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Conservation on Karst and Cave: Potential Geosites related Carbonate Rocks in Myanmar

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Abstract

The term "karst" encompasses a broad geological process characterized by the chemical erosion of water on soluble rock. Carbonate rock, a significant type of sedimentary rock, provides as the essential material for the development of karst landscapes. This rock primarily consists of limestone and dolomite. Myanmar occupies a karst area spanning approximately 80,000 sq.km with around 650 sq.km designated as a protected karst area. The Shan Plateau in Myanmar features the most extensive karst landscape in the country, covering an area of 500 km by 300 km. The limestone primarily ranges from the Carboniferous to Lower Triassic periods. The development of karst landscapes is partially influenced by way of irregular rainfall patterns and fluctuations in daily or seasonal temperatures. Some of the popular karst landscapes in Myanmar are Mt. Zwekabin (Kayin State), Kyauk Ka Lat, Taung Kwe Mountain and Lwe Maung Mountain. The longest cave in Myanmar is Som Hein Cave (11.6 km) and other prominent long caves are Khauk Khaung Cave (4.9 km) and Phruno River Cave (4.6 km). Some of the tourist destination caves in Myanmar are Htan Sam Cave, Sadan Cave, Bayin Nyi Cave, Eait Sar Tharya Cave and Kyat Cave. Karst water plays a significant role in karst and cave conservation. The importance of aquifers with karst permeability is increasing as they presently supply around 25% of the global demand for drinking water. The Inle basin, situated in the heart of the Shan Plateau is believed to represent a type of polje. The 800 karst features including caves, sinkholes and springs have collected. The main purpose is to learn about the conditions of climate change related to Karst and the methods of preservation concerning the environment, and to see more about the importance of geosites and geoparks in the tourism sector of the country's economy.

Keywords: karst landscapes, karst water, aquifers, chemical erosion, geoparks, limestone, Shan Plateau

မြန်မာနိုင်ငံတွင် ကာဗွန်နိတ်ကျောက်များနှင့်ဆက်စပ်၍ အလားအလာရှိသော ဘူမိရုပ်သွင်ထူးခြား လှပသည့်နေရာများ၌ ကဒ်တ်နှင့်လိုဏ်ဂူထိန်းသိမ်းခြင်း

အောင်အောင်ဖေ၊ လက်ထောက်ဘူမိဗေဒပညာရှင်
ဒေါက်တာမြင့်စိုး၊ ဒုတိယညွှန်ကြားရေးမှူးချုပ်
ဘူမိဗေဒလေ့လာရေးနှင့် ဓာတ်သတ္တုရှာဖွေရေး ဦးစီးဌာန

စာတမ်းအကျဉ်း

"ကဒ်တ်"ဟူသော ဝေါဟာရသည် ရေဇ၏ ဓာတုတိုက်စားမှုကြောင့် ပျော်ဝင်နိုင်သော ကျောက် များ၌ ဖြစ်ပေါ်လာသည့် ကျယ်ပြန့်သော ဘူမိဗေဒဖြစ်စဉ်တစ်ခုကို ဆိုလိုပါသည်။ သိသာ ထင်ရှားသော အနည်ကျကျောက်အမျိုးအစားဖြစ်သည့် ကာဗွန်နိတ်ကျောက်သည် ကဒ်တ် ရှုခင်းများ ဖြစ်ထွန်းမှုအတွက် မရှိမဖြစ်လိုအပ်သော အရာဖြစ်သည်။ အဆိုပါကျောက်၌ အဓိက အားဖြင့် ထုံးကျောက်နှင့် ဒိုလိုမိုက်ကျောက်တို့ပါဝင်ပါသည်။ မြန်မာနိုင်ငံသည် ခန့်မှန်းခြေ ၈၀,၀၀၀ စတုရန်း ကီလို မီတာခန့် ကျယ်ဝန်းသော ကဒ်တ်ဇရိယာကို ပိုင်ဆိုင်ထားပြီး ကဒ်တ်ဇရိ ယာ ၆၅၀ စတုရန်း ကီလို မီတာခန့်ကိုသာ ကာကွယ် ထိန်းသိမ်းထားပါသည်။ မြန်မာနိုင်ငံ၊ ရှမ်းကုန်းပြင်မြင့်တွင် နိုင်ငံအတွင်း အကျယ်အဝန်းဆုံးသော ကဒ်တ်ရှုခင်းများရှိပြီး အလျား ၅၀၀ ကီလိုမီတာနှင့် အနံ ၃၀၀ ကီလိုမီတာ ခန့်ကျယ်ဝန်းပါသည်။ ထုံးကျောက်များသည် အဓိက အားဖြင့် ကာဗွန်နီဖားရပ်စ်မှ ထရိုင်ဆစ် နှောင်းပိုင်းသက်တမ်းအတွင်း ဖြစ်ပေါ်ခဲ့ပါသည်။ ကဒ်တ်ရှုခင်းများဖြစ်ထွန်းမှုကို ပုံမှန်မဟုတ်သော မိုးရွာသွန်းမှုပုံစံများနှင့် နေ့စဉ် သို့မဟုတ် ရာသီအလိုက် အပူချိန်အတက်အကျများက တစ်စိတ် တစ်ပိုင်း လွှမ်းမိုးထားပါသည်။ မြန်မာနိုင်ငံ တွင် ထင်ရှားသော ကဒ်တ်ရှုခင်းအချို့မှာ ဇွဲကပင်တောင် (ကရင် ပြည်နယ်)၊ ကျောက်ကလပ်၊ တောင်ကွဲတောင်နှင့် လွယ်မောင်တောင်တို့ဖြစ်ကြသည်။ မြန်မာနိုင်ငံတွင် အရှည်ဆုံးဂူမှာ ဆုန်ဟိန်းဂူ (၁၁.၆ ကီလိုမီတာ) ဖြစ်ပြီး အခြားထင်ရှားသော ဂူများမှာ ခေါင်ခေါင်းဂူ (၄.၉ ကီလိုမီတာ) နှင့် ဖရူဆိုမြစ်လှိုဏ်ဂူ (၄.၆ ကီလိုမီတာ) တို့ဖြစ်ကြပါသည်။ မြန်မာ နိုင်ငံတွင်

