

THE INVENTORY OF PRELIMINARY GEOLOGICAL SITES ASSESSMENT IN MYANMAR

Myint Soe¹, Naw Diana², Zaw Win Lwin³, Ye Myint Swe⁴

1, 2, 3, 4 Department of Geological Survey and Mineral Exploration, Ministry of Natural Resources and Environmental Conservation, the Republic of the Union of Myanmar.

ABSTRACT

This study focuses on different geological sites inventory data in Myanmar. This inventory include geological sites of regional and local relevance. Presently, Myanmar has not yet collected inventory of geological sites database. There are no brochures, no inventory of geoconservation potential, no map, no written geological site books and research papers in Myanmar. It is also expected that this work will contribute to create an increasing public awareness on geological heritage, as an important natural resource with major strategic importance. The geological sites were classified as lithological sites, geological or geomorphological landscapes, caves and grottos, mineral sites, historical mine sites, fossil sites, geohazard sites and geological environments that support an ecosystem and meteorite impact sites. This preliminary study collected 70 geological sites for preliminary assessments and we describe some of geological sites in Myanmar.

Keyword: Framework list, Geological sites in Myanmar, Issue and challenge

INTRODUCTION

Geological sites (geosite) called geological heritage are tangible materials such as rocks, fossils, minerals, sedimentary sequences, or structures, mountain ranges, rift valleys, great escarpments, volcanoes, karst landscapes and arid environments that reveal an event, process, or occurrence during the evolution of Earth in which there are results and/or documents of significant events in the geological history (Nizamettin et. al., 2015). Geological heritage sites can play an important role in the economic development of local communities through, for example, geological tourism. The geological sites also give aesthetic value of natural landscapes.

In 2008, CCOP (Coordinating Committee for Geoscience Programmes in East and Southeast Asia) published “Geoheritage in East and Southeast Asia”. The aim of this first

book, written for the general public, was to promote interest in the earth sciences by introducing and explaining some of the many wonderful geological sites to be seen in the various countries of the region. And then, CCOP continued to publish *Stone Heritage of East and South East Asia* in 2015. But Geoheritages, geological sites and stone heritages of Myanmar have not included in these books. Because Myanmar participated in CCOP as an observer in 2014 and became a full CCOP member at the 64th CCOP Steering Committee Meeting held in Krabi, Thailand in March 2015. Moreover, Department of Mineral Resource (DM) published *the Invaluable Natural Heritage Thai Geological Site* book on June 2015. These books are very interesting and motivated us to collect geological sites data assessment in Myanmar and we would like to fill the black place of Myanmar in future.

Presently, Myanmar has not yet collected inventory of geological sites database. There are no brochures, no inventory of geoconservation potential, no map, no written geological site books and research papers in Myanmar. Moreover, several large tourist attractions are pagodas and beaches in Myanmar. Geological heritage and/or geological sites can raise national income of a country and their existence adds value to a region. Their determination requires a high level of geological knowledge and expertise. It is expected that we should research, protect, and exploit geological sites for the benefit of society. Department of Geological Survey and Mineral Exploration (DGSE) has been collaborating with the Geological Society of Myanmar in promoting the geological site initiative in Myanmar.

OBJECTIVES

One of the main goals of the paper is to establish an inventory of the most important Myanmar geological sites, under the scientific point of view. In a near future, national authorities will consider this inventory as a technical support for the implementation of nature conservation policies and land use strategies. The research aims to select geodiversity sites with potential tourism value and facilitate the establishment of national and UNESCO global geoparks in Myanmar. This research project will attempt to get adequate inventory of geoheritage and geodiversity of tourist value in Myanmar. It will also suggest strategies of management and interpretation of its geodiversity in order to contribute to the sustainable development of the country, to facilitate geotourism in Myanmar and also to establish National and UNESCO global geoparks in the future. This research will support CLMTV (Cambodia-Laos-Myanmar-Thailand-Vietnam) geoscience projects.

METHODOLOGY

There are numerous papers on the evaluation of geosites worldwide (e.g. Henriques et al., 2011, Tomic, 2011, Vujicic, et al. 2011, Boskov, et al., 2015). The Geosite Assessment Model (GAM) was created according to several existing evaluation methods and most of the criteria proposed for the numerical assessment were taken from extant literature on the field. The complete structure of GAM specified base on the indicators such as scientific/education, scenic/aesthetical and protection value and functional and touristic value (Reynard et al. 2007, Pereira et al. 2007). In this study, we also consider the Geosite Assessment Model (GAM) indicators.

A new classification of geoparks has been created based on the conventional division of geoscientific disciplines such as stratigraphy, palaeontology, geomorphology, volcanology and engineering geology (Zhao Ting & Zhao Xun 2007). This paper, evaluation of the chosen localities is based on the preliminary geological site assessment model by Zhao Ting & Zhao Xun 2007. According to this new classification system, the geological site of Myanmar can generally be subdivided into different categories.

The geological sites were classified as lithological sites, geological or geomorphological landscapes, caves and grottos, mineral sites, historical mine sites, fossil sites, geohazard sites and geological environments that support an ecosystem and meteorite impact sites. Geological site selection criteria means that only a single criterion such as size, accessibility, scientific value, geotourism appeal, educational value, historical significance, cultural, spiritual and social value, economic value, international significance, link with biodiversity and aesthetic quality may be sufficient to recognize the outstanding character of a geological site.

Table 1. List of geological site selection criteria in which only a single criterion may be sufficient to recognize the outstanding character of a geological sites.

TYPE OF SITE	DEFINITION	SELECTION CRITERIA	EXAMPLES
LITHOLOGICAL SITES (VOLCANIC ROCK AND IGNEOUS ROCK SITES)	Outcrops with outstanding value in terms of composition and stratigraphic, phenomeno-logical, petrologic, structural, tectonic or historical significance	Scientific value. Refuge for rare species. Vulnerability. Educational value. Palaeo-biodiversity.	Mt. Popa Volcano, Volcanic rocks columnar Joint Hot spring Kyaiktiyo pagoda

GEOLOGICAL OR GEOMORPHOLOGICAL LANDSCAPES	Site that represents a significant record of the geological history or landscape evolution. It may be a particularly beautiful geological formation, or an example of harmonious development.	Historical significance. Educational value. Scientific value. Vulnerability. Geotourism appeal. Aesthetic quality. Economic value.	Hpa an Karst land form Kayah Karst landform Waterfalls Zalon taung mountain Nawbubaw
CAVES AND GROTTOS	These are natural openings. Grottos form as a result of geodynamic processes such as the freeze/thaw cycle. Caves form because of the dissolution of calcium carbonate.	Scientific value. Geotourism appeal. Vulnerability. Educational value. Refuge for rare species. Economic value. Paleo-biodiversity.	Sadan cave Htan san cave Hpa an caves Kyah caves Son Hein
FOSSIL SITES	Outcrops that contain well-preserved fossils, and that have an Outstanding value in terms of stratigraphy, palaeobiology, aesthetics, or else represent a specific ecosystem.	Scientific value. Vulnerability. Educational value. Palaeo-biodiversity. Economic value.	Padauk Pin Coral Reef Htansan Coral Reef Dattaw Taung Fossil
GEOHAZARD & GEOLOGICAL ENVIRONMENTS THAT SUPPORTS AN ECOSYSTEM TECTONIC STRUCTURE	Site that, given its mineral or geochemical composition, becomes a refuge for rare or threatened species of wildlife or vegetation.	Link with biodiversity. Precious character. Representiveness. Scientific value. Geotourism appeal. Economic value.	Sagaing Acitve Earthquake Geohazard Indawgyi Lake Yega Sag Pond Innle lake
MINERAL SITES (Mineral Deposit and Mining)	Outcrops that contain several types of minerals of outstanding value in terms of composition and crystallo-graphic, petrologic, aesthetic or historical significance.	Scientific value. Vulnerability. Educational value. Economic value.	Mogok gemtract Manganese mines. Bawdwin lead-zinc mine Mawchi tine and tungsten mine Monywa copper mine

The approach used for the geological sites assessment research paper is based on both the recovery of data from previous surveys and internet website as well as the desktop detection of new sites by means of remote sensing techniques. These remote sites are identified by satellite images and GIS and conceived as a preliminary task to be later validated in the field.

