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STUDY ON SPELEOTHEMS FROM GEOHERITAGE SITES OF THE LIMESTONE CAVES AT THE HPA-AN TOWNSHIP, KAYIN STATE, MYANMAR

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Abstract

The research area is located at the vicinity of the Hpa-an Township, Kayin State, Myanmar. In Hpa-an area, there are so many historical limestone caves with beautiful speleothem, such as Ba-yint-nyi cave, Ya-thae-pyan cave, Kawtgon cave, Sadan cave, Waè-byan cave, Hlaing-kawt-pya cave, Kawt-ka-thaung cave, Badom cave, Linno cave and Thayar-shwe cave. Among them, Ba-yint-nyi cave, Ya-thae-pyan cave, Kawtgon cave, Sadan cave and Linno cave are distinct and famous for tourism. These limestones caves are composed of micritic limestone, dolomitic limestone and brecciated limestone of the Moulmein Limestone Formation (Permian in age). According to morphology of speleothems by Hill and Forti (1997), at least 17 kinds of speleothems can be classified as the cave deposits of Ba-yint-nyi cave, Ya-thae-pyan cave, Kawtgon cave, Sadan cave and Linno cave in this study. All of the speleothems formations are mainly controlled by the five hydrological mechanisms such as dripping, flowing, seeping, pooled water and splashing water. Thermogene travertines form from carbon dioxide sources which receive most of their carrier CO_2 from thermally-driven processes in this area because of the sub-tropical climate condition. The preservations of these beautiful limestone caves are important for geotourism as geoheritage sites. Moreover, these caves act natural ornaments for our country.

Keywords: Speleothem, limestone cave, tourism, geoheritage, geotourism

Introduction

A "speleothem" is a secondary mineral deposit formed in a cave by a chemical reaction from a primary mineral in bedrock or detritus, (Moore, 1952). "The term "speleothem" refers to the mode of occurrence or shape of a mineral deposit.

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The research area, Hpa-an Township, has so many historical limestone caves with beautiful speleothem, such as Ba-yint-nyi cave, Ya-thae-byan cave, Kawtgon cave, Sadan cave, Waè-byan cave, Hlaing-kawt-pya cave, Kawt-ka-thaung cave, Badom cave, Linno cave and Thayar-shwe cave. Among them, Ba-yint-nyi cave, Ya-thae-byan cave, Kawtgon cave, Sadan cave and Linno cave are distinct and famous for tourism.

Location and Accessibility

The research area is located at the vicinity of the Hpa-an Township, Kayin State which is bounded between North Latitude 16°44' to 16°56' and East Longitude 97°33' to 97°43'. According to the Universal Tranverse Mercator Map Index, this area lies within 1697-9, 10, 13 and 14. The area coverage is 378 km^2 and the cave distribution area is 16 km^2.

The research area is easily accessible by car, train and various kinds of vehicle because most of the areas are lowlying topography and fairly good condition of bedrock for road constructions.

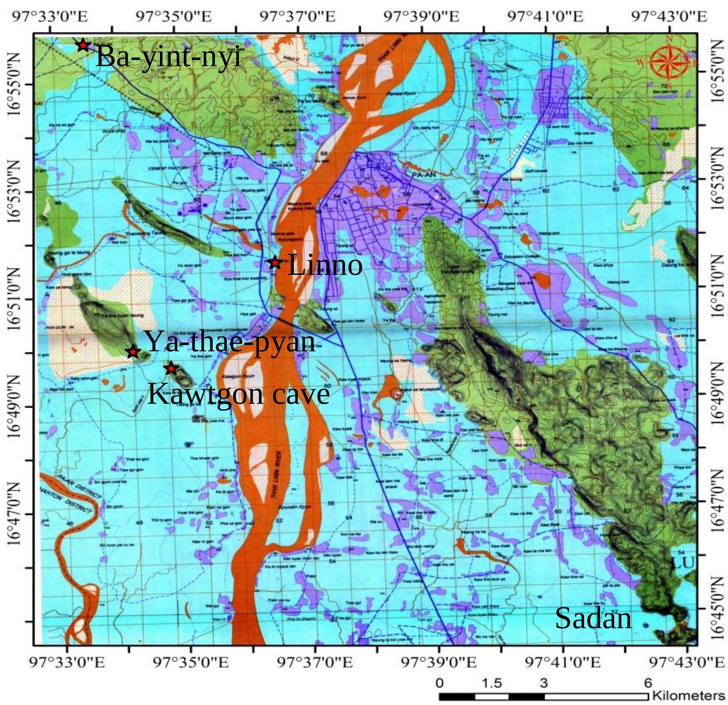


Figure 1: Location map of the research area

Physiography and Drainage

Physiographically, isolated hills with steep slopes, mountain ranges and flat plain are observed in the study area. The study area lies within the western part of the Shan-Tanintharyi Block.

Elevated hilly regions occur only at the south-eastern and north-western part of this area and most of the areas are flat-plain with isolated hills shown in Figure (2). The highest elevation of the research area is Zwekabin Range with 401-503 meter.

In the research area, Thanlwin River and its tributaries flow from north to south. The major influence streams are Kawyin Chaung and Binnlaing Chaung that mainly affect to the Ba-yint-nyi Cave and Ya-thae-pyan Cave. Besides, three main drainage patterns occur in this area such as dentritic pattern, subparallel pattern and centripetal pattern, (Figure 3).