ကမ္ဘာလှည့်ခရီးသည်များ လာရောက်လည်ပတ်သည့် ဂူအချို့မှာ ထမ်းဆန်းဂူ၊ ဆဒ္ဒန်ဂူ၊ ဘုရင့် ညီဂူ၊ ဂျစ္ဆာသယဂူနှင့် ကြတ်ဂူတို့ဖြစ်ကြပါသည်။ ကာ့တ်ရေသည် ကာ့တ်နှင့် လိုဏ်ဂူ ထိန်းသိမ်းရာ တွင် အရေးပါသော အခန်းကဏ္ဍမှ ပါဝင်လျက်ရှိသည်။ ယခုအခါ ကမ္ဘာတစ်ဝန်း သောက်သုံးရေ လိုအပ်ချက်၏ ၂၅ ရာခိုင်နှုန်းခန့်ကို ကာ့တ်စိမ့်စမ်းရေမှ ထောက်ပံ့ပေးနေသောကြောင့် ကာတ့် ရေအောင်းလွှာများက ပို၍ အရေးပါလာပါသည်။ ရှမ်းကုန်းပြင်မြင့်၏ အလယ်တွင် တည်ရှိသော အင်းလေး ချိုင့်ဝှမ်းသည် ပိုလ် (Polje) အမျိုးအစားကို ကိုယ်စားပြုသည်ဟု ယူဆရပါသည်။ ဂူများ၊ မြေကျွံတွင်းများနှင့် စမ်းရေတွင်းများအပါအဝင် ကာ့တ် အသွင်အပြင် လက္ခဏာ ၈၀၀ ခန့်ကို ပြုစု ထားပြီးဖြစ်ပါသည်။ အဓိကရည်ရွယ်ချက်မှာ ကာတ့်နှင့် ဆက်နွယ်လျက် ရာသီဥတု ပြောင်းလဲမှု ဖြစ်စဉ် အခြေအနေများနှင့် သဘာဝပတ်ဝန်းကျင် ထိန်းသိမ်းနိုင်မည့် နည်းစဉ်များအား လေ့လာ သိရှိနိုင်စေရန်နှင့် နိုင်ငံတော်၏ စီးပွားရေးအတွက် ခရီးသွားကဏ္ဍ၌ ကာ့တ်နှင့်ပတ်သက်၍ ဘူမိရုပ်သွင် ထူးခြားလှပသည့် နေရာများ (Geosites)၊ ဘူမိပန်းခြံများ (Geoparks) မှ အရေးပါသော အခန်းကဏ္ဍ အဖြစ် ဆောင်ရွက် နိုင်မှုကို ပိုမိုသိမြင် လာစေရန် ဖြစ်သည်။

Conservation on Karst and Cave: Potential Geosites related Carbonate Rocks in Myanmar

1. Introduction

Karst refers to the landscapes and associated features that arise from an extensive geological process primarily initiated by the chemical dissolution of water acting on soluble rocks, such as carbonate, gypsum, anhydrite and halite. This process is further influenced by the erosion and sedimentation caused by water, as well as the gravitational collapse of rock mass. When most of the water on the surface of the earth dissolves from the cracks and falls through the holes in the bedrock, it generally forms a type of karst landscape that creates sinkholes, underground streams, rivers, caves, canyons, stone forests and other characteristics. In the 19th century, European academics undertook scientific research of the Karst Highlands located in the former Yugoslavia along the eastern shore of the Adriatic Sea, subsequently adopting the German term "karst" as a standard terminology (After International Research Centre on Karst (IRCK), 2024).