The first task concerning the inventory concluded with the definition of the frameworks representing the most important geological features in Myanmar and covering

the different types of geological sites, like paleontological, petrological, geomorphological, stratigraphy, mineralogy, volcanism, hydrogeology, geothermal, old mine sites, tectonic or stratigraphic heritage. We have discovered and listed literature review and consultation, and then detailed description in field and assessment of the value for selected geological sites. All spatial information together with the attributes have been used to create a multi relational Database and a GIS with geological sites symbols, libraries, multi users maps, as well as other selective either digital or printed products on demand.

GEOLOGICAL SITES ASSESSMENT IN MYANMAR

Myanmar is very rich in natural resources and has many spectacular geological features, such as the beautiful Mt. Popa Volcano, Mt. Khakaborazi (the highest mountain in Myanmar), Myeik Islands (Southern Myanmar Coastal), Limestone caves in Kayin state, Inlay lake, Indawgyi lake, Yekhar Inn (Fault sag ponds), Twin taung volcanic lakes, hot springs, and waterfalls, all of which should be conserved and protected by local authorities, the private sector and local communities. This study collected 76 geological sites for preliminary assessments and we have described some of geological sites in Myanmar.

VOLCANIC AND IGNEOUS ROCK SITES

Mount Popa

Mount Popa (Heart of Myanmar / Great Mountain of Myanmar) is located in the middle of the Central Burma Belt between latitude 20° 48' to 20° 58' N and Longitude 95° 11' E to 95° 18' E. Mt. Popa is an ancient volcano. It has a horse shoe shape as its northern slope was blown away by violent explosion at a later phase of volcanic activity. Crater is measured approximately one mile in diameter from rim to rim and about 1968 ft (599.8 m) in depth. Cumming et al. (2009) estimated 4.3 million years by ⁴⁰K / ⁴⁰Ar dating method. The summit is 4981 feet high above sea level. Two main kind of volcanic rocks are several lava flows locally forming plateau like topography. Pyroclastic rocks include tuff, ignimbrites, pozzolan and lahar deposits. Kaolinite, bentonite, Manganese veins, agate, carnelian and specular hematite are found at Popa area. Taunggalat lying at the west is an isolated hill which was a neck of a subsidiary volcano. The fabulous Mt. Popa is not only rich with legends but also with resources for earth scientific research. Mt. Popa area is a geologically interesting place forming as an ancient volcano composed with various kinds of volcanic rocks and typical volcanic landform. It is necessary to preserve these resources and make good use of them for the benefit of future generations. Myanmar Geological Society (MGS)

has reported that the Government of Myanmar is planning to nominate Mount Popa for inclusion on the list of UNESCO Global Geopark in 2019.

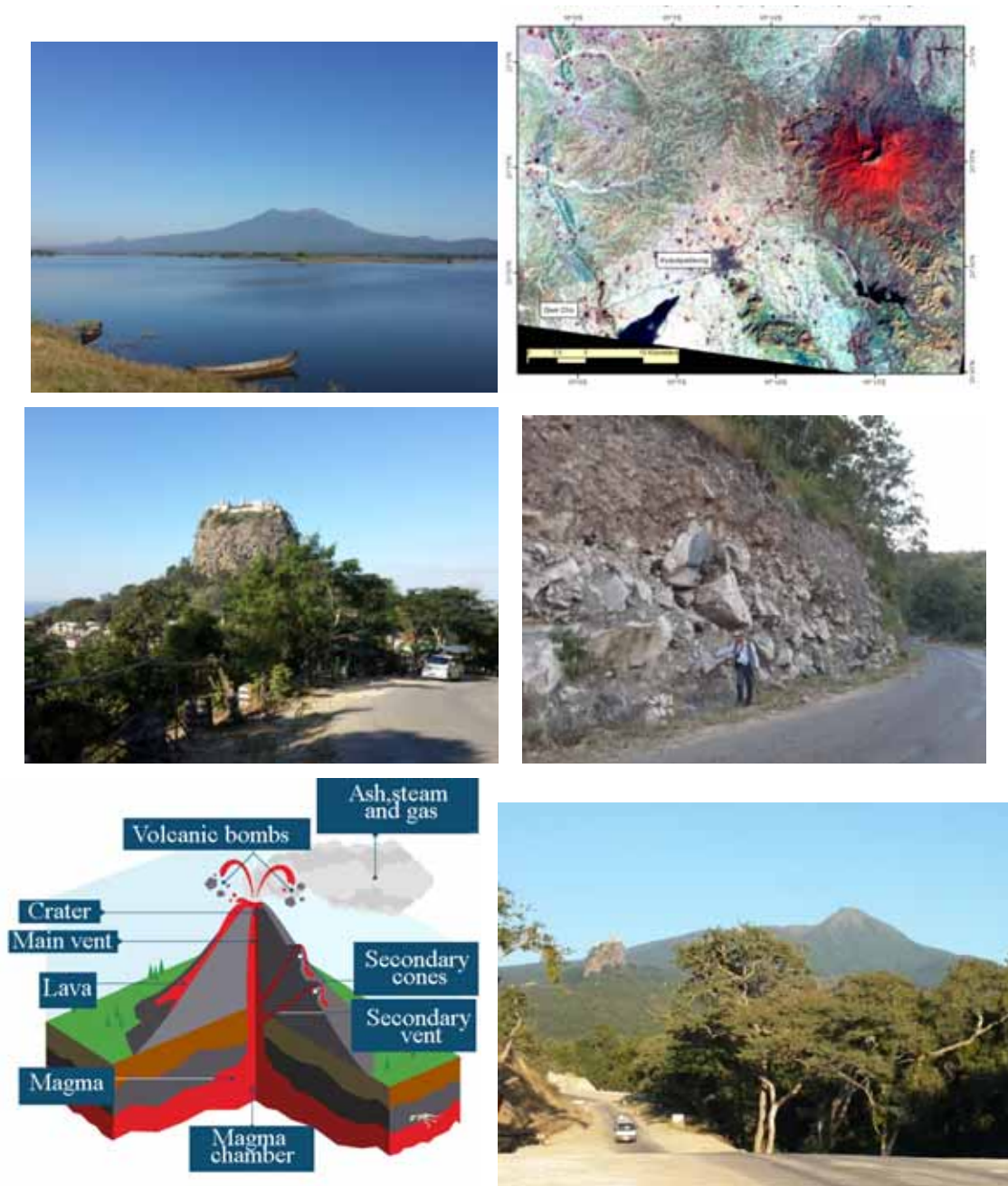


Fig. 1 Photos showing Horse shoe shape Mount Popa Volcano, Central Myanmar.

Twin Taung Lake

The Lower Chindwin is an area of around seven or eight explosion craters, located some 30 km (20 mi) northwest of the town of Monywa in the Sagaing Region, Myanmar. The volcanoes originated from the late Pliocene and Pleistocene times. The major rock types

of the group are Basalt, Rhyolite, Dacite and Andesite. Three to four craters have lakes, one of which is east of the Chindwin River, the others are to the west. The eastern lake is named Twin Taung (or Twindaung), the others Taung Pyauk, Twyn Ma and Yay Khar. In the lakes the cyanobacteria *Spirulina* (often called blue-green algae) grows. It is harvested, dried and sold as medicine. At the end of 2014 it was reported that the Government of Myanmar planned to nominate Twin Taung Lake for inclusion on the list of UNESCO World Heritage Sites.