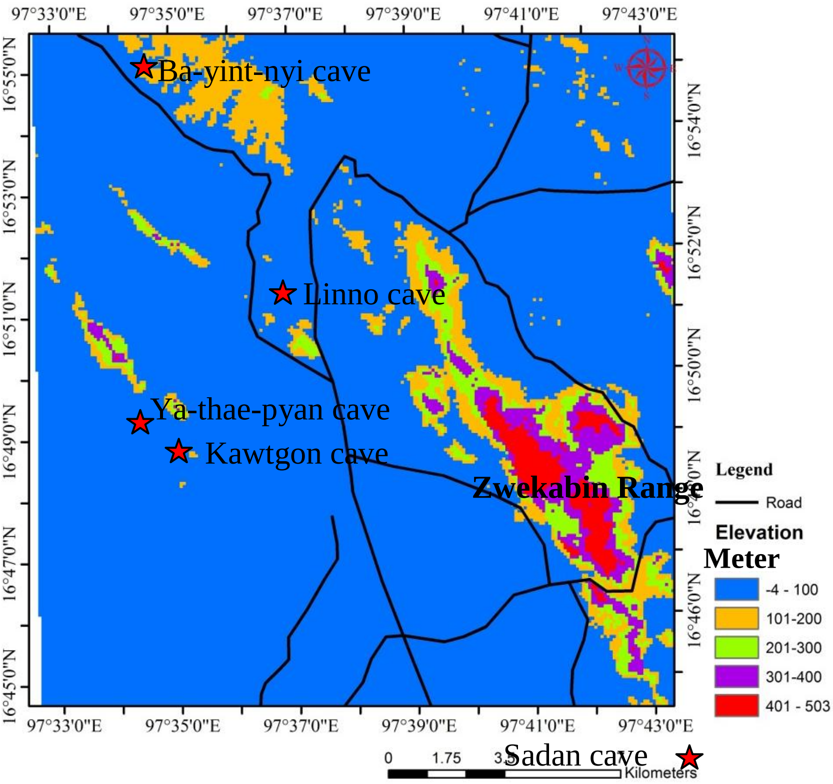


Figure 2: Physiography of the research area

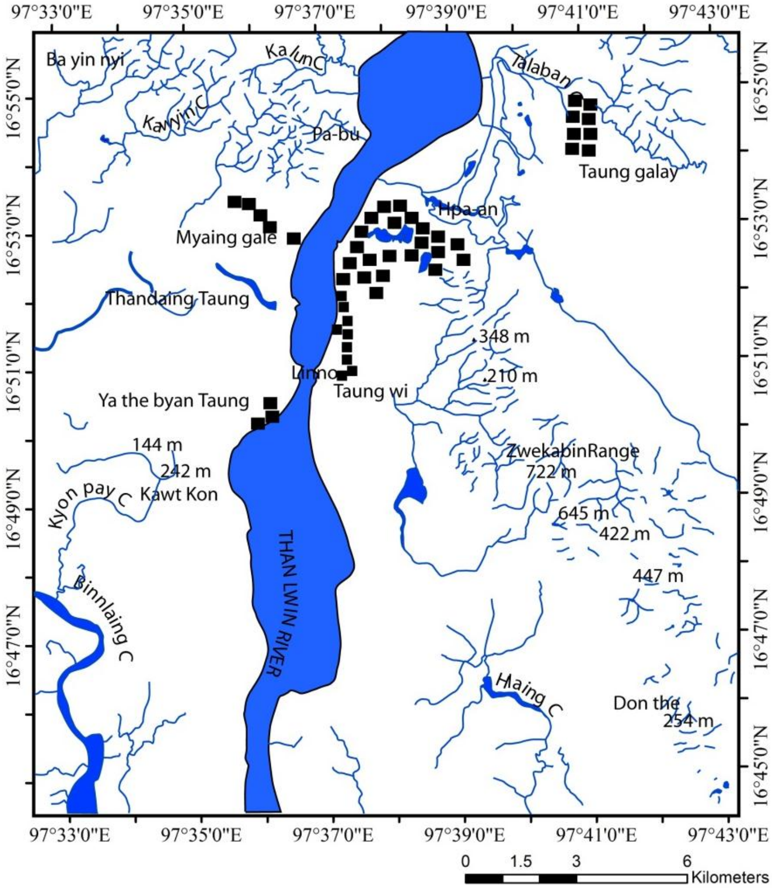


Figure 3: Drainage map of the research area

Geology of the Research Area

The rocks of Taungnyo Formation (Carboniferous to Early Permian), Moulmein Limestone (Middle to Late Permian) and Alluvium (Quaternary) cover the study area with different relief.

The rocks of the Taungnyo Formation are exposed at the northern part of the Zwekabin Range and southern part of the Hpa-an Town. The rocks are mainly composed of clastic units; thin bedded, whitish grey to pinkish colored siltstone intercalated with thinnly laminated shale, partly fine grained nodular sandstone which is shown in Figure (4).

Moulmein Limestone is mostly composed at the Zwekabin Range with gentle dipping. The other isolated hills with karst topography are also composed of Moulmein Limestone. The rocks consist of medium to thick bedded, light grey to grey colored micritic limestone, dolomitic limestone and brecciated limestone of the Moulmein Limestone. (Figures 5, 6 & 7)

Most of the flatplains are covered by reddish brown to yellowish brown colored, thick alluvial soils. (Figure 8)

Figure 4: Thin bedded, whitish grey to pinkish colored siltstone intercalated with thinnly laminated shale, partly fine grained nodular sandstone of Taungnyo Formation at the northern part of Zwekabin Range

Figure 5: Medium to thick bedded, light grey to grey colored micritic limestone of the Moulmein Limestone at the entrance of Ba-yint-nyi Cave

Figure 6: Medium to thick bedded, grey to dark grey colored dolomitic limestone of the Moulmein Limestone at the exit of Ya-thae-pyan Cave

Figure 7: Medium to thick bedded, grey to dark grey colored brecciated limestone of the Moulmein Limestone at the western part of the Zwekabin Range

Figure 8: Reddish brown colored lateritic soil of the Alluvium at the north-eastern part of the Hpa-an Town

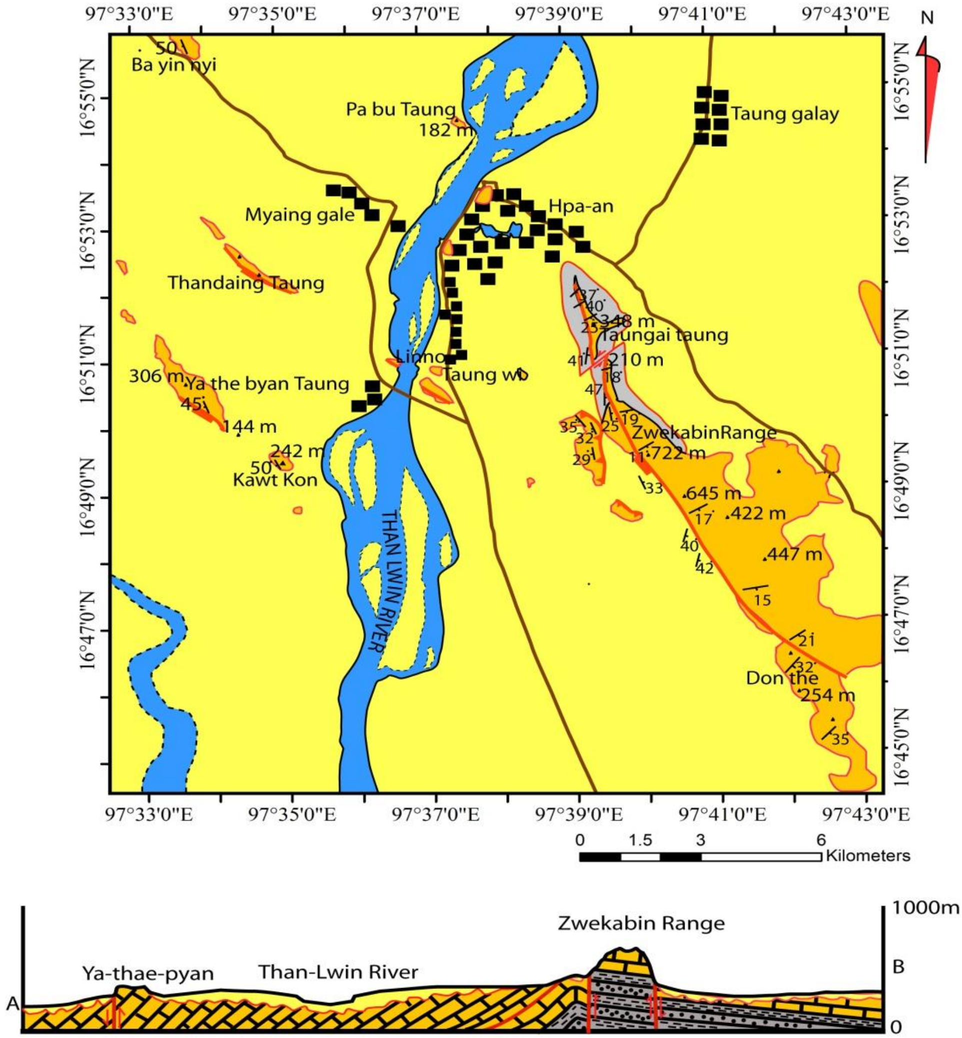
Geological Structures

The research area is mainly characterized by NNW-SSE trending stratigraphic units in eastern part and NW-SE trending in central and western part. Besides, the major longitudinal fault with normal sense occurs at the western flank of the Zwekabin Range which is trending nearly north-south in direction. (Figure 9) Another thrust fault is also trending parallel to the normal fault. (Figure 10) Other minor faults are trending nearly NW-SE direction which occurs as the normal faults at the western part of the research area which are shown in Figure (11). Moreover, the anticlinal fold occurs with NNW-SSE trending at the western part of the Zwekabin Range. The geological map of the research area is illustrated in Figure (12).

