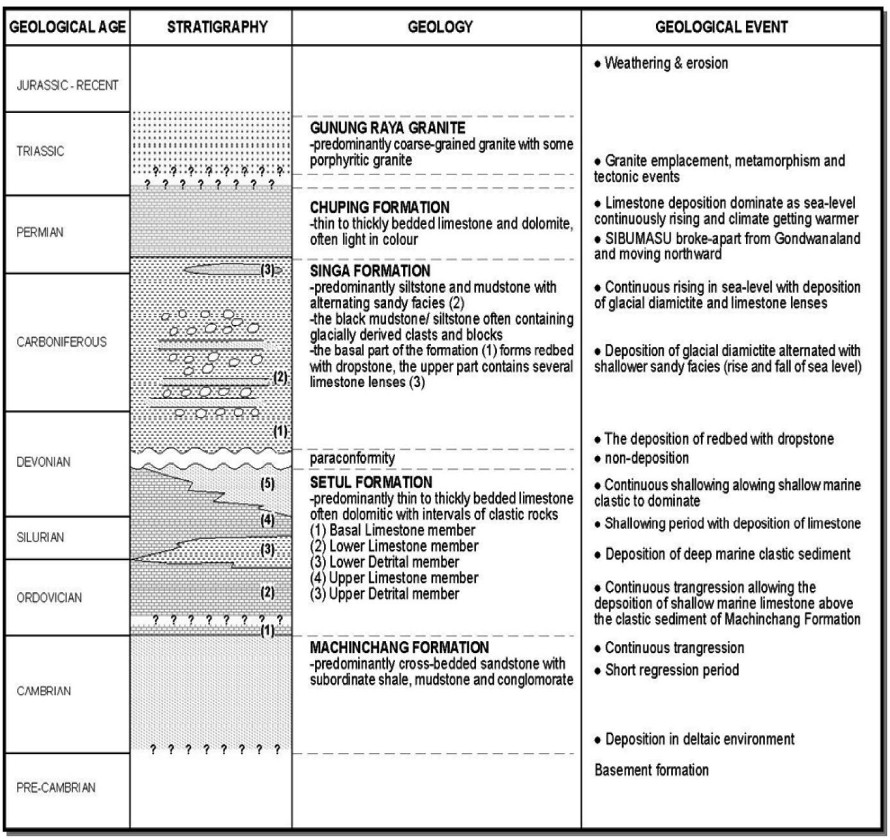


TABLE 1. : List of Geosites Based on Geodiversity and Significance (Modified after Tanot Unjah 2011).

No	Geosites	Geodiversity	Significance
1	Tg. Chinchin – Tg. Buta Sandstone	Rock	Exposed the complete sequence of Machinchang Formation
95	Teluk Mempelam Mudstone	Rock	The only record of basal part of Setul Formation
2	Scarn of Pulau Bumbon	Mineral	Scarn mineral consist of variety of garnets and amphiboles
3	Ilminite Mineral of Black Sand Beach	Mineral	Accumulation of ilminite mineral that forms dark beach
93	Tg Apau mineral	Mineral	Patches of Ag and Silver in Langkawi
96	Tourmaline of Gunung Raya	Mineral	Patches of 120cm2 of tourmaline mineral
15	Glacier Dropstone of Pulau Tepor	Primary structure	Glacier palaeoenvironment during Permian.
16	Cross bedding of Pasir Tengkorak	Primary structure	Shallow marine deposition in Machinchang Formation
17	Kuah Tor	Primary structure	Porphyritic granite underneath the alluvium of Kuah
18	Primary Sediment Structure of Tok Manap	Primary structure	Deltic to shallow marine environment of Machinchang Formation
19	Cross bedding of Pondok Nibong	Primary structure	Shallow marine deposition in Machinchang Formation
94	Scree Breccia of Dayang Bunting	Primary Structure	Angular limestone cemented by sponge tuffa. The evident of underground river during the formation of limestone
20	Boudine of Tuba Granite	Tectonic structure	The only example of granite boudine in Malaysia
21	Recumbent Fold of Tuba	Tectonic structure	An evident of fold that formed the sill and dyke
22	Sill and Dyke of Tuba Granite	Tectonic structure	Plastically deformed granite sills to form tight disharmonic folds
23	Breccia fault limestone of Kisap	Tectonic structure	Crushed Chuping limestone as an evident of Kisap Thrust Fault
24	Recumbent Fold of Tg. Timun	Tectonic structure	An evident of parallel fold to Kisap Thrust