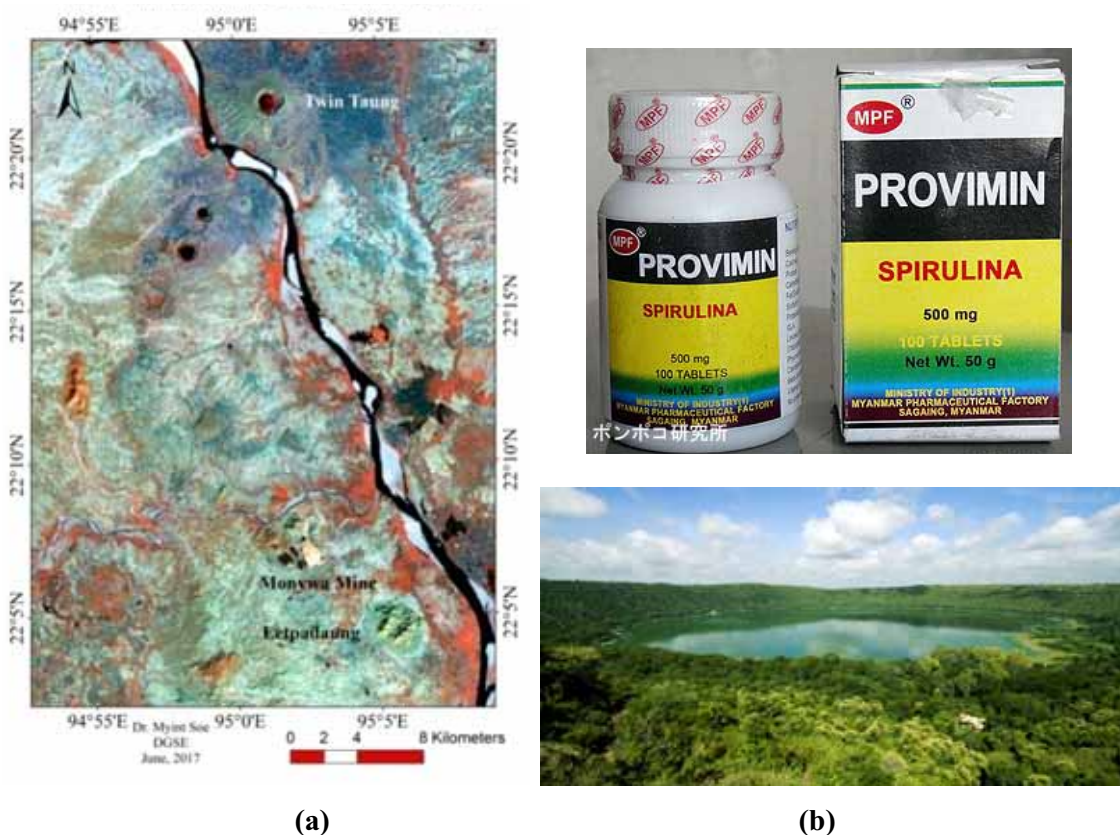


Fig.2 (a) Satellite Image show Twin Taung & Monywa Mine and (b) PROVIMIN was produced by Spirulina from Twin Taung.

Spectacular columnar joints

Theinni Spectacular columnar joints can be seen within the upper part of a basaltic lava flow in Theinni township, Northern Shan State. These columnar joints were formed when liquid lava form magma. Most of columns are straight with diameters up to maximum of about one meter. The length of the column may extend up to 8 metres and most tend to have 5 or 6 sides but sometimes have as few as 3 or as many as 8 sides.

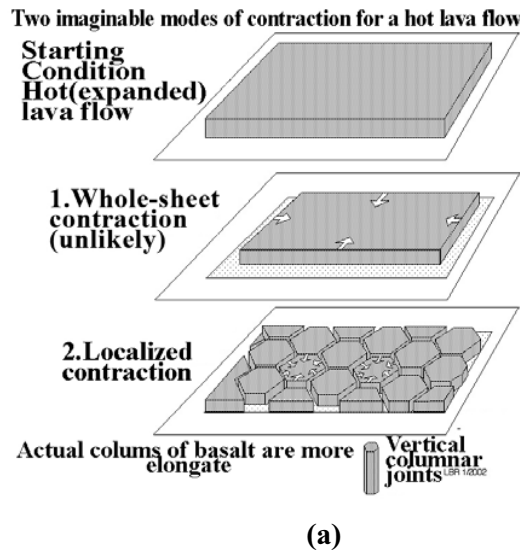


Fig. 3 (a) Two imaginable modes of contraction for a hot lava flow and (b) Columnar joints in basalt (hexagonal prism) exposed at near Naypyitaw, capital city of Myanmar.



Fig. 4 Columnar joints in basalt (hexagonal prism) exposed at Theinni Township, Northern Shan State

Hot Springs Diversity

A hot spring is a spring produced by the emergence of geothermal heated groundwater that rises from the Earth's crust. There are geothermal hot springs in many locations all over the crust of the earth. Most of the hot springs is located in and around the

igneous (granite) alignments in Myanmar. In some cases, hot water and steam bubbles up from the spring bed, rising through fissures, fractures, faults, and joints of the surrounding rocks. The preliminary investigations have recently begun on 43 hot springs in 16 areas (Tin Tun Aung, 1988). The main theme of the hot spring geosite is to enable visitors to understand natural earth processes and to reflect on living in harmony with nature.

Naypyitaw Hot Spring

Naypyitaw hot spring is situated in the eastern mountains of Nay Pyi Taw, about 1h 30 to 2 hours from the Nay Pyi Taw city. This place is situated right in the middle of the mountain and is only accessible by car for a day return trip. The road will be impressed by the super views landscape of the mountains. There are also a few swimming pools in the resort, where you can enjoy the hot water. The temperature of hot water is about 98°C. Egg boiling in these hot water has become a novel specialty of the area. The Nay Pyi Taw hot spring is located on the granite intrusion.

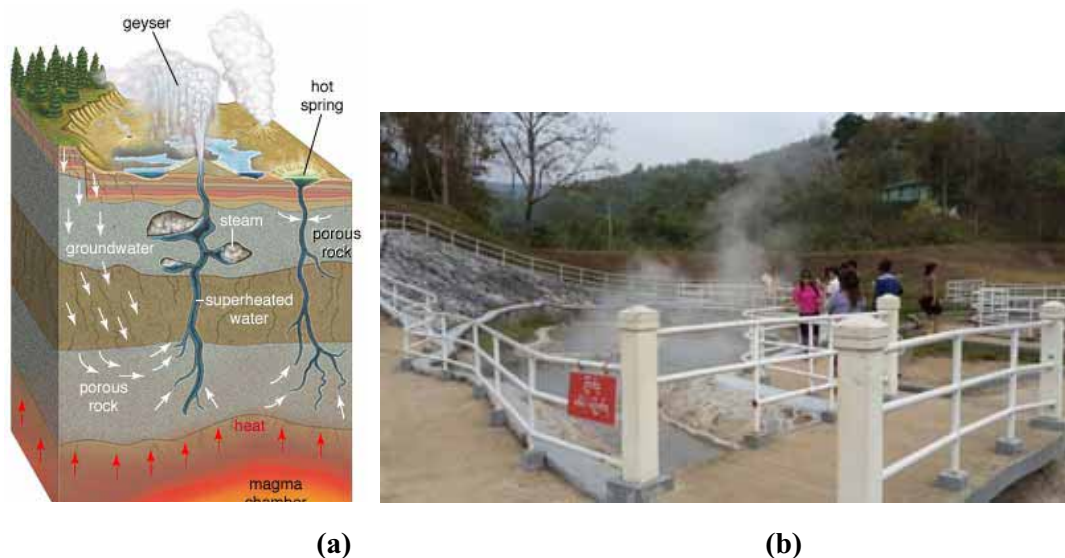


Fig. 5 (a) Hot spring model and (b) Naypyitaw hot spring near Naypyitaw capital of Myanmar

GEOMORPHOLOGY AND LANDSCAPE

Landscapes of geotourism interest include mountain ranges, rift valleys, great escarpments, volcanoes, karst landscapes and arid environments. Geological materials include rocks, sediments, and fossils. Geotourism is tourism that sustains or enhances the

geographical character of a place, including its environment, culture, aesthetics, heritage, and the well-being of its residents. The idea is to determine the list of geologically and geomorphologically important makers in Myanmar by geoconservation to represent them in the best possible way for scientific purposes, but also to determine their potential for the development of tourism.

Karst landforms are strongly developed in Hpa-An, Kain State and Loikaw, Kayah State because of the wide occurrence of carbonate rock containing well developed cracks and joints. The formation of karst is controlled partially by uneven rainfall and differential daily or seasonal temperatures.