Figure 9: Normal fault scarp at the western part of the Zwekabin Range

Figure 10: Thrust sheet at the west of the Zwekabin Range

Figure 11: Normal fault scarp at the western part of the Ba-yint-nyi Cave



Geology by Aung Kyaw Myat and Aung May Than (2017)

Explanation

Alluvium (Quaternary)

Moulmein Limestone (Middle to Late Permian)

Taungnyo Formation (Carboniferous to Early Permian)

Figure 12: Geological map of the research area

Methodology

It has been done by the study and collection of all available geological Thesis and Papers (Iyer, 1938; Clegg, 1953; Chhibber, 1934; Brunnschweiler, 1970; Zaw Win and Kyaw Htin Khine, 2006; Win Swe, 2012; Maung Thein, 2014; Aung May Than, 2014; Saw Naing Tint Oo; 2015) and text books and papers of traventine (Allen, 2005; Caroll and Paolo, 1995; Fairchild, et al., 2006).

Topographic map interpretation is plotted on the UTM map no. 1697-9, 10, 13 and 14 of Survey Department (Ministry of Environmental Conservation and Forestry). Topographic units as features, elevation contrast and topographic trends, drainage systems in relation with structural controlled features are described in these studies.

By using the Arc GIS 10.1 (GIS software), the terrain analysis of the research area was done on the DEM image with 30 meter resolution.

And then, tape and compass traverse method compiled with distance meter measurement was used to draw the outcrop mapping and detail cave morphology.

The collection of water samples made by Saw Naing Tint Oo (2015) in each caves have been carried out to test the chemical composition of water and to know the water qualities.

The identification and analysis of cave deposits were done by the classification of Hill and Forti, 1997. Moreover, the mechanisms and processes of cave developments were followed by the Allen Pentecost, 2005.

Results and Discussions

Formation of Speleothems

The development of big cave system with dozens or hundreds of meters in length begins with micro-karst cavities. And then larger pores, pits, shafts and small caverns are developed by the opening of bedding planes, fissures, joints and faults which gradually integrate and expand into channels that collect the water flows. Finally, cave system comes into existence when many such channels are connected.

On the other hand, the speleothems are formed by the following processes. When rainwater seeps through the soil, it absorbs carbon dioxide (CO2) given off by plant roots, soil animals and decaying matter. This carbon dioxide makes the water acidic and able to dissolve limestone (calcium carbonate).

These limestone caves in Hpa-an area were formed, related with micritic limestone, dolomitic limestone and brecciated limestone of the Moulmein Limestone (Permian in age). These rocks dissolve in the acidic water as it finds its way through tiny cracks such as joints, fractures, etc in the rock. When the water reaches the cave, it loses carbon dioxide to the cave air. Water is now less acidic and unable to hold the same amount of limestone. Tiny crystals of calcium carbonate are deposited slowly to make the decoration to the caves with speleothems.

Classification of Speleothems

Hill and Forti (1997) classified the speleothems depend on the five hydrological mechanisms such as dripping, flowing, seeping, pooled and splashing water. They classified into 31 kinds of speleothems based on their forms and water conditions. (Figure 13A & B)

Among them, the common types of speleothems are stalactite, stalagmite, column, flowstone and rimstone dam. They are formed by the following processes.

Stalactite

When a soda straw is forming, the solution will also deposit calcite along the inner part of the tube as it travels through it. Eventually, the straw will become solid. At that point, as the solution continues to enter the cave, it is forced to the side of the tube, then runs down outside. Over time, the result looks like an icicle.

Stalagmite

As the watery solution falls from the ceiling, it lands on the floor or a ledge where it splashes or runs over an area, leaving the remaining calcite in its wake. The continued deposits build into a mound.

Column

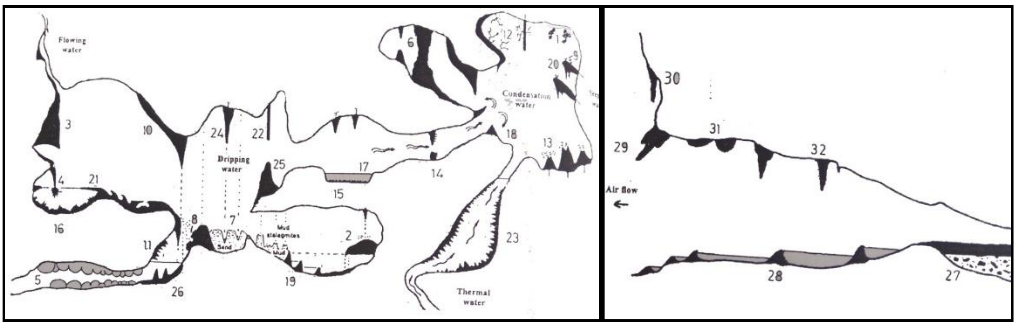
As usual, a stalagmite is directly below a stalactite. Over much time they may finally meet. As calcite continues to run down the length of the stalactite, it now continues to run down the connected stalagmite smoothing the connection point. Some columns have been together for so long that it is hard to tell where the two formations first joined.

Flowstone

It is similar to the formation of a stalagmite. However, the area receiving the deposit has a slope to it, so the water runs down the slope in a wide spread. A flowstone can cover a large area.

Rimstone Dam (also known as Gours in Europe)

Depressions in the cave floor may collect saturated water. The calcium in the solution will deposit around the edge of the pool. Eventually the deposits build up so high that more and more water can be held. The calcite deposits act as a dam.



(A) (B)

Figure 13: Diagram of speleothem type (after Hill and Forti, 1997)

(A) (1) Anthodites, (2) Baldacchino canopy, (3) Bell canopy flowstone, (4) Bottle brush stalactite, (5) Cave clouds, (6) Column, (7) Conulites in sand, (8) Coralloids, (9) Cups, (10) Drapes, (11) Folia, (12) Helictites, (13) Geysermites, (14) Oriented popcorn, (15) Pearls, (16) Pool spar, (17) Raft/floe, (18) Rims, (19) Rimstone dams, (20) Shields, (21) Shelfstone, (22) Soda straw stalactite, (23) Spar, (24) Stalactite, (25) Stalagmite, (26) Tower cones

(B) (27) Clastic traventine under stalagmite floor, (28) Dam, (29) Phototropic stalactite, (30) Remora or aussenstalactit and (31) Roof boss.

Identification of Speleothems at the Ya-thae-pyan Cave

The Ya-thae-pyan cave is 433 meter long and its alignment is NW-SE in direction. The rocks are made up of micritic limestone, dolomitic limestone and brecciated limestone of the Moulmein Limestone. There are 16 kinds of speleothems according to Hill and Forti (1997) which is shown in Figure (14-19).