No	Geosites	Geodiversity	Significance
25	Overturn Fault of Teluk Air taun	Tectonic structure	Evident of fault that separate Setul Formation and Chuping Formation
4	Fossil Bed of Teluk Mempelam	Fossil	Age determination for Basal part of Setul Formation and palaeoenviron ment fossil
5	Fossil of Pulau Anak Tikus	Fossil	Rich fossils island representing the early Ordovician ancient life.
6	Graphtolite Fossil of Batu Puyoh	Fossil	Age determination of Silurian fossil
7	Kisap Fossil	Fossil	Abundant fossil significant age as it corelated to Chuping Formation
8	Kilim Fossil	Fossil	Abundant cold climate fossil significant in palaeoenvironment during Early Permian.
9	Jemuruk Island Fossil	Fossil	Age and stratigraphical correlation for upper part of Machinchang Formation
10	Fossil of Bukit Tekuh	Fossil	Abundant cold climate fossil significant in palaeoenvironment during Early Permian.
11	Fossil of Bukit Asah	Fossil	Record of palaeoenvironment and palaeobatrymetri as well as palaeo biogeography and palaeoclimate fossil.
12	Kuah Fossil	Fossil	Abundant cold climate fossil significant in palaeoenvironment during Early Permian.
13	Fossil of Pulau Langgun	Fossil	Reference specimen of fossil that recorded the palaeoenvironment and plaeobatrymetri of Setul Formation
14	Fossil of Pulau Jong	Fossil	Age determination for stratigraphical correlation of Chuping Formation during Permian.
26	Machinchang Range	Landscape	Rugged range with sharp peak formed by Cambrian rock
27	Gunung raya	Landscape	Highest peak of Langkawi at 807m high, part of hornfel roof-pendant features.

No	Geosites	Geodiversity	Significance
28	Seven Well Waterfall	Landforms	Waterfall with 7 huges pot holes of which the name came from
29	Durian Perangin Waterfall	Landforms	Waterfall that exposed the Singa Formation
30	Lubuk Semilang Waterfall	Landforms	Waterfall mix with cascade at granite rock
31	Temurun Waterfall	Landforms	The highest waterfall in the island at 150m exposed the Machincang beds
32	Telaga Ayer Hangat	Landforms	Hot spring along the fault lines
33	Teluk Datai Beach	Landforms	Long curve beach with golden fine grain sand. The best quality in Langkawi
34	Teluk Burau Beach	Landforms	Pocket sandy beach mixed with rocky beach made of granite
35	Teluk Baru Beach	Landforms	Small pocket beach of fine sand near to fishing village
36	Teluk Yu Beach	Landforms	Local small linear sandy pocket beach sometimes intruded by large granite boulder
37	Batu Hampar Beach	Landforms	Pocket sandy beach
38	Kok Beach	Landforms	White sandy beach with granite boulder
39	Chenang Beach	Landforms	Longest linear sandy beach at Langkawi at 1.5 km
40	Tengah Beach	Landforms	Adjacent to Chenang Beach is a mixed of sandy and rocky beach at 1km long.
41	Dato' Syed Omar	Landforms	BeachPocket sandy beach Kuah
42	Tg. Rhu Beach	Landforms	Sandy beach and a cove surrounded by limestone hill
43	Pasir Hitam Beach	Landforms	Dark ilminite beach close to fishing village
44	Pasir Tengkorak Beach	Landforms	Golden pocket sandy beach and rocky beach
45	Beringin Beach	Landforms	Pocket beach surrounded by wall of limestone and granite side by side
46	Karren-like features granite	Features	Direct waves action on granite crafts a karren-like features that is common in limestone

