A GEOMORPHOLOGICAL STUDY ON THE DIVERSITY OF MICRO KARST LANDFORMS OF A LIMESTONE CAVE (WITH SPECIAL REFERENCE TO WAULPANE CAVE IN RATNAPURA DISTRICT)

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ABSTRACT

Karsts are the result of complex interaction between geology, climate, hydrology and biological factors over long-time periods. It is a collection of surface and subterranean landforms, formed through the dissolution of soluble bedrocks. Sri Lanka consists of several limestone caves and Waulpane limestone cave in Ratnapura is important among such limestone caves. The main objective of this study is to identify the diversity of micro karst landforms of a limestone cave. The entire Waulpane cave was taken as the sample. Water and rock samples were collected and landforms were measured and photographed while respondents were interviewed to get further information. The research findings show that the cave is consisted of speleothems like stalactites, stalagmites, drapery like features and karren on the walls, ceilings and ground with various sizes. Some stalactites seem like bulbs, cones, leaves and pillars while some resemble pencils, wall lamps, rounded arches, sand clocks and flower petals. Most of the features have scattered in the middle of the cave due to favourable conditions.

INTRODUCTION

The Earth, or else the world where humans live in is the only planet in the universe known to have life. The surface of the Earth is basically covered by land and water. The solid part of the Earth, the lithosphere or else geosphere is being changed by many different forces such as wind, water and other elements to make shapes out of the Earth. These natural features of the solid surface of the Earth are known as the landforms. There are several types of landforms in the world; such as coastal and oceanic landforms, aeolian landforms, mountain and glacial landforms, fluvial landforms and karst landforms.

Karsts are known as living landscapes and a terrain with distinctive landforms and drainage formed as a result of solution of the underlying bedrock mostly carbonate rocks. Scholars have defined karst as ‘comprising terrain with distinctive hydrology and landforms that arise from a combination of high rock solubility and well-developed secondary (fracture) porosity. Such areas are characterized by sinking streams, caves, enclosed depressions, fluted rock outcrops and large springs’ (Ford & Williams, 1989)[3].

When considering about the karst landforms, they are characterized by mainly the cave together with the landforms formed inside of the cavern and some karstic features created on the surface of the ground. Accordingly, those two main types of karst landforms are surface karst landforms and subterranean karst landforms. Most likely these surface karst landforms are large in size and are erosional landforms while the subterranean karst landforms are both erosional and depositional and the size can be varied. This research mainly focuses on studying about the subterranean karst landforms or the micro karst landforms formed inside of a limestone cave rather than the meso or macro scale or surface karst landforms. Scientists have studied more about macro and meso scale karst landforms than micro and nano scale karst landforms in the world. So, there is a clear gap between the findings regarding the micro and macro scale karst landforms and macro and meso scale karst landforms. The main goal of this research is to investigate about the micro scale landforms in order to lessen the scarceness of knowledge regarding micro scale landforms. There are several limestone caves in Sri Lanka also. Most of them are located in and around of provinces of Sabaragamuwa Uva and the Central. Waulpane limestone cave, Pannila calcareous cave and fresh water limestone cave in Balangoda.

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are few among them. Among these caves, Waulpane cave is more important as it holds geological, archaeological, paleontological, anthropological and biological value. Waulpane limestone cave grips only few of macro scale karstic landforms and rest of others are in micro scale. So, this research attempts to find the answers to the questions such as what type of micro karst landforms are in the Waulpane cave, why this cave mostly has micro scale landforms, what are the factors affecting to form those micro landforms, the nature of the distribution of speleothems inside of the cave and as a whole to identify the diversity of micro karst landforms of a limestone cave.

**Empirical Review**

The significant and often undervalued element of geo-diversity is karst landscape. It reflects the complex relationships between surface water and groundwater. These landforms are part of the rich geo-diversity upon which we live and are highly regarded for their natural, cultural, scientific, recreational, socio-economic and aesthetic values. And also, karstic features such as caves and surface limestone habitats have a tremendous range of importance not only in Geology, Geomorphology and Speleology and also in many fields such as, Hydrology, Hydrogeology, Palaeontology, Paleoclimatology, Pedology, Biology, Botany, Zoology, Mycology, Entomology, Biospeleology, Archaeology and Physical Anthropology.

Scientists and other academicians have done numerous researches and investigations about karst topography in the world. The book of ‘Karst hydrology and geomorphology’ written by scholars Derek Ford and Paul Williams in 1989[3] reveals facts about karst topography in relation to Hydrology and Geomorphology. In that book they have mentioned about karst rocks and their geological structure, physics and chemistry of dissolution process and global dissolution rates, karst water resources, karst hydrological systems, cave systems, variety of dissolutional and depositional landforms created by karst processes and hydrology and groundwater management which has a major importance in the academic world and in practical management.


Research articles published in journals also reveal lot about karst topographies in several countries and parts of the world. Researches named ‘Caves of New Jersey’ written by Richard F. Dalton (1976)[2], ‘Geologic and hydrologic controls on karst and cave development in Belize’ by Thomas E. Miller (1996)[6], ‘The limestone caves and caverns of Ohio’ by George W. White (1926)[10] and ‘Limestone caves in the Sigtokta valley Viti Levu, Fiji’ written by Dick Watling and John C. Pernetta describe about karst topography and particularly limestone caves of those countries in detail. The research article of ‘Origin and morphology of limestone caves’ written by Arthur N. Palmer reveals a lot about the karst topography and its characteristics in United States of America using some improved techniques and methods.