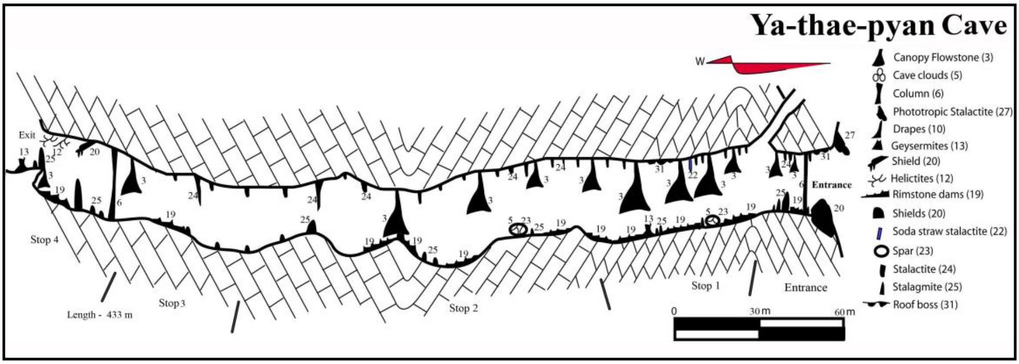


Figure 14: Morphology of speleothem with cross-sectional view at the Ya-thae-pyan cave

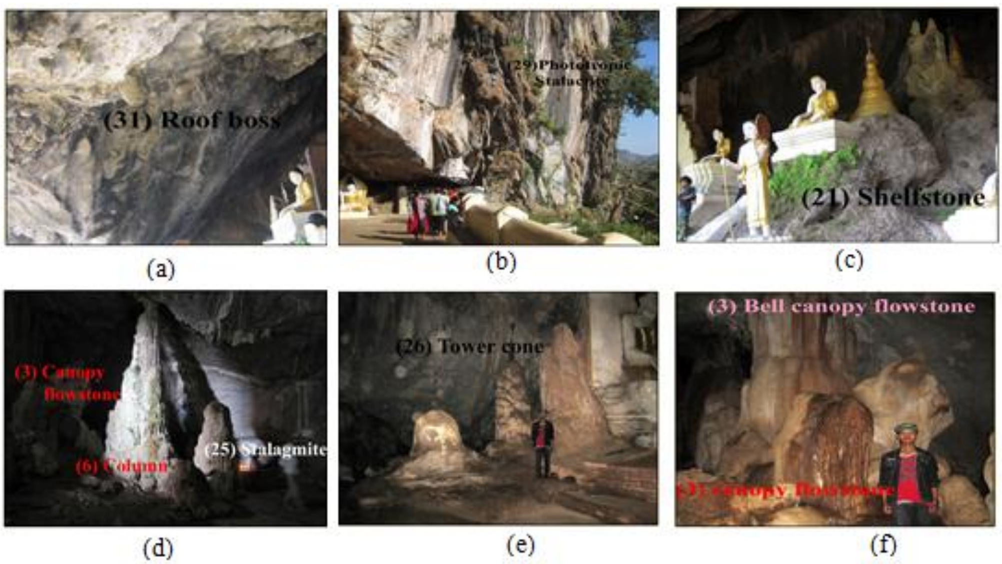


Figure 15: (a-f) Types of the speleothem at the entrance of Ya-thae-pyan cave

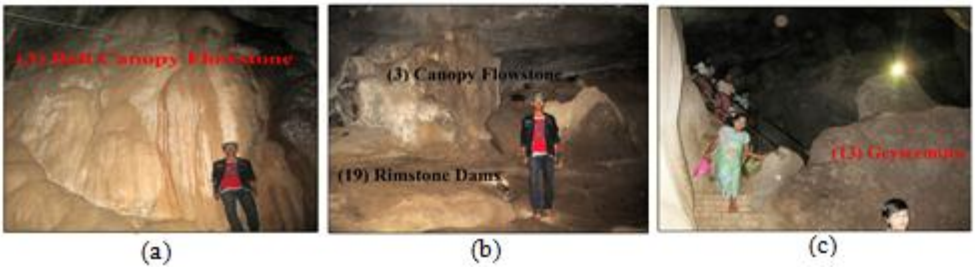


Figure 16: (a-c) Types of the speleothem at the (Stop 1) of Ya-thae-pyan cave

Figure 17: (a-b) Types of the speleothem at the (Stop 2) of Ya-thae-pyan cave

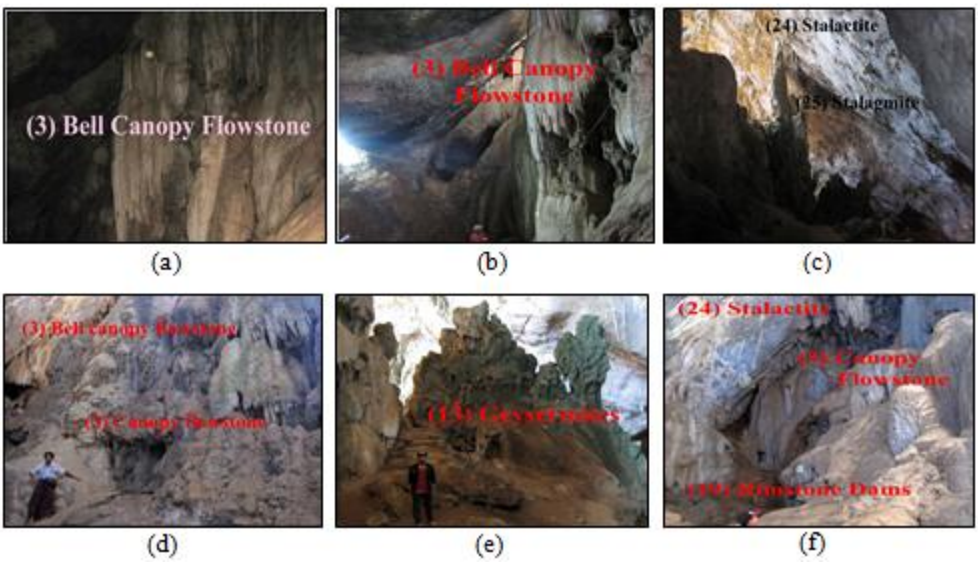


Figure 18: (a-f) Types of the speleothem at the (Stop 3) of Ya-thae-pyan cave

Figure 19: (a-c) Types of the speleothem at the (Stop 4) of Ya-thae-pyan cave

Identification of Speleothems at the Ba-yint-nyi Cave

The Ba-yint-nyi cave is 205 meter long and its alignment is also NW-SE in direction. The rocks are made up of micritic limestone and dolomitic limestone of the Moulmein Limestone. There are 14 kinds of speleothems according to Hill and Forti (1997) which is shown in Figure (20-26). Among these speleothems, stalactite, stalagmite, flowstone and rimstone dam are commonly occurred along the cave.