Karst is extensively distributed over the world, encompassing around 22 million square kilometers, which represents approximately 15 % of the Earth's total land area (After IRCK, 2024). Myanmar contains an area of karst about 80,000 sq km (Protected karst area about 650 sq km) shown in (Fig.1). After Indonesia, this region is the second largest karst area in Southeast Asia (Day & Urich, 2000). The karst and caves of Myanmar are one of the least studied in Asia due to the country's civil armed conflicts (Dreybrodt et al., 2022). The Shan Plateau in Myanmar is home to the largest karst landscape in the nation, covering an area of 500 km by 300 km, with an average elevation of 1,100 meters above sea level (Dreybrodt & Steiner, 2015). The majority of this karst landscape is situated on the Shan Plateau, where limestone ridges extend in a north-south direction for over 1500 kilometers, reaching its southernmost point in the Myeik Archipelago (Dreybrodt et al., 2022).

The limestone is mostly from the Carboniferous to Lower Triassic periods with some components from the earlier Ordovician period and has underlying Devonian strata that can reach a thickness of up to 2 km (Thura Oo et al., 2002). A detailed stratigraphic evaluation has been conducted by Thura Oo et al., (2002) who categorizes the carbonates into two primary units: the Thitsipin Limestone Formation, which transitions upward into the Nwabangyi Dolomite (Dolostone) Formation.

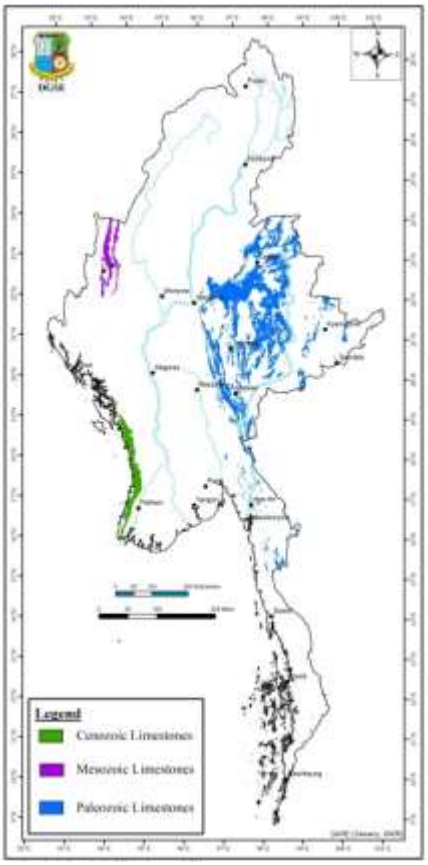

Figure 1. Distribution Map of Carbonate rocks in Myanmar (After DGSE, 2008)

2. Objectives

The main purposes of study are as follows:

- To find out the research work on Karst Geology,
- To learn the methods of preserving and protecting Karst Mountains, Caves, Canyons and Stone Forests,
- To learn the methods of conservation and protection of water resources in Karst area,
- To learn the conditions of climate change related to Karst and the methods of preservation concerning the environment,
- To know more the importance of geosites and geoparks in the tourism sector of the country's economy, and
- To appear the emergence of UNESCO-recognized geoparks related to Karst and Caves in Myanmar in the future.

3. Previous Works

In Myanmar, karst and carbonate study were carried out by the following authors; (Aung Kyaw Myat & Aung May Than, 2019, Dreybrodt et al., 2022, Jiang et al., 2020, Nyi Nyi Aung et al., 2020, Parise et al., 2018, Piccini et al., 2009, Thura Oo et al., 2002) and data and facts from reports of Department of Geological Survey and Mineral Exploration (DGSE, 2018, 2020 & 2024). In addition to the published literature, some data in this study were adapted from "the 16th International Training Course on Karst and Climate Change" organized by International Research Centre on Karst (IRCK) under the auspices of UNESCO on 15 - 28 April 2024 in Beijing, Wuhan and Guilin, China. The investigation and identification of the inventory of preliminary geological sites assessment were done by field party from Department of Geological Survey and Mineral Exploration (DGSE, 2018, 2019). Moreover, the data and records of field trip in Hopon Area, Southern Shan State and Loikaw Area, Kayah State are described in this paper.