Mergui Archipelago in Myanmar is one of the least explored archipelago islands in the world. This archipelago of islands counts around 800 small uninhabited islands that all have crystal clear water and white sand beaches filled with coconut trees. Most people have not yet noticed that Myanmar has some of the most beautiful beaches and islands in Myanmar’s Mergui Archipelago, Southern part of Myanmar. (eg. Kyun Phi lar, Lampi Island, Macleod Island and Nyaung Wee Island). This area offers one of the most beautiful diving sites in Myanmar.

Kyaiktiyo Pagoda / Golden Rock Pagoda

Kyaiktiyo Pagoda also known as Golden Rock pagoda is a well known Buddhist pilgrimage site in Mon Statge, Myanmar. It is a small pagoda (7.3 meters (24 ft)) built on the top of a granite boulder covered with gold leaves pasted on by its male devotee. The balancing rock seems to defy gravity, as it perpetually appears to be on the verge of rolling down the hill. The rock and the pagoda are at the top of Mt. Kyaiktiyo. There are numerous granite boulders on the mountain, perched in precarious condition. It is the third most important Buddhist pilgrimage site in Myanmar after the Shwedagon Pagoda and the Mahamuni Pagoda. Homogeneous granitic plutons are created in high pressure environments and slowly solidify beneath the earth’s crust. Vertical compression of overburden releases through erosion, or removal of overlying rocks resulting in unloading. Other contributors of unloading are tectonic uplift and mass wasting. The pressure is relieved when the granites is exposed at the surface, allowing to expand toward the atmosphere. Water seeps into these joints eroding the rock at these seams. The more water that can get in, the faster the crack widens. The large feldspar crystals are altered by acidic water and become kaolinite, a soft clay mineral. The granite blocks that do not erode away are left in place and referred to as core stones.

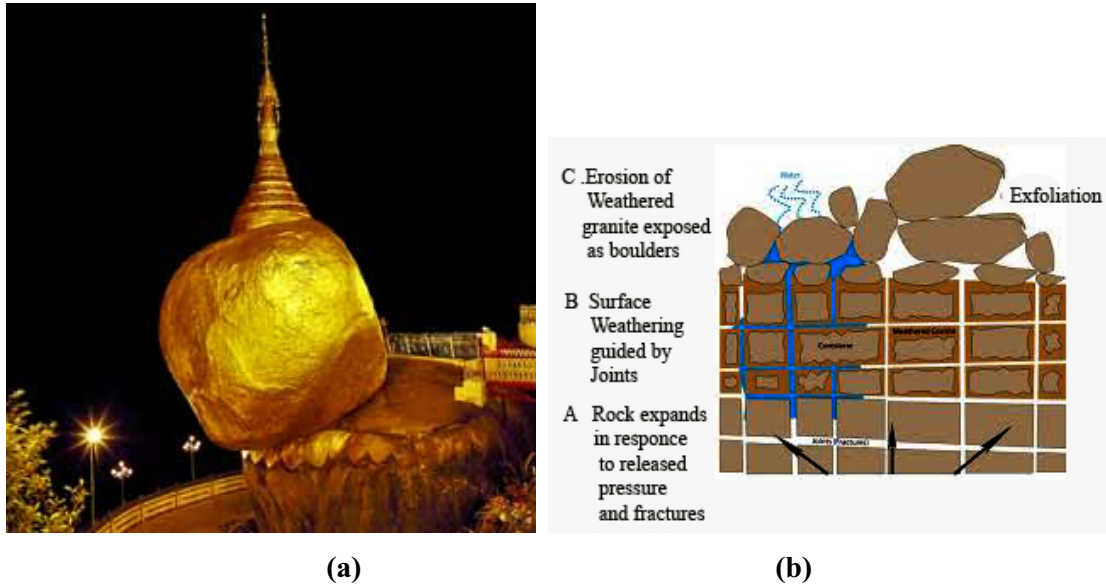


Fig.6 (a) Kyaiktiyo Pagoda and (b) Erosion of Weathered granite exposed as boulders

Amazing Zalon Taung Pagoda

Zalon Taung pagoda is located 12 miles North West of Banmauk Township, Sagaing Region. The granite mountain morphology which looks like on elephant is very fantastical and charming on visitors. Zalon Taung pagoda is similarly to Kyaiktiyo pagoda and a well known Buddhist pilgrimage site in Banmauk area. Therefore Zalon Taung pagoda has become a popular pilgrimage and also tourist attraction.



Fig. 7 Zalon Taung pagoda which well known Buddhist pilgrimage site in Banmauk Area, Northern Myanmar.

Naw Bu Baw Mountain

The old British hill station of Thandaung Gyi in Myanmar’s Kayin State boasts the kind of dramatic setting out of which strange legends are born. On the edge of town juts the highest point in the Dawparkho Range, a craggy 1462-metre (4824-foot) peak that on clear days provides great views of forest-covered mountains in all directions. Naw Bu Baw’s Mountain, as it is known locally, is now topped by what must be one of the biggest Christian crosses in Myanmar. Thandaung is a romantic place. It is in the Kayin State and is inhabited mainly by the lovable and simple Bwe Kayin (Karen) people who are mostly Christians.



(a)

(b)

Fig. 8 (a) Nawubaw Mountain, Thandaung Gyi area and (b) Karst Limestone Mountains from Hpa –An Area



(a)

(b)

Fig. 9 (a) Labutta beach at Ayeyawaddy delta and (b) Marine life in Myanmar’s Mergui Archipelago.

Waterfall Landform Diversity

Most waterfalls in Myanmar are located where highly resistant bedrocks such as granite, sandstone, limestone and other highly siliceous sedimentary and metamorphic rocks. Many would say that Myanmar’s most beautiful landform is the waterfall, and most of impressive waterfalls lie around Pyin U Lwin, Northern Shan State. Four waterfalls were selected for detailed analyses of their geotouristic potential. They are Anisakan waterfall, Pwe kauk water fall, Nam Tok waterfall and Zin Kyaik waterfall. To each of these geosites values for their geodiversity were attributed considering their intrinsic characteristic, cultural, aesthetic, economic, functional and scientific/educational aspects.

Anisakan waterfall, Pyin U Lwin

This breathtaking waterfall is around 120m high. To put this into perspective, the puny niagara falls are only around 50m high. Take a dip in the plunge pool at the bottom of waterfalls is a very pleasant on. And just getting damp in the spray is enough to feel the power of these falls.

Pwe Kauk Water Fall, Pyin Oo Lwin

Pwe Kauk waterfall which is not too far from Pyin Oo Lwin town, northern Shan State. There are two waterfalls in Pwe Kauk, both are not too big/high and the water is not strong, so it is very good for people to swim or play with water. Besides waterfalls, it also have a market where you can buy local products and souvenirs such vegetables, wines, strawberry, snacks, flowers etc.



(a)



(b)

Fig.10 (a) Anisakan water fall and (b) Pwe Kauk waterfall in Pyin U Lwin, Shan State.



(a)



(b)

Fig. 11 (a) Nam Tok waterfall (Hsipaw) and (b) Zin Kyaik waterfall (Mawlamyine)

Nam Tok waterfall, Hsipaw

Nam Tuk dolomitic limestone waterfall is located near Hsipaw city, northern Shan State. The journey to the waterfall is all part of the fun and most of the trail can be done by bicycle. The visitors can also swim in the refreshing pool at the bottom of the waterfall and get the most exhilarating view.

Zin Kyaik waterfall, Pyin Oo Lwin

Zin Kyaik granite waterfall is located near the main road and rail line of Yangon – Mawlamyine, nearby Zin Kyaik village. It is panoramic and a pleasant place as a picnic spot. As it is a monsoon waterfall you may not see much water in other season except rainy season. The water is so clear and transparent. The environment is clean and fresh.

CAVE AND GROTTO SITES

This category of geoheritage is not only seen on the surface, but also underground. Among the main features are deep valleys, clusters of peaks, columns, stone forests, natural bridges, karst window, sinkholes, ponds or lakes, underground streams and caves. The latter contains mud and pebble accumulations, chemical deposits such as stalactites, stalagmites and sinters with strange shapes sometimes resembling human and animal sculptures that have become important geotourism resources. The following image (d) was taken at Sadan Cave showing the natural beauty of stalactite and religion by Kyaw Win Hlaing (Myanmar) who got SONY world photography award 2017 winners and runner-up.