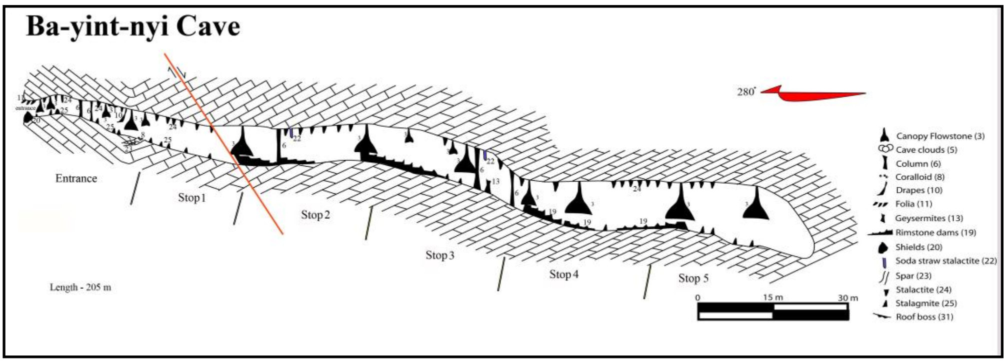
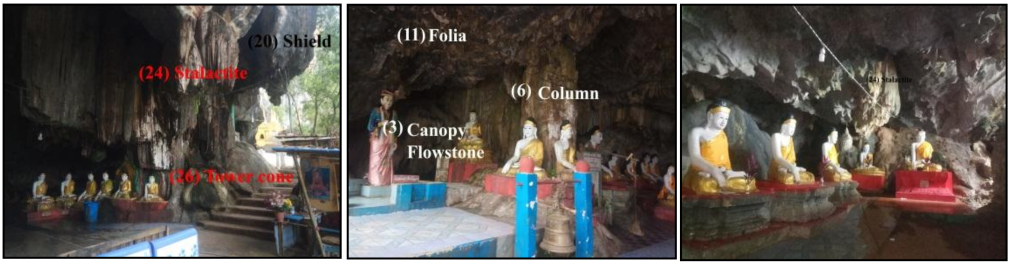


Figure 20: Morphology of speleothem with cross-sectional view at the Ba-yint-nyi cave



(a) (b) (c)

Figure 21: (a-d) Types of the speleothem at the entrance of Ba-yint-nyi cave

(a) (b) (c)

(d) (e)

Figure 22: (a-e) Types of the speleothem at the (Stop 1) of Ba-yint-nyi cave

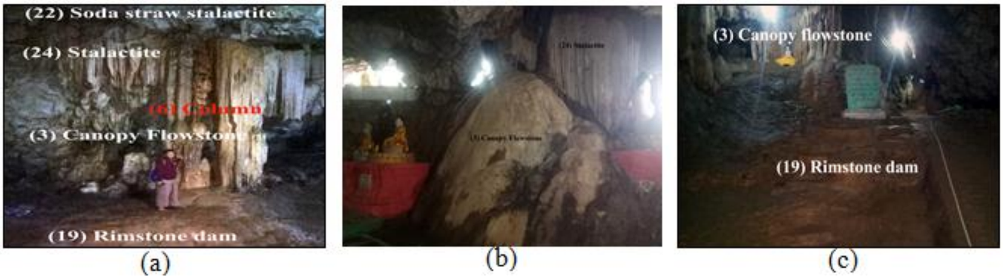


Figure 23: (a-c) Types of the speleothem at the (Stop 2) of Ba-yint-nyi cave

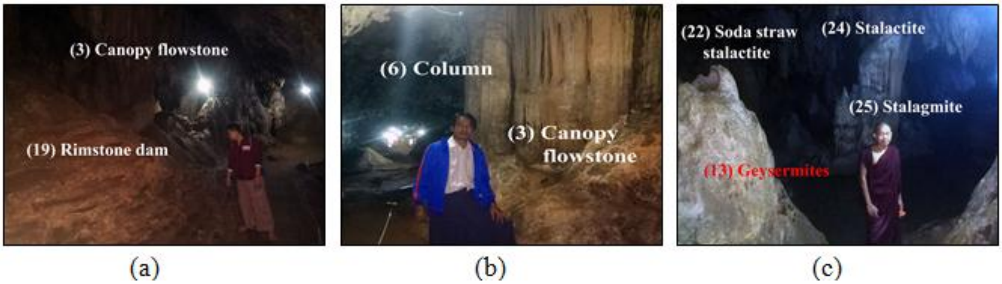


Figure 24: (a-c) Types of the speleothem at the (Stop 3) of Ba-yint-nyi cave

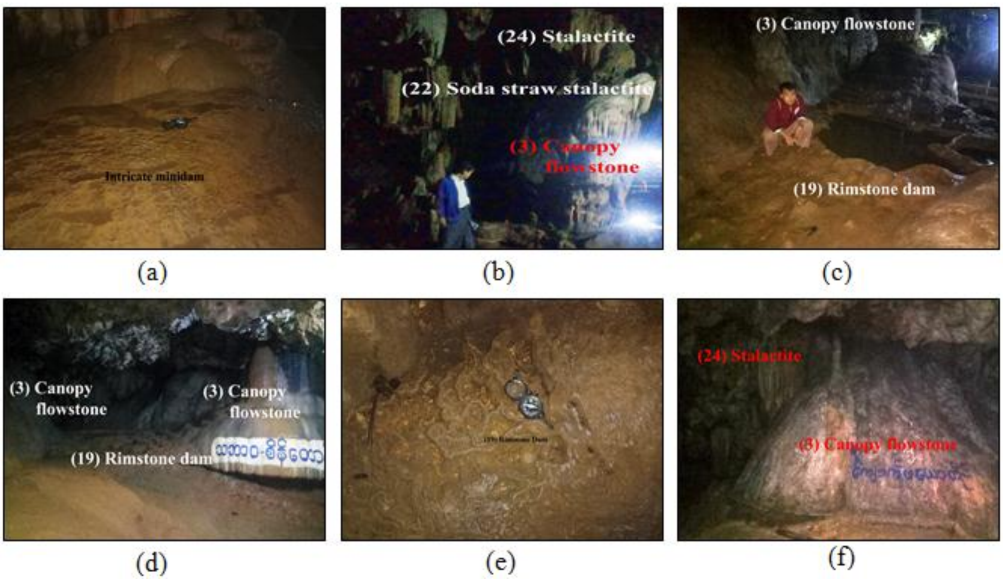


Figure 25: (a-f) Types of the speleothem at the (Stop 4) of Ba-yint-nyi cave

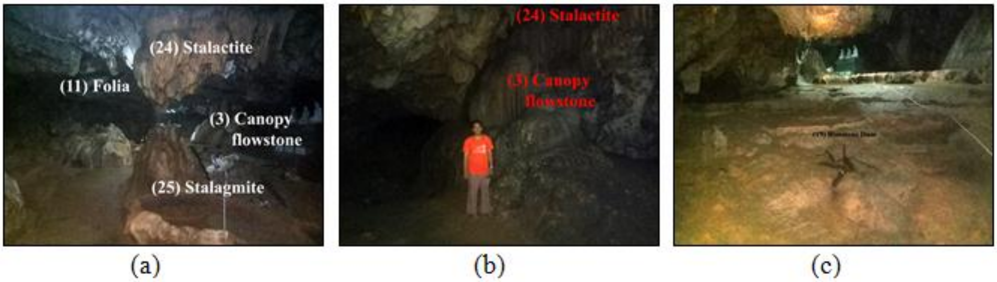


Figure 26: (a-c) Types of the speleothem at the (Stop 4) of Ba-yint-nyi cave

Identification of Speleothems at the Kawtgon Cave

The Ba-yint-nyi cave is also 70 meter long and it is trending nearly NNW-SSE in direction. The rocks are made up of micritic limestone and dolomitic limestone of the Moulmein Limestone. There are 9 kinds of speleothems according to Hill and Forti (1997) which is shown in Figure (27-29). Among these speleothems, stalactite, stalagmite, flowstone and rimstone dam are commonly occurred along the cave.