4. Karst Landscape

Geotourism is described as a form of tourism that preserves or improves the distinctive geographical character of a place, including its environment, heritage, aesthetic appeal, cultural significance, and the well-being of its inhabitants (https://en.wikipedia.org/wiki/Geotourism). Geotourism attractions encompass a variety of landscapes, including mountain ranges, rift valleys, significant escarpments, volcanoes, karst landscapes and arid environments. Karst landscapes are renowned globally for their striking beauty and significant aesthetic appeal, often characterized by remarkable surface geomorphology and the subterranean formations observable within caves (Parise et al., 2018).

Most karst is located in mountainous areas that are primarily situated at the western boundary of the Shan Plateau close to Ywangan (Fig. 2) , with the southern part extending into Kayah State (Dreybrodt et al., 2022). Karst landforms are prominently developed in Loikaw area, Kayah State, and Hpa-An area, Kayin State, Myanmar due to the extensive occurrence of carbonate rock that exhibits well-defined cracks and joints. The development of karst landscapes is influenced in part by irregular rainfall patterns and variations in daily or seasonal temperatures (Myint Soe et al., 2018).

Some of the popular Karst landscapes in Myanmar are described as follow; **Taung Kwe Pagoda Mountain** is the most famous religious landmark of Loikaw, Kayah State (Fig. 4). Taung Kwe means as broken mountain. It is 119 m high and pagoda was built on natural hillocks. This striking formation of craggy limestone, accompanied by white and gold stupas, seemingly erupts from the terrain. Taung Kwe Pagoda Mountain exemplifies a type of karst landscape from the typical features of the Thitsipin Limestone Formation that was shaped from an extensive area of Plateau Limestone sediment that originated on the seafloor during the Permian to Triassic period, approximately 252.2 million years ago. (Myint Soe et al., 2020)

Mt. Zwekabin is located in Kayin State at the southern part of the country, around 450 km south of the capital Nay Pyi Taw. The top of Mt. Zwekabin is 722 m above sea level. The terrain around Mt. Zwekabin is flat to the north-west, but hilly to the south-east. The surroundings around the mountains are a mosaic of agricultural land and natural vegetation (https://en.wikipedia.org/wiki/Mount_Zwegabin). **Kyauk Ka Lat** Pagoda is situated near Hpa An, the capital of Kayin State. The temple complex is constructed on a prominent limestone rock formation, encircled by an artificial lake (Fig. 5). The Kyauk Ka Lat complex consists of several buildings, shrines, and temples situated on a limestone rock formation (https://en.wikipedia.org/wiki/Kyauk_Ka_Lat_Pagoda).

Lwe Maung Mountain is the highest peak near Pinlaung rising to a height of 1867 m. At this elevation, the weather conditions at the summit of the mountain are harsh and can shift dramatically in an instant. At the peak, there are a monastery and a pagoda, making the mountain highly appealing to active sports enthusiasts, mountaineers, and hikers. The summit is accessible by both cars and motorcycles, allowing individuals who may not be particularly athletic to appreciate the view from that vantage point. Many ascended to enjoy the view of the sunset, coordinating their climb to align with the setting sun. Lwe Maung Mountain is formed from limestone that dates back from the Jurassic to Cretaceous periods. (Myint Soe et al., 2020)

The Mergui, or Myeik Archipelago, consists of around 800 islands and extends over a distance of 600 kilometers along the Andaman coast of Myanmar. It's a hidden place of untamed beauty along the southern coast of Myanmar. The most remarkable images of its tropical islands feature towering limestone cliffs that ascend hundreds of meters above the sea, frequently interspersed with caves and surrounded by dense forests (https://en.wikipedia.org/wiki/Mergui_Archipelago).

Figure 2. Karst landscape with Yontaung near Ywangan (Photo by Aung Aung Pe, DGSE).

Figure 3. Karst Scenery on the Shan Plateau with the north- south trending ridges near Kalaw (Photo by Aung Aung Pe, DGSE).

Figure 4. Taung Kwe Pagoda Mountain in Loikaw, Kayah State (Photo by Myint Soe, DGSE)

Figure 5. Kyauk Ka Lat Pagoda in Hpa An area, Kayin State (Photo by Myint Soe, DGSE)

5. Major Cave Sites

This type of geoheritage is observable not only at the surface but also the underground. Show caves frequently rank among the most popular tourist attractions globally, resulting in karst landscapes becoming familiar to a wide range of people (Parise et al., 2018). The latter features accumulations of mud and pebbles, along with chemical deposits including stalactites, stalagmites, and sinters that exhibit unusual shapes (https://en.wikipedia.org/wiki/Cave).