Fig.12 (a) Sadan cave nearby to Hpa An, Kayin State (b) The photo got SONY world photography award 2017 winners and runner-up.

Nearby to Hpa An, Kayin State, south east of Myanmar can also be found Sadan Cave, which opens into a gigantic cavern filled with Buddhas and pagodas and can be walked all the way through to the other side, under the mountain. Emerging at the cave's far side, the wonders only increase and the burst of sunlight reveals an idyllic secret lake full of ducks and flowering lilies hidden in a bowl of craggy peaks.

Htan San Cave



Fig.13 (a) Htan San cave nearby to Ho Pong, Shan State (b) Numerous beautiful and interestingly shaped mineral deposits inside Htan San cave

Htan San Cave is located 42 kilometers (26 miles) east of Taunggyi in southern Shan State. According to local lore, the cavern was found by a 10-year-old novice named Shin Borida. For a long time he kept his discovery secret, using it as a place for meditation and

sharing it only with the spirits who lived there. The entire cave system was about 6000 feet (1818 meters) long, but so far only about one-third of that has been made accessible. Originally, water flowed across the tunnel floor, but a dam was built to divert its course and gravel was put down to create a walking path for visitors. Some water still trickles through, and pilgrims believe that splashing it onto one's skin will bring good luck.

Numerous beautiful and interestingly shaped mineral deposits (speleothems) with a variety of names such as soda straws, stalactites and stalagmites, cave corals, flowstones, curtains, cave pearls, cave pisolites, cave shields, helictites, heligmites, and moonmilk can be seen in the cave. These speleothems are usually composed of either calcite or aragonite.

FOSSIL SITE

This category of geological site is represented by important fossil sites such as palaeobotanical sites, crucial fossils and stratigraphic correlation. Most of fossil sites can be seen in limestone area, Shan State, eastern part of Myanmar. Palaeogeographical (Fossil) geological sites preserve palaeoenvironments, palaeoecosystems, and other relevant phenomena. However, the value of these sites can only be fully understood through professional interpretation of the observed features. Moreover, the palaeogeographical geosite type always associates with other types of geosites which are Htan san cave and Peik Chin Myaung cave in Myanmar.

Htan San middle Devonian Coral Reef

Htan San coral reef (middle Devonian age) area is N20° 49' 0.4" , E 97° 18' 58.7" with an elevation of 4306' of GPS, located at about one mile west of Htan San village and cave, Ho-pong township, Southern Shan State (Htay Lwin, 2005). This coral reef is rich in fossil, especially Brachiopods, Bryozoans, Crinoid stem and corals (Favosites, Zaphrentis, Caenites, Alveolites, Alveolites placenta, Fenestella, Strophomena, Stropheodonta, Atrypa, Chonetes, Cyrtina, Spirifer, Fossiliferous band, Lingula).

Padaukpin Coral Reef

Padaukpin coral reef area (N22° 05' 45" , E 96° 37' 06") near Peik Chin Myaung Cave which is a limestone stalactite cave is situated South of Wetwun village, near Pyin Oo Lwin, Mandalay Region, Myanmar (Win Min Oo et. al., 2015). Padaukpin coral reef is rich Brachiopods and 30 different species of coral. Geoscientists recorded the coral reef age about

middle Devonian (396 million years to 385 million years). Peik Chin Myaung cave is a famous tourist sightseeing place and the shops sell fossils from the Padaukpin Coral Reef.



Fig. 14 The photo showing Padauk Pin Coral Reef in Mandalay Region.

ENGINEERING GEOLOGICAL, ENVIRONMENTAL GEOLOGY AND GEOHAZARD

Sagaing Fault.

Myanmar has suffered from more than 16 large earthquakes with strong magnitudes ($M \geq 7$) during the last 170 years. The Sagaing fault is certainly the biggest single earthquake threat to the people of Myanmar because of its location in well populated central Myanmar. Seismicity along the course of the Sagaing fault is quite well known in Myanmar since the days of the Myanmar kings, because many of the ancient city states and royal capitals of Myanmar were located on or close to the Sagaing fault. In fact, the present capital or the Nay Pyi Taw is also located close to the Sagaing fault. The Sagaing fault, being active and extending through the well populated part of the country, is the most earthquake hazardous structure in Myanmar (Win Swe, 1970). Myanmar is perhaps one of the best places for the study of earthquake geology of strike-slip faults, because, in addition to the active transform Sagaing fault extending 1100 km in land, there are other active and possibly active faults in the country as well.

Sag Ponds of Sagaing Fault

Indawgyi Lake is one of the largest inland lakes in Southeast Asia. It is located in Mohnyin Township in the Kachin State of Myanmar. The lake measures 13 kilometres east to west, and 24 kilometres north to south. it is believed to be formed by earth movements associated with the northwest trending Sagaing Fault Zone. Indawgyi Lake is within the

confines of Indawgyi Lake Wildlife Sanctuary, which was established in 1999 by the Ministry of Tourism. The sanctuary, which encompasses 780 km² (300 sq mi), contains a variety of animal species, including rare mammals and birds. The main reason for people to visit Indawgyi lake and Innle lake which the second largest lake in Myanmar is to enjoy its natural beauty. A sag pond is a geomorphological body of fresh water collected in the lowest parts of a depression formed between two sides of an active strike-slip, transtensional or normal fault zone. Indawgyi lake, Innle lake and Yega lake were effected by active strike slip fault in Myanmar.

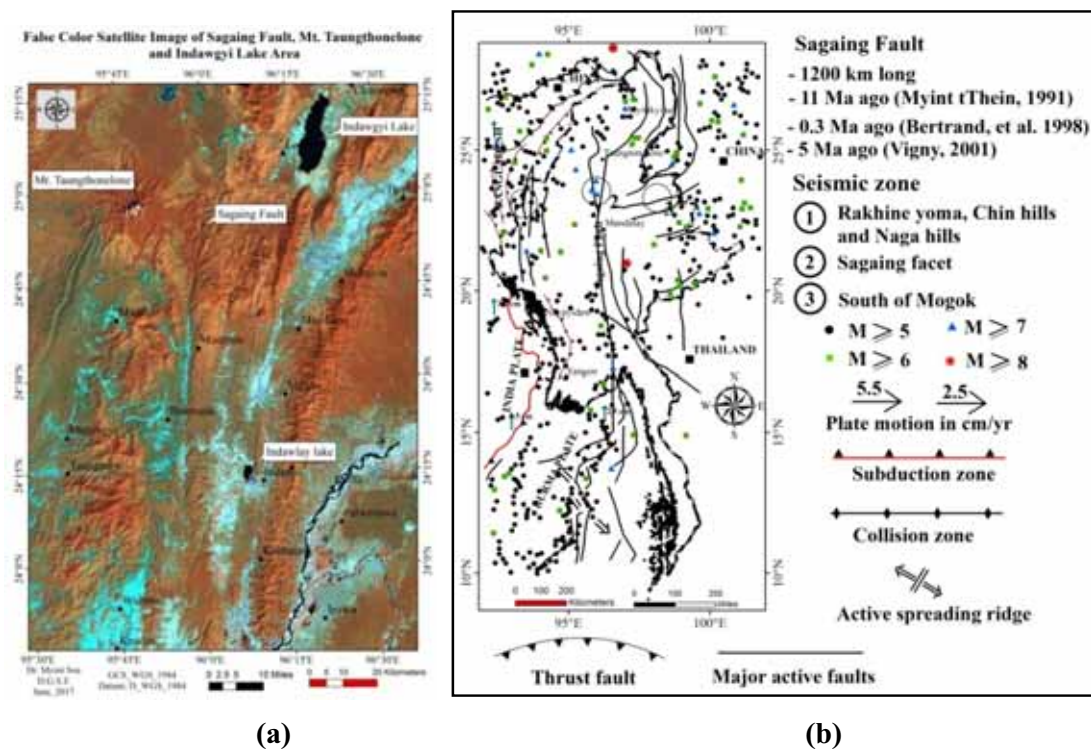


Fig. 15 (a) Sagaing Fault on Satellite Image (b) Seismotectonic map of the Myanmar region (Earthquake data: NEIC for the period 1964-2004; from other sources for 1912-1963. Tectonic boundaries and fault locations are mainly based on GIAC reports (1997, 2000)).