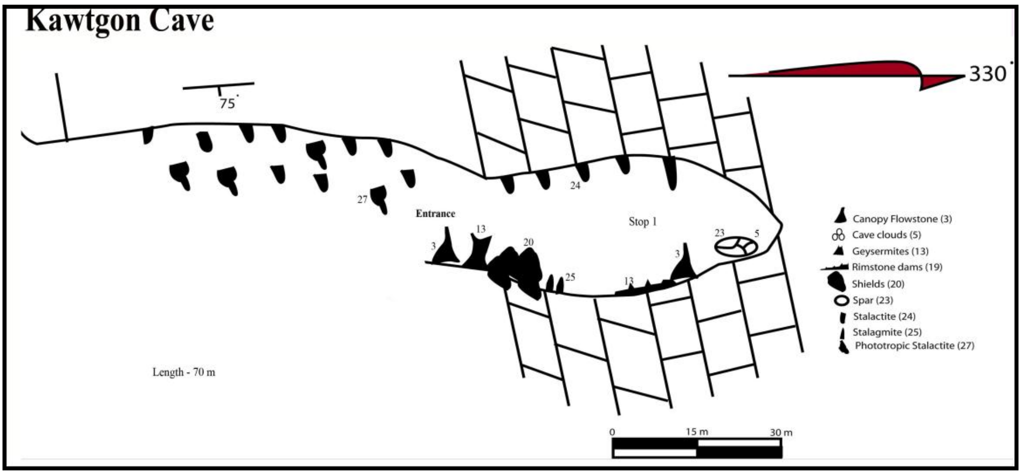


Figure 27: Morphology of speleothem with cross-sectional view at the Kawtgon cave

Figure 28: (a-c) Types of the speleothem at the entrance of Kawtgon cave

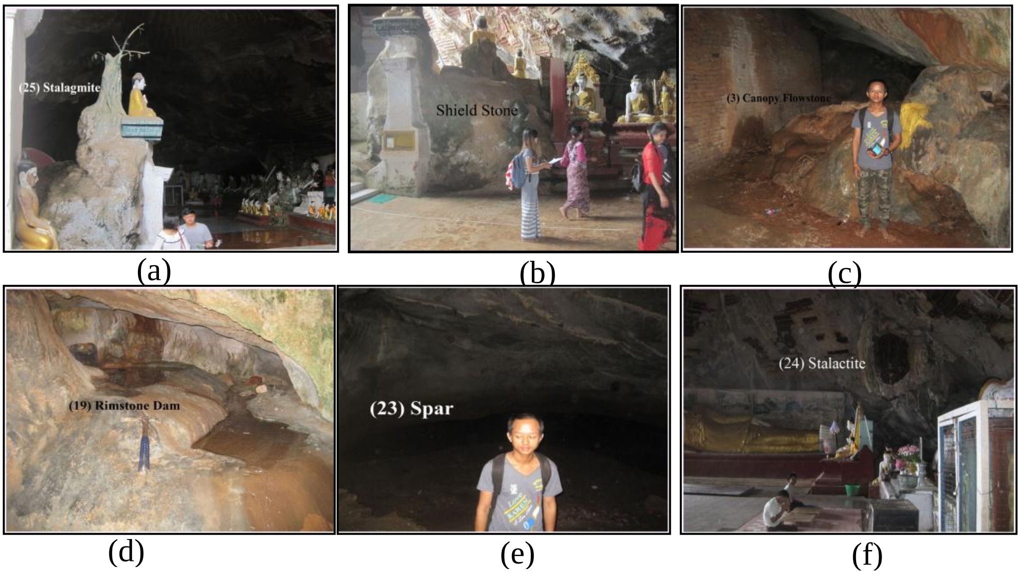


Figure 29: (a-f) Types of the speleothem at the (Stop 1) of Kawtgon cave

Identification of Speleothems at the Sadan Cave

This cave is the longest cave with beautiful speleothems and 800meter long, trending nearly N-S in direction. The rocks are made up of micritic limestone, brecciated limestone and dolomitic limestone of the Moulmein Limestone. There are 13 kinds of speleothems according to Hill and Forti (1997) which is shown in Figure (30-36). Among these speleothems, stalactite, stalagmite, flowstone, column and rimstone dam commonly occur along the cave.

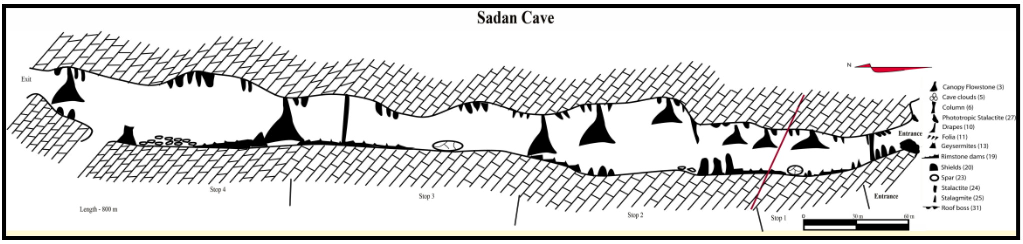


Figure 30: Morphology of speleothem with cross-sectional view at the Sadan cave

(a) (b) (c)

Figure 31: (a-c) Types of the speleothem at the entrance of Sadan cave

(a) (b) (c)

Figure 32: (a-c) Types of the speleothem at the (Stop 1) of Sadan cave

(a) (b) (c)