The occurrence of limestone caves is caused by the combination of Carbon Dioxide and rainwater within the atmosphere to form Carbonic Acid (H_2CO_3). When it flows to the surface of the ground, it combines with carbon dioxide from the leaf compost in the soil and the roots to form strong Carbonic Acid. Limestone is a Calcium Carbonate ($CaCO_3$) compound that can easily be decomposed by Carbonic Acid and dissolves easily in water. Carbonic Acid-dissolved rain water erodes through cracks in the limestone layers, causing chemical weathering which over time leads to the occurrence of sinkholes and limestone caves. Stalactites and stalagmites are formed because the carbon dioxide is dissolved in the small water droplets that drip down on the cave roof and cave floor. When they dry up (with some evaporation), calcium carbonate (limestone) remains attached. When they gather together, stalactites are formed on the roof of the cave as well as stalagmites are occurred on the floor of the cave (https://en.wikipedia.org/ wiki/Cave).

In Shan Plateau, the largest part of this karst is bordered by China, Laos and Thailand (Dreybrodt et al., 2022). At the end of December 2019, an international team from the Myanmar Cave Documentation Project (MCDP) cavers from Myanmar, the United Kingdom, the United States, and Germany, carried out field work in Tachileik, Eastern Shan State. In December 2019 and January 2020, this team measured to Som Hein Cave, the longest cave in Myanmar, in Monghpyak area near the Thai-Myanmar border, the Eastern Shan for cave mapping. This team documented 11.6 km (7.2 miles) in a complicated cave system (Nyi Nyi Aung et al., 2020).

The primary caving areas extend from the north to the south: Mandalay with Pyin Oo Lwin and Kyaukse, Shan State with Ywangan, Hopon and Pinlaung areas, Kayah State and Kayin State with Hpa-An area shown in Fig (6). **Dee Dote Cave** will be reached by walking about 10 minutes from the road to Dee Dote Blue Lagoon that is located on Yeywa (Hydro Power Plant) Road. This Road is from the split of Mandalay - Pyin Oo Lwin Road near Ohn Chaw (16 Mile). The width of the entrance of the cave is about 6 m with the length of about 91 m, and the inside of about 15 to 18 m. The host rocks are dolomite, dolomitic limestone, compact to highly crushed, massive, locally fossiliferous rock strata with a general NNW-SSE dip to the east from the Maymyo Dolomite Formation that is of Upper Devonian – Permian age (299 to 359.2 million years). Tourists will be able to relax and study the natural conditions of Dee Dote Cave, where the beauty of stalactites, stalagmites and natural spring water are intertwined. It is a place that should be especially studied and preserved for geology students and researchers (Myint Soe et al., 2024).

Phoe Inn Cave is located near Phoe Inn Village, the Kyi Tai Group, Myittha Township, Mandalay Region, and it is situated on the Shan Plateau at the border of Myittha Township and Ywangan Township. The area where the cave is located in the Nwalabo Fault Complex (NFC) zone that is of Lower Tertiary to Permian age and trends almost south to north. The underlying rock layers are greatly deformed by faulting and folding. Undifferentiated Jurassic and Cretaceous Rocks such as Sandstone, Siltstone, Shale, Marls, Conglomerate, and Limestone are generally found, and Phoe Inn Cave is even a natural limestone cave. The Phoe Inn Cave is about 1210 m long and is a closed cave. It takes about an hour to go from the beginning to the end. Phoe Inn Cave is unrecognizable from the outside, but the entrance can only be found up close. It is very beautiful with stalactites, stalagmites and natural spring water. The stone walls and stalagmites are like a natural art gallery with a variety of natural shapes (Fig. 7). Formerly, there was only one cave, but a second natural cave was discovered in February, 2017. It is a place that should be studied especially for tourists, researchers and students of geology (Myint Soe et al., 2024).

The second largest horizontal river cave of Myanmar is located in Ywangan, known as Khauk Khaung (Stone Cave), which extends for a distance of 4.9 km (Dreybrodt & Steiner, 2015). It features a sinking river, accompanied by seasonal monsoon floods. Other river caves are Stone Spring Cave and the Linwe Sink Systems, measuring 1.9 kilometers and 0.9 kilometers in length, respectively (Dreybrodt et al., 2022). **Shwe Oo Min Cave** is also prominent in Pindaya area (Fig. 8).The deepest caves in Myanmar can be found within the highest karst ridge situated near Pinlaung, at an elevation of 1700 m above sea level. The 160 m depth record indicates that **Mai Lone Kho** is connected to **the Hti Ngut** shaft, which is situated at a depth of 157 m in the adjacent hill, and this connection leads into an active passage (Dreybrodt & Steiner, 2015).

The Hopon region features a cluster of river caves with **Htan Sam Cave** being the most renowned as a pilgrimage site for the Pa-O tribe, showcasing statues of Buddha. This cave is situated approximately 42 km (26 miles) to the east of Taunggyi in the southern part of Shan State (Fig. 9). The entire length of the cave system is approximately 1818 m; however, to date, only around one-third of this length has been opened for public access. A wide array of aesthetically pleasing and uniquely formed mineral deposits, known as speleothems, can be observed within the cave. These deposits include various types such as soda straws, stalactites, stalagmites, cave corals, flowstones, curtains, cave pearls, cave pisolites, cave shields, helictites, heligmites, and moonmilk (Myint Soe et al., 2018).