No	Geosites	Geodiversity	Significance
47	Granite Residual Island	Landforms	An almost oval shape like residual granite. Also the only one in Langkawi
48	Ular Abrasitional platform	Landforms	A huge abrasional platform crafted by waves on sedimentary rock
49	Tg. Dendang Ancient Sea Notches	Features	A 23m high sea notch, highest record of ancient sea level, circa 7000 years old.
50	Mahsuri Ring	Landforms	Two large rounded features cause by meteorite impact, only visible from the Gunung Raya
51	Singa Kecil Mogote	Landforms	A top rounded limestone or mogote of Chuping Formation lies on the top of Singa Formation
52	Kubang Badak Pinacle	Landforms	A wall of limestone cliff with sharp pinnacle
53	Karst Kilim (Limestone Hill at t he East of Kilim)	Landforms	Series of tropical limestone hills surrounded by mangrove
54	Sungai Siam Caves	Landforms	Limestone caves with features located at 25m above current sea level.
55	Sg. Banjar Limestones cave	Landforms	Caves in the limestone
56	Layang Limestones cave	Landforms	Limestone caves with caves features and sea shells.
57	Pasir Dagang Limestones cave	Landforms	Caves in the limestone, displayed numerous features.
58	Langsiar Limestones cave	Landforms	Limestone caves with entrance approximately 80m from current sea level
59	Gubang laut Limestones cave	Landforms	Hollow features leave by the erosion in limestone
60	Gubang Darat Limestones cave	Landforms	An ancient and current sea caves
61	Kelawar Limestones cave (Sg. Kilim)	Landforms	Limestones cave known to host a numbers of bats.
62	Kelawar Limestones cave (Pulau Tuba)	Landforms	Limestone caves with caves features

No	Geosites	Geodiversity	Significance
63	Tg. Dendang Limestones cave	Landforms	Limestone cave connected to sea caves 20 metres below.
64	Balai Limestones cave	Landforms	Limestone caves with chambers
65	Langsir Limestones cave	Landforms	A small underground tunnel that connects the large lake to the sea
66	Nau Limestones cave	Landforms	Limestone caves
67	China Limestones cave	Landforms	Limestone caves
68	Asam Limestones cave	Landforms	Limestones cave
69	Tembus Limestones cave	Landforms	Tunnel in the limestone area
70	Cherita Limestones cave	Landforms	Two chambers cave at two seperate levels, closely related to the local myth Garuda (bird) and the Chinese Princess
71	Teluk Udang Limestones cave	Landforms	Limestone caves located at more than 80m from today sea level
72	Teluk Dedap Limestones cave	Landforms	A tunnel connecting a bay with calm turquoise water to a doline intermittently filled with marine or brackish water
73	Tok Jangkit Limestones cave	Landforms	Limestone caves with basic chambers hidden in the limestone hills.
74	Tok Sabung Limestones cave	Landforms	Limestone caves with two chambers
75	Dangli Limestones cave	Landforms	Limestone caves with fabulous caves features
76	Siam Limestones cave	Landforms	Limestone caves at the main land with archeological remains.
77	Pinang Limestones cave	Landforms	Limestone caves with sea shell located 25m above current sea level
78	Pulau Lima	Landscape	Clusters of limestones island with sea archs, depth sea notch and sea caves. Own the highest sea arch at 15m above current sea level.

No	Geosites	Geodiversity	Significance
79	Bukit Kecil Limestones cave	Landforms	Limestone caves with c omparativelyshallow chamber and low ceiling
80	Bukit Putih Limestones cave	Landforms	Limestone caves with faboluos white stalactites and stalacmites. Current stream running through the caves
81	Landak Limestones cave	Landforms	Limestone caves with caves features. The mouth located 20 metre bellows the land.
82	Dukung Adik Limestones cave	Landforms	Limestone caves with basic caves features. The mouth close to the sea
83	Buaya Limestones cave	Landforms	Limestone caves at 2 meter for the limestone tunnel. Preseved layer of ancient sea shell.
84	Batak Limestones cave	Landforms	Limestones caves
85	Asam Limestones cave (K. S. Kisap)	Landforms	Limestone caves
86	Lake of Dayang Bunting	Landforms	The biggest fresh water lake in Langkawi, formed by a collaped doline
87	Langgun Lake	Landforms	Second largest fresh water lake in Langkawi.
88	Pulau Langgun Landscape	Landscape	A structured control limestone island
89	Pulau Singa Besar Landscape	Landscape	An island landscape dominated by mudstone and shale
90	Pulau Anak Datai Landscape	Landscape	The oldest strata of Machinchang formation, remnant island and numerous features such as sea caves, sea arch, sea stacks and spit
91	Pulau Rebak Tombolo	Landforms	A 1km long tombolo connected the Pulau Rebak Kecil and Pantai Chenang
92	Wang Buluh Caves	Landforms	Limestone caves with numerous caves features
97	Pulau Dua	Landforms	Clusters of limestone island with dinasour like sea arch.