Figure 33: (a-c) Types of the speleothem at the (Stop 2) of Sadan cave

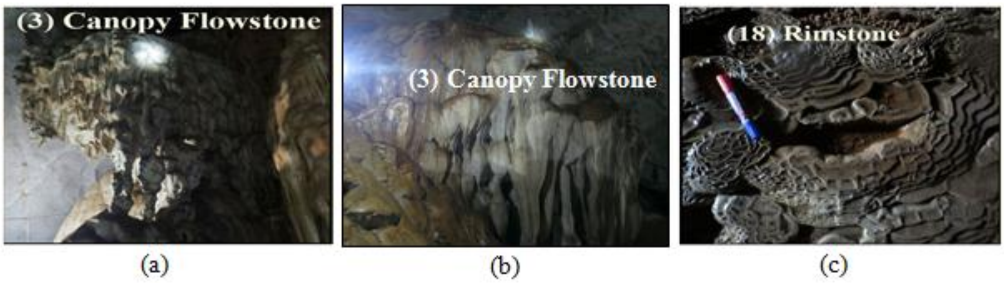


Figure 34: (a-c) Types of the speleothem at the (Stop 3) of Sadan cave

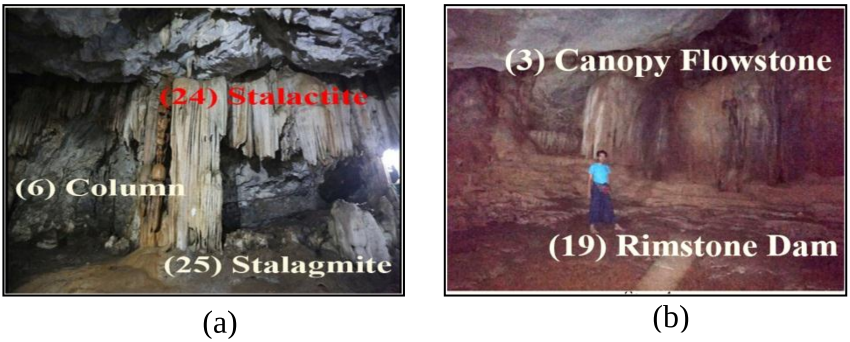


Figure 35: (a-b) Types of the speleothem at the (Stop 4) of Sadan cave

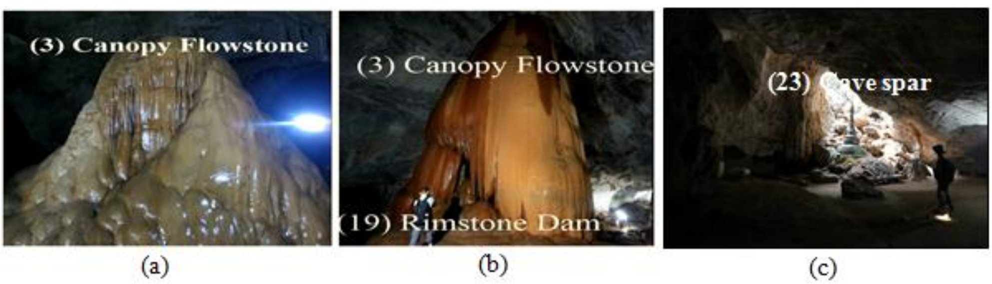


Figure 36: (a-c) Types of the speleothem at the (Stop 5) of Sadan cave

Identification of Speleothems at the Linno Cave

The Linno cave is not favourable for conservation because the cave is also home for many bats. The cave is 67 meter long and it is trending nearly NW-SE in direction. The rocks are made up of cherty limestone of the Moulmein Limestone. There are 5 kinds of speleothems according to Hill and Forti (1997) which is shown in Figure (37-41). Among these speleothems, stalactite, stalagmite, flowstone and rimstone dam commonly occur along the cave. Besides, the landslide, rockfall occurs at the entrance of the Linno cave.

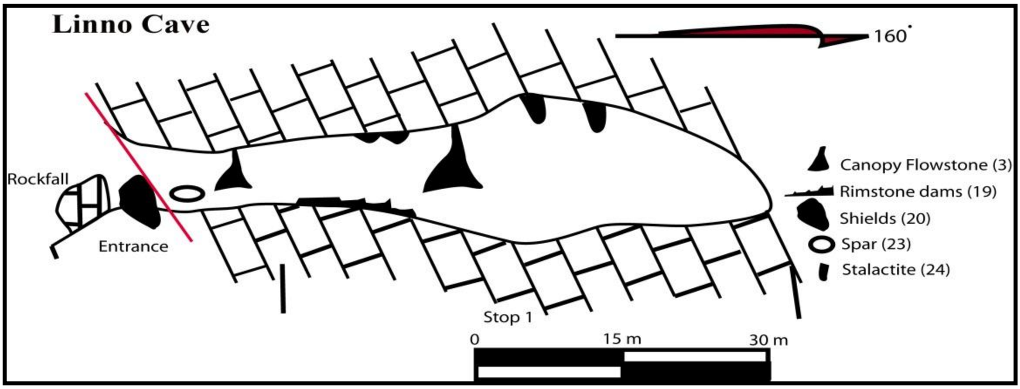
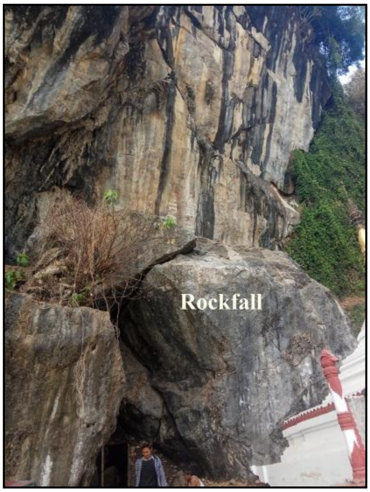


Figure 37: Morphology of speleothem with cross-sectional view at the Linno cave



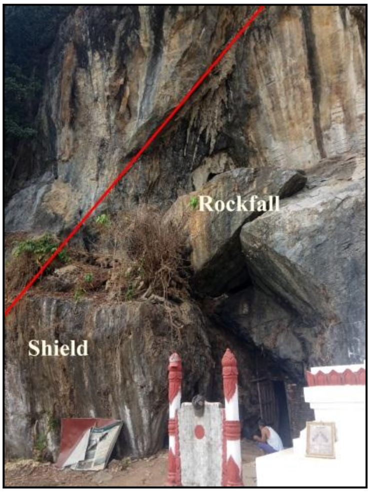


Figure 38: Photograph showing nature of landslide at the entrance of Linno cave

Figure 39: Photograph showing nature of fault, landslide and type of speleothem at the entrance of Linno cave

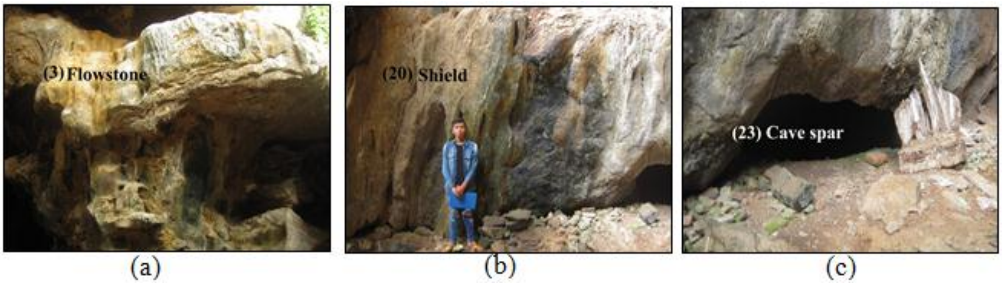


Figure 40: (a-c) Types of the speleothem at the entrance of Linno cave

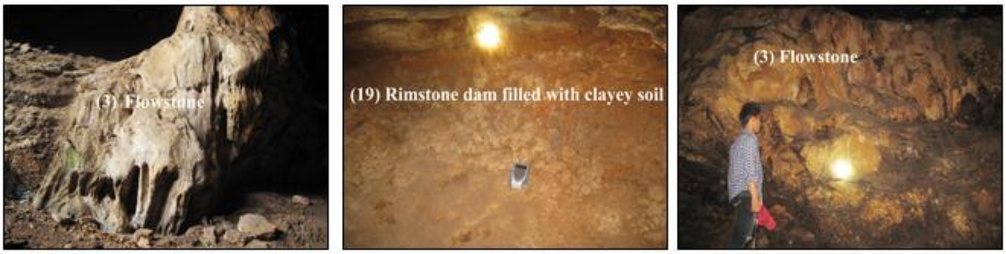


Figure 41: (a-c) Types of the speleothem at the (Stop 1) of Linno cave

Controlling Factors in the Formation of Speleothems

In the limestone terrain, the water condition, opening of rocks such as joints, cracks, bedding plane and faults and inclination of wall rocks are the main controlling factors in forming the speleothems. Besides, the amount and rate of water flowage can also influence on the shape and size of the speleothems. The water condition with their related types of speleothems is as follows in Table (1).