The recent discoveries in Kayah State from a 2015 reconnaissance of the German-Swiss team are highly encouraging, revealing a significant expanse of tower karst found near Hpruso (Dreybrodt & Steiner, 2015). This area is characterized by its rough terrain, featuring limestone ridges covered with numerous sinkholes. The **Phruno River Cave**, measuring 4.6 km in length, is located in the Hpruso district and ranks as the third longest cave in Myanmar (Dreybrodt et al., 2022). The **Red River Cave** located near Bawlakhe was measured to a length of 4.08 km (After Myanmar Cave Documentation Project, 2020). **Aung Tha Pyay Cave**, a natural limestone cave

characterized by extensive stalactite and stalagmite formations, is situated in the Loikaw area of Kayah State. **Lwal Tamu Cave** (Fig. 10) and **Kyat Cave**, the remarkable natural caves, are also located in the Loikaw area of Kayah State (Myint Soe et al., 2020).

Bayin Nyi Cave is located at the north of Hpa-An, and the cave and temples are on one of the limestone mountains. The cave is about 207 m long and is a type of cave closed on one side. The hot spring exit and the cold spring exit are located separately at the eastern foot of the cave. The stalactites and stalagmites naturally occur in the cave. It is structured with limestone from the Permian age Moulmein Limestone group and has beautiful karst topography (Myint Soe et al., 2018).

Eait Sar Tharya Cave is located near Naung Plein Village, Hpa-An Township, Kayin State. The length of the cave is about 366 m with a width of 15 to 46 m and an average height of about 15 m (Fig. 11). There is a natural hole in the roof of the cave that protrudes to the outside and provides good light and ventilation. Stalactites and stalagmite found in the cave are more beautiful than other caves. The cave is composed of Permian age Moulmein Limestone Formation and has beautiful karst topography (Myint Soe et al., 2018).

Sadan Cave, can also be found nearby to Hpa An, Kayin State, south east of Myanmar and 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 (Fig. 12). This cave is about 800 m long and the average height is about 10 m. It can be accessed through a 100-foot-wide tunnel. It is a geomorphological site that tourists should visit due to its beautiful karst topography, formed by limestone from the Permian-age Moulmein Limestone (Myint Soe et al., 2018).

Pha Paung Cave is located at southwest of Wa Chaeng Kone Village, east of the Attram River in Kyaikmaro Township, Mon State. This cave is more than 610 m long with an average width of 15 m and an average height of 21 m. Stalactites found in the cave are more beautiful. It is structured with limestone from the Permian age Moulmein Limestone Group (Myint Soe et al., 2018).

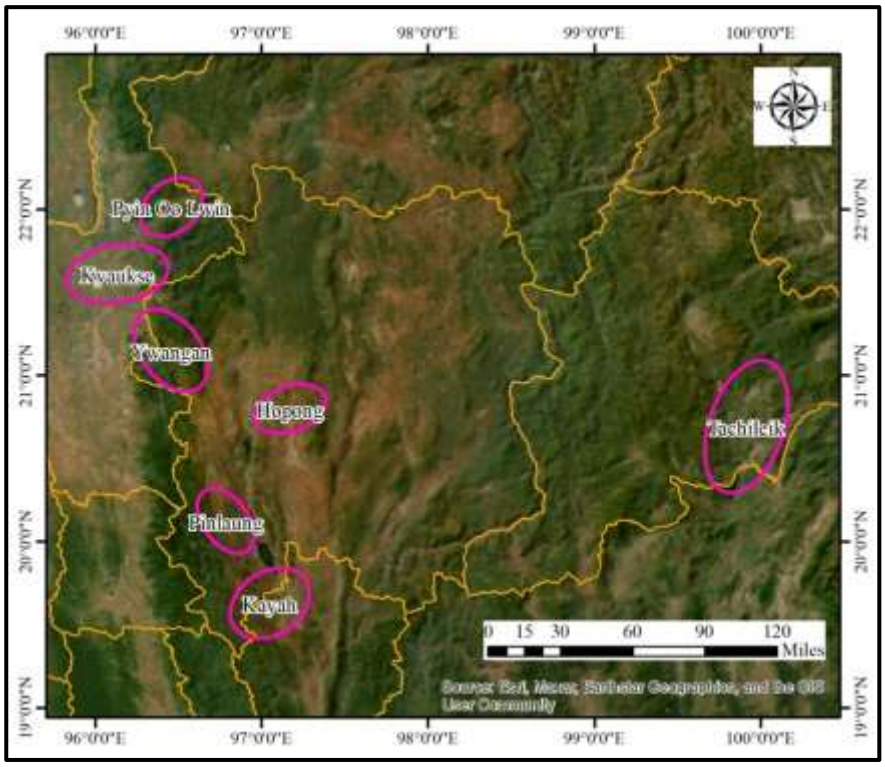

Figure 6. Map of the Shan Plateau and major caving areas.