Fig. 16 (a) Indawgyi lake from Northern Myanmar and (b) Innle Lake Eastern Myanmar

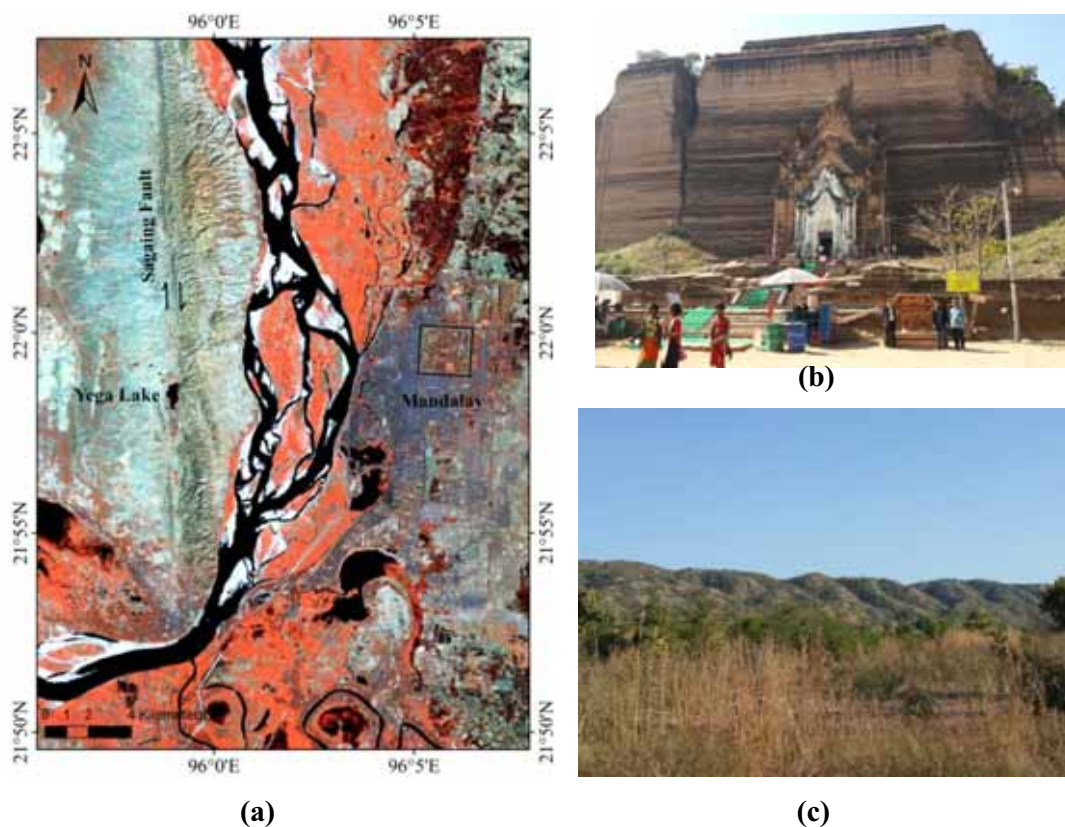


Fig. 17 (a) Sagaing Fault in Satellite Image, (b) Mingun pagoda was effected by Sagaing Fault and (c) Traingular facets at Min Wun Ridge.

Metamorphism and metamorphic rock, geological type section, gem tract

Mogok Gemtract

Mogok Gemtract (city of gems), the heart of the gem zone and the centre of the gem trade is located 200 km north east of Mandalay at 1170 meters in elevation. Mogok and other villages nearby have been famous since ancient times for its gemstones, especially ruby and sapphire, but semi-precious stones such as lapis lazuli, garnet, moonstone, peridot and chrysoberyl are also found. The gems are found in alluvial marble gravels by means of panning, tunneling and digging pits by hand. There is little mechanization of the mining. The gravels derive from the metamorphosed limestones (marbles) of the Mogok metamorphic belt. Gems are sold in markets in Mogok. 90% of a certain version in the world's rubies come from Myanmar. There are many other ruby sources in the world such as Sri Lanka and various places in Africa. Only in terms of quality Mogok rubies are best.



Fig. 18 (a) Mogok Underground Mining (b) Mogok Gem Market



Fig. 19 (a) Ruby price in Gem Emporium (b) Sapphire price in Gem Emporium

The Mogok area is mainly underlain by a series of undifferentiated high grade metamorphic rocks (Iyer, 1953; Searle and Ba Than Haq, 1964; Khin Zaw, 1990, 1998; Mitchell et al., 2007; Themelis, 2008). The protolith age of the metamorphic rocks may be Paleozoic or younger. The primary occurrence of ruby in the Mogok area, northern Myanmar is exclusively found in marble along with spinel-foresterite-bearing marble and phlogopite-graphite marble. These marble units are enclosed within banded biotite-garnet-sillimanite-okigoclase gneisses.

Mineral deposit, Mining Geological Sites

Myanmar contains important deposits of tin, tungsten, copper, gold, gemstones, zinc, lead, nickel and silver. It has one of the most diverse and richly endowed collections of natural resources in Southeast Asia, largely reflecting a geological history stretching from the Late Triassic to the Miocene. At least three world class deposits include Bawdwin (Lead-Zinc-silver), Monywa (copper) and Mawchi (tin-tungsten).

We selected for mineral sites based on their deposit, mineralization style and historical world class mines such as Mawchi Tin and Tungsten Mine, Bawdwin lead-zinc mine, Hermyingyi Tin and Tungsten Mine, Kyaukpazat gold mine, Modi – Momi gold mine, Kyaukse - Sabe Taung copper mine, Kalewa coal mine, Lashio coal mines, Monywa copper mine, Ar Ye manganese mine, Tachileik, Eastern Shan State and Shagalon gold and copper deposit, kawlin area, Northern Myanmar.

Bawdwin Lead-Zinc-Silver Mine

The Bawdwin Mine, a Pb-Zn-(Cu-Ag-Ni) deposit sited in the Northern Shan States, is probably the most famous historical mine in Myanmar. One of several world-class mineral deposits within the country, it has seen near-continuous mining since the early 1400's to the present for a range of commodities including: silver, lead, zinc, copper, and nickel. It was redeveloped in the early 20th Century as a dominantly lead-zinc producer, in the process making it one of the largest producing lead mines in the world pre-Second World War. The geology was first described early in the 20th century, and its nature and origin have been much debated since – its genesis has remained enigmatic. Cambro-Ordovician magmatism associated with this subduction setting (e.g., Wang et al., 2013) has been proposed as being responsible for the development of the Bawdwin Mine, a major Pb-Zn VMS type deposit now located within Sibumasu (Gardiner et al., 2016).

Monywa Copper Mine

High sulphidation epithermal-type Cu deposits and low sulphidation epithermal-type Au mineralisation occur in the area west of Monywa City, Central Myanmar (Knight 2012, Knight & Khin Zaw 2015, accepted). The Monywa area occurs within a N-S running antiformal area. The deposits include four known ore bodies (Sebataung, Sebataung South, Kyisintaung and Letpadaung) with an estimated combined resource of 2010 7 Mt @ 0.35 % Cu (7 million tons of copper were obtained from 2 billion tons of ore) making the Monywa deposits the largest Cu resource in mainland SE Asia.

Mawchi Tin & Tungsten Mine

The Mawchi mine is located in Kayah State, Eastern Myanmar, at latitude 18° 49' N and longitude 97° 10' E with a general elevation of 1100 m. Mawchi was one of the largest producers of tin and tungsten in the world before World War II. From 1939 to 1940, it produced 60 percent of the total production of Myanmar, which then accounted for 17.4% of the world output of tungsten. The mine has been developed by main crosscuts in five levels. Quartz veins containing tin and tungsten are found within the apical zone of granitoid, whereas some of the veins penetrate the adjacent meta-sedimentary rocks for short distances.