Geosites in Langkawi archipelago can be divided into at least four (4) categories depending on the underlying geology where the geosites occur. Geosites on granites are normally related to the weathering and erosional features that was produced after the rock was exposed to the surface. Rare and unique features like tafoni, solutioning grooves due to wave erosion along weak zones or minerals, strangely shaped granite torrs and remnants of erosion processes have aesthetic and recreational values and at the same time have become subjects of scientific studies especially for those who want to study the tropical weathering on granite terrain (Ibrahim Komoo and Tanot Unjah 2003; Tanot Unjah 2011). Such interesting and significant features can be found at Burau Bay, Pulau Anak Burau and also along the northern coast of Pulau Dayang Bunting and around Kuah town.

Geosites on clastic sedimentary rocks are normally related to the clastic rock diversity, fossil content, sedimentary and secondary structures, metamorphic minerals at places where the rock has been metamorphosed and also weathering and erosion features that embody the whole landscape of this rock type. Those geosites can be found scattered all over the area underlain by the Machinchang and Singa Formation on the main island and also on the islands in the southern part of the archipelago. In the Machinchang area, geoheritage features such as sedimentary structures that were created when the sediments were deposited in the shallow sea occured in very excellent condition and according to some experts they are the best textbook examples found in the country. These features can be found at several geosites along the coast from Teluk Belua to Tanjung Buta in the northwestern part of the main Langkawi island. Many more geosites occur in areas underlain by the Singa Formation on smaller islands in the southern part of the Langkawi archipelago such Pulau Tepur, Pulau Singa, and Pulau Beras Basah. These geosites on the Singa Formation possess high value geoheritage resources which tell the earth history during the formation of the rock itself. Geoheritage resources such as fossils of shallow marine life, sedimentary structures and the variation in the sediment patterns give us clues as to what happened during the Middle Paleozoic time. Some geosites around Kuah area (e.g. Batu Asah) and Sungai Itau are associated with fossils of cold water marine fauna that thrived in the area during that time. Fossil and lithofacies evidences show that Langkawi at that time was influenced by cold climatic condition in the southern hemisphere (Mohd Shafeea Leman 2003). Some geosites of the Singa Formation on the smaller islands also show the same evidence such as at Pulau Tepur, which show the presence of the oldest piece of rock that was brought to the area by floating ice and dropped to the bottom of the sea when the ice melted. The so called dropstone was dated using radiometric dating by the previous researcher (Jones, 1981) and accorded an age of about 1 billion years old. This very rare and internationally significant geological resource should always be protected and be made an icon of the geological heritage of Langkawi. Some geosites on the Singa Formation are associated with geomorphic and landscape features that resulted from weathering and erosion on the surface. Features such as remnant islands and erosion platforms are commonly seen on the smaller islands as well as along the southern coast of Langkawi island. The most outstanding landscape feature on the Singa Formation is Pulau Ular where weathering and marine erosion (especially wave and tide) have carved the island into a swimming snake when viewed from far (Ibrahim Komoo & Syafrina Ismail 2001). Pulau Ular can become a good example of a very outstanding geosite where in one small place a combination of several geoheritage resources can be found including beautiful scenic landscape, rare shallow marine cold water coral, u-shaped arenicolites and other trace fossils, sedimentary structures including channelised sandstone and varve, quaternary faults, and synsedimentary deformation features. This geosite is now considered as the most beautiful and outstanding geological monument that carries the highest scientific, aesthetic as well as recreational values. However, this highly regarded geosite is under threat and have been partly disturbed by structural development.

Limestones in Langkawi bear the most interesting geological heritage features of all. As shown in Figure 2, limestones of Langkawi are concentrated in Kilim-Kisap and Dayang Bunting areas. Most of them belong to the Setul Formation. Chuping Formation is only dominant in the western part of Pulau Dayang Bunting and in the north of Kuah Town. Due to its meta-stable condition the rock can be easily modified and shaped into various unique landscape and morphologies by weathering processes. This has resulted in a wide range of geoheritage resources in those areas.

Kilim-Kisap and Dayang Bunting areas are characterised by rugged but beautiful karst landscapes and seascapes. Unique limestone morphologies in the shape of dome, pinnacle, table, cone, pillar and messa and fresh water lake are common features in these areas (Figure 4). Some morphology are so strange that they resemble certain objects that we commonly encounter in life such as human face, animals, ship, etc. Large and small limestone caves laden with unique and beautiful cave features are also commonly found in Dayang Bunting and Kilim areas.

FIGURE 4