Figure 7. Inside of Phoe Inn Cave near Myitta Area (Photo by Myint Soe, DGSE).

Figure 8. Shwe Oo Min Cave near Pindaya Area (Photo by Aung Aung Pe, DGSE)

Figure 9. Htan Sam Cave near Hopon, Shan State (Photo by Aung Aung Pe, DGSE)

Figure 10. Lwal Tamu Cave near Loikaw Kayah State (Photo by Aung Aung Pe)

Figure 11. Eait Sar Tharya Cave near Hpa An, Kayin State (Photo by Myint Soe, DGSE).

Figure 12.Sadan Cave near Hpa An, Kayin State (Photo by Myint Soe, DGSE).

6. Karst Water

Karst water plays a significant role in karst and cave conservation. According to the topographic differences, karst terrains were classified into four types: karst on plateaux, karst in mountains, karst in plains, and karst on islands (Jiang et al., 2020). Karst landscapes host significant value due to their remarkable natural resources, particularly karst aquifers. The water resources found in karst areas have played an important role in the historical and economic advancement of many regions (Parise & Sammarco, 2015).

Karst aquifers frequently provide substantial groundwater reserves, which serve as essential resources pertinent to human health, food security and industrial activities. The importance of aquifers characterized by karst permeability is growing as they currently provide approximately 25% of the worldwide demand for drinking water (Ford & Williams, 2007).

Karstification in limestone forms to the development of extensive underground spaces that facilitate both water movement and habitation. Drainage systems can potentially become underground. Some areas feature large subterranean river systems (Parise & Sammarco, 2015).

A karst lake is a significant, enduring body of water located within a karst sinkhole or a closed depression (After IRCK, 2024). The **Inle basin,** situated in the heart of the Shan Plateau and encompassing several lakes, is believed to represent a type of polje shown in (Fig. 13). The Shan Plateau, often referred to as the karst plateau, possesses significant water resources due to its extensive exposed karst formations and the presence of underlying synclinal structures. Groundwater in karst regions primarily flows into rivers and fills lakes through deep fault systems, whereas the contribution from karst springs is relatively minor (Jiang et al., 2020).

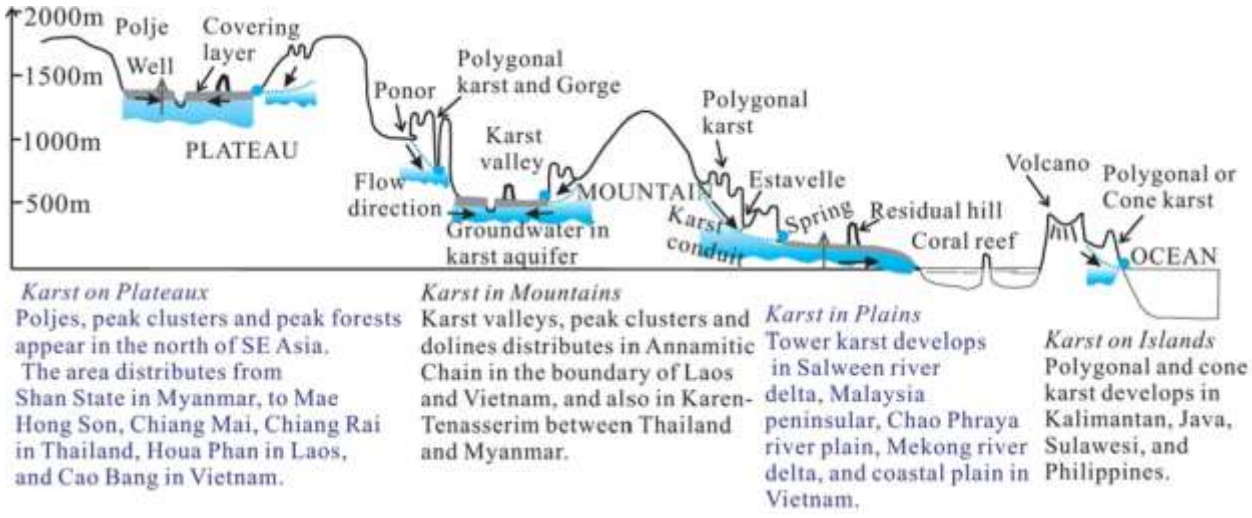

Figure 13.Karst distribution and environmental classification in Southeast Asia (Jiang et al., 2020).