Table 1: The relation between water condition and types of speleothems

Water condition	Types of Speleothems
Dripping	(2) Baldacchino canopy, (4) bottle brush stalactite, (6) Column, (7) conulites in sand, (13)Greysermites , (14) oriented popcorn, (15) pearls, (22) Soda straw stalactite, (24) stalactite, (25) stalagmite, (29) Phototropic stalactite, (30) Remora or aussenstalactit
Flowing	(3) Bell canopy flowstone, (5) cave cloud, (8) coralloids, (18) Rims, (19) Rimstone dams, (23) spar, (26) Tower cones, (27) dam
Seeping	(1) Anthodite, (9) Cups, (10) Drapes, (11) Folia, (12) Helictites, (20) shield, (31) Roof boss
Pooled water	(16) Pool spar, (17) raft/toe, (21) shelfstone, (26) clastic traventine under stalagmite floor
Splashing water	Few

Source Water Chemistry

In this study, hydrogen ion concentration (pH), electrical conductivity (EC), bicarbonate (BC), calcium (Ca) and temperature (T) analysis containing the water in each cave have been carried out by the laboratory test which is described in Table 2 and Figure 42-46. According to these results, all caves have good condition in pH. Some high contents of calcium occur where calcium content is more than 75 mg/l of WHO standard. Besides, among the temperature test results, water in Ba-yint-nyi cave has high temperature that is affected by hot spring in there.

Groundwater precipitation from which traventine in the cave varies greatly in their chemical composition. According to the chemical composition of source water after Allan (2005), Calcium hydroxide waters may have in excess undetectable levels of CO_2 and a low ionic strength while thermogene springs may have pH range from less than 6 to more than 12. Moreover, under high temperature and pressure, aqueous solutions of CO_2 are very reactive and capable of dissolving large amounts of carbonate. So, thermogene travertines form from a range of carbon dioxide sources and receive most of their carrier CO_2 from thermally-driven processes in this area because of the sub-tropical climate condition.

Table 2: Chemical composition of water in each cave

Cave name	pH	EC	BC (mmol/L)	Ca (mg/l)	T (C°)
Ba Yint Nyi	7.5	132	3.4	246	38.6
Kyauk Gon	7.85	387	4.8	80	27.5
Ya Thet Pyan	7.04	613	7.5	122	27.8
Sadan	7.69	327	4.1	74	25.6

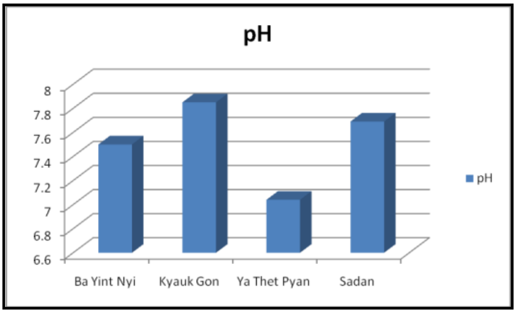


Figure 42: Comparative study of hydrogen ion concentration (pH) in caves

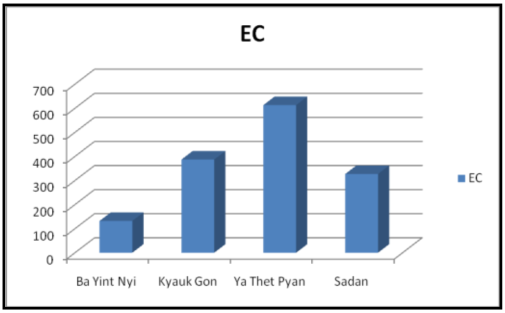


Figure 43: Comparative study of electrical conductivity (EC) in caves

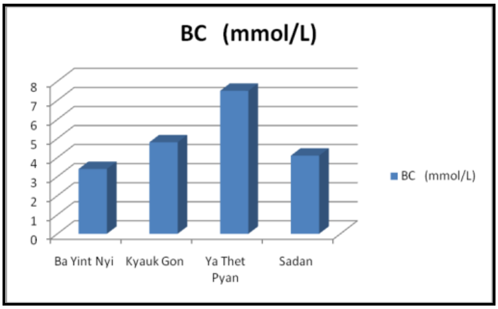


Figure 44: Comparative study of Bicarbonate (BC) in caves

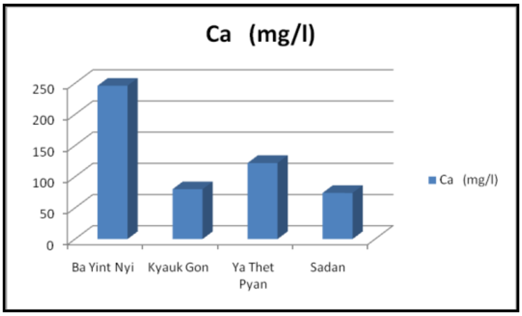


Figure 45: Comparative study of Calcium (Ca) in caves

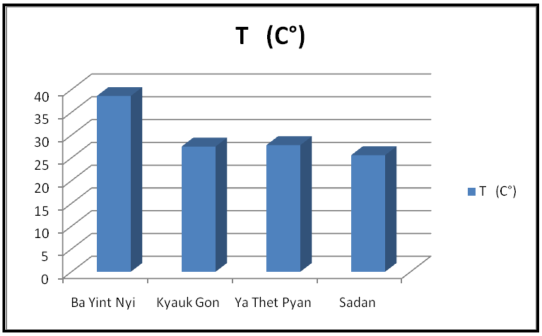


Figure 46: Comparative study of Temperature (T) in caves

Conclusions

The research sites are in the Ba-yint-nyi cave, Ya-thae-byan cave, Kawtgon cave, Sadan cave and Linno cave in Hpa-an Township, Kayin State, Myanmar. This area is mostly composed of the sedimentary rocks such as siltstone with laminated shale and nodular sandstone of the Taungnyo Formation (Carboniferous to Early Permian), micritic limestone, dolomitic limestone and brecciated limestone of the Moulmein Limestone (Middle to Late Permian) and Alluvium (Quaternary). Moreover, the caves in this study are mainly composed of the rocks of Moulmein Limestone with beautiful speleothems.

According to the classification of speleothems after Hill and Forti (1997), there are at least 17 kinds of speleothems in these caves. These speleothems are formed by the controlling of five hydrological mechanisms such as dripping, flowing, seeping, pooled water and splashing water. Moreover, the other controlling factors in forming speleothems are opening of rocks such as joints, cracks, bedding plane and faults and inclination of wall rocks. The amount and rate of water flowage also influence the shape and size of the speleothems.

According to the laboratory test results for water chemistry, all caves have good condition in pH. Some high contents for calcium occur where calcium contents is more than 75 mg/l of WHO standard. Besides, among the temperature test results, water in Ba-yint-nyi cave has high temperature that is affected by hot spring in there. According to the chemical composition of source water after Allan (2005), Calcium hydroxide waters may have in excess undetectable levels of CO_2 and a low ionic strength while thermogene springs may have pH range from less than 6 to more than 12. Moreover, under high temperature and pressure, aqueous solutions of CO_2 are very reactive and capable of dissolving large amounts of carbonate. So, thermogene travertines form from a range of carbon dioxide sources and receive most of their carrier CO_2 from thermally-driven processes in this area because of the sub-tropical climate condition.

The beautiful limestone caves are not only difficult in formation but also rare in Myanmar. So, these caves are important for preservation as geoheritage sites as well as geopark because of the geotourism. Moreover, these caves act natural ornaments for our country.

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