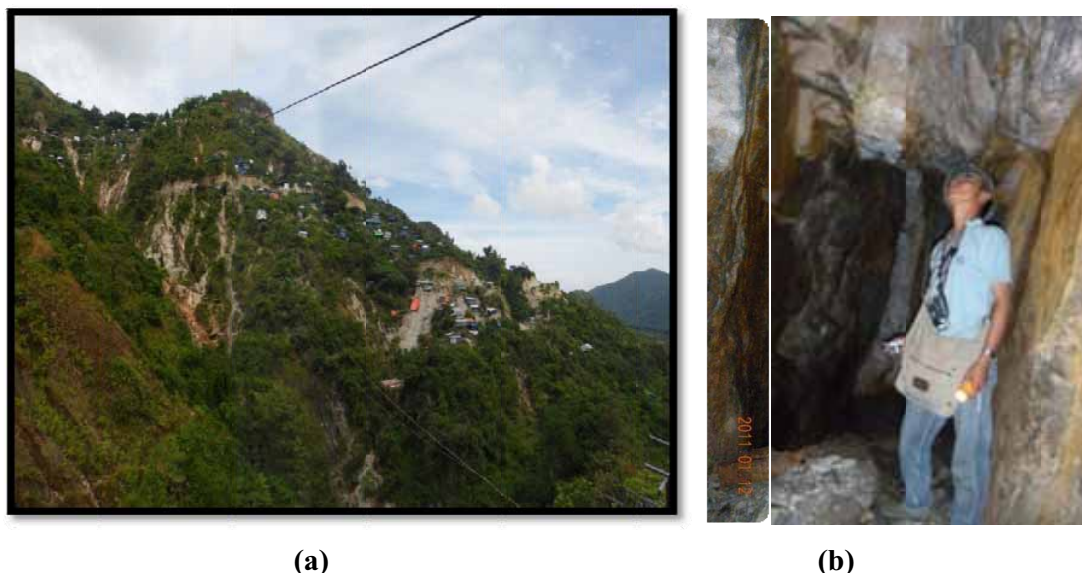


Fig. 20 (a) Maw Chi Tin & Tungsten Mine (b) Hermyingyi Tin & Tungsten Mine



Fig. 21 (a) Bawdwin Lead-Zinc-Silver Mine (b) Tachileik Manganese Mine of Eastern Myanmar



(a) **(b)**
Fig. 22 **(a)** Kalaywa Coal Mine and **(b)** Kyaukse – Sabe Taung copper Mine



(a) **(b)**
Fig. 23 **(a)** Monywa Copper Mine and **(b)** Shangalon – Kawlin copper Worksite

Sakyin Taung Marble



(a) **(b)**
Fig. 24 **(a)** Sakyin Taung Marble Mine and **(b)** Marble sculptures in Sakyin village near Sakyin Taung, Madaya Township.

White marble rock was obtained from Sakyin hill, Madaya Township, Mandalay region in upper Myanmar. A big white marble rock of high quality was obtained from Sakyin Hill and conveyed to Mandalay and a Buddha Image of 27 feet high was carved from it. The marble carving workshop is near Sakyin hill. Many religious items, mainly Buddha images and stone slabs for inscription, are produced. Other figures such as images of other religions, animal figures are also made by order.

Issues and challenge of Geological Sites

Mostly, pagodas were built in the cave. These problems could be due partly to the lack of geological knowledge and understanding of its importance to conservation by both the public and the management organizations and administrators. Mt. Popa stone gardens were quarried for construction stone. Others were utilized for cult activities. Some of the caves were plundered and vandalized. Some of the conflicting land-use demands faced in geoheritage areas include logging, mining, forest produce collection, cultural and agricultural activities of local residents. These problems could be due partly to the lack of geological knowledge and understanding of its importance to conservation by both the public and the management organization and administrators.

Discussion and Conclusion

Geological sites are features such as a landscape, a group of landforms, a single landform, a rock outcrop, a fossil bed, caves, volcano and even a mine site. A list of geological sites in Myanmar were compiled and they were classified according to various criteria as well as their selection criteria. Moreover, the selected geological sites are potentially usable for different purposes, namely scientific and educational, but mostly tourism site. The creation of geological tourism sites or geoparks is undoubtedly one of the most important steps to promote the conservation of geological sites, and the promotion of earth science education should help expand and consolidate their protection.

Myanmar geological sites can be classified and recorded according to the following table. This table presents an overall perspective of the geological sites, but minor final adjustments are still in progress.

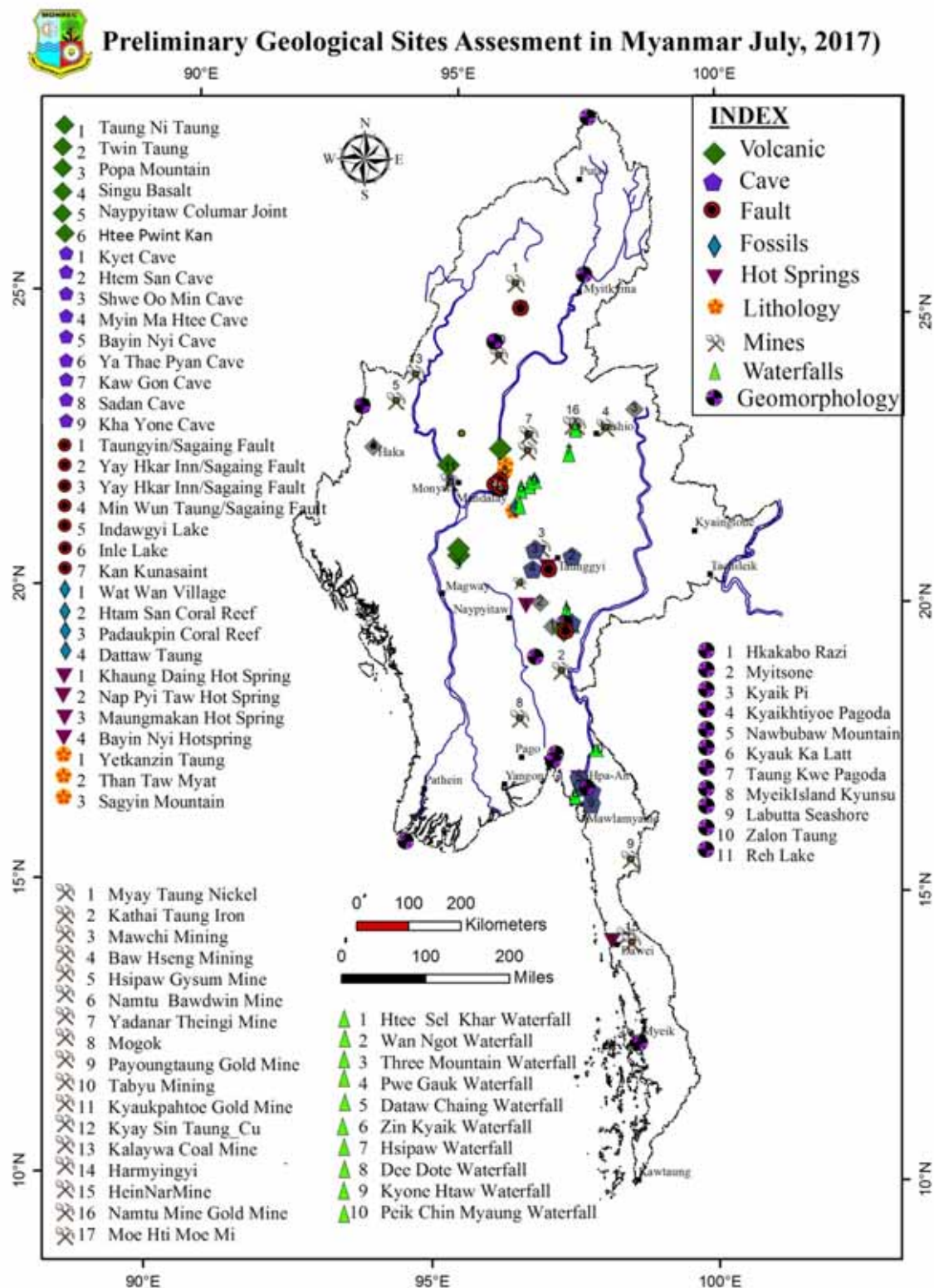


Fig. 25 Preliminary Geological Sites in Myanmar.