7. Karst Conservation

Limestone habitats with caves may support distinct flora and fauna that have adapted to the unique geological, hydrological, and associated microclimatic conditions present in these environments (Bird Life., 2014). A significant portion of the Shan plateau exhibits a remarkably low population density and is recognized for possessing one of the highest levels of biodiversity globally (Dreybrodt & Steiner, 2015). The outcomes of the Myanmar Cave Documentation Project (MCDP) are recorded in a Karst Database that includes comprehensive metadata. This database encompasses approximately 800 karst features, such as caves, sinks, and springs along with 110 kilometers of cave passages (Dreybrodt et al., 2022).

In 2017, Lourenco has described a new species of scorpion in Sadan Cave located in Hpa-An along with the discovery of millipede and beetle species from Stone Cave in Ywangan. Recent

discoveries have identified new species of snails and a cave-dwelling fish from Kayah (Kottelat & Grego, 2020). White fish have been discovered in Namun Spring Cave in Ywangan but no cave fish species have been documented in Myanmar (Dreybrodt & Steiner, 2015).

Collaborations were established with universities and NGO to share knowledge and enhance awareness regarding the susceptibility of the karst ecosystem to pollution. The initial significant step was the 1st Myanmar Cave Training in June 2017, in collaboration with the Fauna & Flora International (FFI) and the German Development Agency (GIZ), held in Parpant Cave situated in Hopon District, Shan State. The training led to the establishment of local cave and karst groups that have been participating in annual expeditions since 2018. The collaborative efforts of the Myanmar-International teams have significantly improved communication with the local community, resulting in a more streamlined process for additional research (Dreybrodt, 2017).

8. Results and Discussions

Karst landforms are significantly prominent in mountainous regions, particularly within the Shan Plateau, the Loikaw area of Kayah State, and the Hpa-An area of Kayin State. The majority of limestone caves in Myanmar were formed, in association with micritic limestone, dolomitic limestone, and brecciated limestone from the Thitsipin Limestone and Moulmein Limestone, which date back to the Permian period. Qualitative and qantitative assessment of geosites for potential geoheritage resources and geotourism attractions of some popular karst landscape and caves are expressed in Table.

Knowledge about karst and cave conservation in Myanmar should be given, and more research related to Karst should be carried out. Measures should be taken to ensure long-term clean water sources and rivers. Climate change conditions and methods to preserve the environment should be properly implemented. Limestone mountains in the Karst area, Caves, Stone Forests, Canyons, Springs and Rivers should be preserved and opened as Geosites, Geoparks that help the country's economy in the tourism sector.

Table 1. Qualitative and Qantitative Assessment of geosites for potential geoheritage resources and geotourism attractions of some popular karst landscape and caves

Sr.	Geosite	Scientific and Educational value	Aesthetic Value	Recretional value	Cultural and Historical value	Economic value	Religious value	Level of significane
1	Taung Kwe Pagoda Mountain	Karst Landform	Attractive landscape and morphology of its surroundings	Enjoy the scenic views	Ancient Pagoda	Local people can generate their income by visitors	The Pagoda for local and Buddhist	National Heritage
2	Mt. Zwekabin	Karst Landform	Attractive landscape of its surroundings	Hiking, Enjoy the scenic views	Ancient Pagoda	Local people guide income	Ancient Pagoda for Buddhist	National Heritage
3	Htan Sam Cave	Karst Landform, Cave Formation	Attractive landscape of cave and its surroundings	Cave exploration	Pagoda and statues	Local people can generate their income by visitors	Pagoda and statues for Buddhist	State
4	Dee Dote Cave	Karst Landform, Cave Formation	Attractive landscape of cave and its surroundings	Cave exploration	-	Local people guide income	The cave is used as a temple for Buddhist	National Heritage
5	Phoe Inn Cave	Karst Landform, Cave Formation	Attractive landscape of cave and its surroundings	Cave exploration	-	-	-	State

9. Conclusions

By studying the conservation of Karst and Cave, Karst Geology and Hydrogeology, they will be able to beneficial in area such as climate changes. One of the important steps is for enhancing karst education initiatives in collaboration with local people and local universities further unexplored areas. Caves, straits and aquifers may develop due to the high permeability of the karstified subcutaneous zone of carbonate rocks. Karst aquifers provide important water storage during floods. As a result, prolonged droughts of climate change can be sustained. The main point is to identify the geologically and geomorphologically significant features in Myanmar through conservation efforts, aiming to represent them effectively for scientific research and also assess their potential for tourism development. Therefore, these karst and caves are important for preservation as geoheritage sites and geopark.

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