Table 2. Number of preliminary geological sites with national and /or international relevance and their cooresponding geological frameworks. This table presents an overall perspective of Myanmar geological heritage, but minor final adjustments are still in progress.

Geological framework		Main geological relevance	Geosites
1	Andisite and basaltic rock, columnar joint, hot spring	Volcanic	6
2	Associated with Granite Rock and limestone	Hot Springs	4
3	Granite, Karst topography	Geomorphology	10
4	Mostly limestone and granite area	Waterfall	10
5	Carboniferous, Ordovician , Permian to Triassic age Limestone	Cave	9
6	Permian to Triassic	Fossils	4
7	Right lateral Active Sagaing, 1500 km N-S trending along central Myanmar, Geohazard Mitigation, earthquake	Fault	7
8	Limestone and marble for cement and dimension stone	Lithology	3
9	Copper, Tin & Tungsten, gold, lead-zinc mineralization style	Mines	17
Total Geological Sites			70

Myanmar people are now gradually adopting new geoheritage concepts. So the value of geoheritage features should be taken into consideration in assuring sustainability of particular ecosystems. Hence, protecting geoheritage resources is vital for integrated or holistic nature conservation and in long term, comprehensive land management planning in Myanmar.

The success of geological sites conservation and management depends largely on readily available geological information and knowledge coupled with the interest, support and cooperation of everybody concerned. Therefore, public education is the most important tool to achieve success.

Reference;

Boškov, J., Kotrla, S., Jovanović, M., Tomić, N., Lukić, T., Rvović, I. (2015), Application of the Preliminary Geosite Assessment Model (GAM): The Case of the Bela Crkva Municipality (Vojvodina, North Serbia). *Geographica Pannonica* 19, 146-152.

- CCOP (2008), *Geoheritage of East and Southeast Asia*, Coordinating Committee for Geoscience Programmes in East and Southeast Asia published.
- CCOP (2015), *Stone Heritage of East and Southeast Asia*, Coordinating Committee for Geoscience Programmes in East and Southeast Asia published.
- Cumming, G., Khin Zaw, Sandy Chitko, Zaw Naing Oo and Horst Zwingmann (2009), Recent Pliocene volcanism recorded at Mount Popa, Central Myanmar, *Geosea 2009*, Eleventh Regional Congress on Geology, Mineral and Energy Resources of Southeast Asia, Kuala Lumpur, Malaysia.
- DMR (2015), *The Invaluable Natural Heritage Thai Geological Site book*, published.
- Gardiner, N.J., Robb, L.J., Searle, M.P., Kyi Htun, Khin Zaw (2016), *The Bawdwin Mine: A Review of its Geological Setting and Genesis*, in: Barber, A.J., Crow, M.J., Khin Zaw, Rangin, C. (Eds.), *Myanmar: Geology, Resources and Tectonics*. The Geological Society, London.
- Gardiner, N.J., Robb, L.J., Searle, M.P., Kyi Htun, Khin Zaw, (2016), *The Bawdwin Mine: A Review of its Geological Setting and Genesis*, in: Barber, A.J., Crow, M.J., Khin Zaw, Rangin, C. (Eds.), *Myanmar: Geology, Resources and Tectonics*. The Geological Society, London.
- Henriques, M.H.; Pena dos Reis, R.; Brilha, J.; Mota, T. (2011), *Geoconservation as an Emerging Geoscience*. *Geoheritage*, 3, 117–128.
- Htay Lwin, (2005), *A New Light on the Middle Devonian Coral Reef of Southern Shan State*, Myanmar, Department of Geology, Taunggyi University.
- Iyer, Lakshinarayanpuran Anantkrishna Narayana (1953), *The geology and gem-stones of the Mogok Stone Tract*, *Burma Geological Survey of India Memoir 82*, Government of India Press, Calcutta.
- Khin Zaw (1990), Geological, petrological and geochemical characteristics of granitoid rocks in Burma: with special reference to the associated W-Sn mineralization and their tectonic setting. *J SE Asian Earth Science* 4, 293-335.
- Khin Zaw (1998), Geological evolution of selected granitic pegmatites in Myanmar (Burma): constraints from regional setting, lithology, and fluid-inclusion studies. *Int Geol Rev* 40:647–662.
- Knight, J., and Khin Zaw, (2015), *The geochemical and geochronological framework of the Monywa high sulfidation Cu and low sulfidation Au-epithermal deposits, Myanmar: Proceedings, Society of Economic Geologists, Annual Meeting, Hobart, Australia.*
- Mitchell, A.H.G., Htay, M.T., Htun, K. M., Win, M. N., Oo, T. & Hlaing, T. (2007), Rock relationships in the Mogtok Metamorphic belt, Tatkon to Mandalay, central Myanmar. *Journal of Asian Earth Sciences*, 29, 891-910.

- Nizamettin K., Fuat S. and Yasar S. (2015), Geological Heritage and Framework list of the Geosites in Turkey, *Bulletin of the Mineral Research and Exploration*, 151, 259-268.
- Pereira, P., Pereira, D. & Caetano Alves, M.I. (2007), Geomorphosite assessment in Montesinho Natural Park (Portugal).– *Geographica Helvetica*, 62, 159–168.
- Reynard, E., Fontana, G., Kozlik, L. & Scapozza, C. (2007), A method for assessing „scientific” and „additional values” of geomorphosites.– *Geographica Helvetica*, 62/3, 148–158.
- Searle, D. L.; Ba Than Haq (1964), The Mogok belt of Burma and its relationship to the Himalayan orogeny, *Proceedings of the 22nd International Geological Conference, Delhi 11*: pp. 132–161
- Themelis, T., (2008), *Gems and Mines of Mogok*. Self-published, 352 pp.
- Tin Tun Aung (1988), Geothermal Resources of Burma, *Geothermic*, Vol. 17, No. 2/3, 429 – 437.
- Tomić, N. (2011), The potential of Lazar Canyon (Serbia) as a geotourism destination: inventory and evaluation. *Geographica Pannonica* 15-3, 103-112.
- Vujičić, M.D., Vasiljević, Dj. A., Marković, S. B., Hose, T. A., Lukić, T., Hadžić, O. (2011), Preliminary Geosite Assessment Model (GAM) and its Application on Fruška Gora Mountain, Potential Geotourism Destination of Serbia. *Acta geographica Slovenica* 51-2, 361–377.
- Wang, Y., Xing, X., Cawood, P.A., Lai, S., Xia, X., Fan, W., Liu, H., Zhang, F., (2013), Petrogenesis of early Paleozoic peraluminous granite in the Sibumasu Block of SW Yunnan and diachronous accretionary orogenesis along the northern margin of Gondwana. *Lithos* 182-183, 67–85.
- Wang, Y., Xing, X., Cawood, P.A., Lai, S., Xia, X., Fan, W., Liu, H., Zhang, F., (2013), Petrogenesis of early Paleozoic peraluminous granite in the Sibumasu Block of SW Yunnan and diachronous accretionary orogenesis along the northern margin of Gondwana. *Lithos* 182-183, 67–85.
- Win Min Oo, Zaw Win Lwin, Aung Zaw Win, Myo Thet Htun, (2015), Padauk Pin Coral Reef Geological heritage, Padaukpin Area, Wet Won –Pyin U Lwin, Mandalay Region, Department of Geological Survey and Mineral Exploration, Ministry of Natural Resources and Environmental Conservation, Myanmar.
- Win Swe, (1970), Rift-features at the Sagaing-Tagaung Ridge. Abstract, Burma Research Congr., Rangoon, 101.
- Zhao Ting & Zhao Xun (2007), Geological heritage taxonomy and application. *Proceedings of the Second International Symposium on Development within Geoparks*. Geological Publishing House, Beijing, 26-97.