Scientists in the world have studied more about karst landforms and limestone caves in the world. Nevertheless, limestone caves and karst landforms in Sri Lanka have not been studied broadly by scholars. Karst landforms in the areas of Matale, Nalanda, Habarana, Kandy, Badulla, Welimada and Maskeliya have been studied by several academicians. S. N. Wikramaratne and Malcolm Jancen have studied about limestone cave in Shreepura comprehensively. They have documented about the vegetation distribution and the formation process of the stalactites and stalagmites inside of the cavern. And also, the pool deposits or sub-aqueous forms, micro-organisms and other organisms living around the cave and the production of gasses such as CO₂, CH₄ and H₂S inside the cave have been studied vastly.

Another research article named ‘Speleothems in Gneissic Caves of Sri Lanka’ written by W.S. Welange and Jayasingha Pathmakumara in 2011[9] have been focused on the speleothems in gneissic cave and these formations are different from the limestone formations. Several studies have done in Kosgala wavul lena in Kehelowitagama, Shreepura lena in Kuruwita and Yahal lena in Nikawalamulla. Speleothems such as stalactites, stalagmites, flowstone, curtains, ridges and rim pools like structures and the colours and its variations, morphological features and the location of deposition have been studied by the researchers.

**Literature Review**

The word ‘karst’ can be traced back to pre-Indo-European origins (Ford & Williams, 1989)[3]. Karst is the German form of the Indo-European word ‘kar’, which means rock. The Italian term is ‘carso’, and the Slovenian ‘kras’. In Slovenia, ‘kras’ or ‘krš’ means ‘bare stony ground’ (Huggett, 2007)[4]. According to Derek Ford and Paul Williams in the book of Karst Hydrogeology and Geomorphology written in 1989[3], ‘Karst is the term used to describe a special style of landscape containing caves and extensive underground water systems that is developed on especially soluble rocks such as limestone, marble, and gypsum.’ In geomorphology, karst is a terrain in which soluble rocks are altered above and below ground by the dissolving action of water and that bears distinctive characteristics of relief and drainage (Jennings, 1971)[3]. Some other sources define the term karst as a distinctive terrain created by erosion of a soluble rock where the topography and landforms are a consequence of efficient underground drainage. Its characteristic features therefore include disrupted surface drainage, closed depressions, dry valleys and caves.

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Karst features form on many types of rocks if soluble components are present not only on limestone. A limestone cave or cavern is a natural cavity that is formed underneath the Earth’s crust by the dissolution of limestone by weak carbonic acid. The carbonic acid is produced by chemical weathering of rock, rather than by mechanical weathering. Karst topography and limestone caves or solutional caves are dramatic examples of the action of acidic groundwater on soluble bedrock. Most solution caves are in limestone. Less frequently they occur in other carbonates such as dolomite ($\text{CaMg(CO}_3\text{)}_2$), Calcite ($\text{CaCO}_3$), gypsum, marble, halite, dolostone, salt, chalk or clastic rocks with soluble cements and any rock on which the solution process can be occurred. The only requirement to form solutional caves and other karstic landforms is that the bedrock be soluble (Huggett, 2007)[4].

Early life forms in the oceans about 3.8-billion years ago and these were single-celled, blue-green algae, named cyanobacteria which produced the food on their own through photosynthesis and released oxygen into the atmosphere in the process. Sedimentary rocks like Dolomitic limestone were formed over millions of years through chemical reactions generated by these early organisms. By the time, sedimentary dolomitic limestone eventually exposed to the ground with the movements within the Earth’s crust. In comparison most of the karstic landforms in the world are formed by the dissolution of limestone by weak carbonic acid. The solution process is accompanied by other processes too. Particularly from the higher carbon dioxide levels in the soil occurred due to root and animal respiration, the decay of organic matter, collapsing of soil and bedrock materials and transport of insoluble debris through subterranean routes can be identified.

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are crystal deposits which form on the ceiling, walls and floor of caves. The type of host rock will determine the mineral makeup of the speleothems. Speleothems do not grow at the same rate. Surface temperature and climate, rainfall, the rate of organic decay in the soil affect to increase the acidity of the water and ultimately to the process of formation of speleothems. The stronger the carbonic acid, the more minerals it can dissolve and deposit. These speleothems can be found in micro and nano scale also. Small scale limestone sculptures are known as ‘karren’ and it includes linear channels or grooves (Huggett, 2007).

Figure 3 Types of speleothems

A - Stalactite
B - Soda straws
C - Stalagmites
D - Coned stalagmite
E - Stalagnate or column
F - Drapery
G - Drapery
H - Helictites
I - Moonmilk
J - Sinter pool, rimstone
K - Calcite crystals
L - Sinter terrace
M - Karst
N - Body of water
O - Shield
P - Cave clouds
Q - Cave pearls
R - Tower cones
S - Shelfstones
T - Baldacchino canopy
U - Bottlebrush stalactite
V - Conulite
W - Flowstone
X - Trays
Y - Calcite rafts
Z - Cave popcorn or coralloids
AA - Frostworks
AB - Flowstone
AC - Splattermite
AD - Speleoseismites
AE - Boxworks
AF - Oriented stalactite
AG - Collapsed rubble

Globally karst topography can be found at all latitudes and at all elevations. It is estimated that the karst topography covers approximately 20% of the Earth’s dry ice-free land surface and roughly 20-25% of the global population depends largely or entirely on groundwater obtained from them (Ford and Williams 2007).

Figure 4 Map of the global distribution of major outcrops of carbonate rocks (mainly limestone except evaporites)

Caves are found throughout the world and the distribution of caves is mostly concentrated to countries such as France, Italy, Australia, UK, USA etc. The world’s longest cave is the Mammoth Cave in Kentucky is also a limestone cave. The largest subterranean chamber yet discovered is in the Carlsbad Caverns in New Mexico. Gouffre Berger Cave near Grenoble, France is the deepest cave yet explored by man. Apart from these limestone caves records of the National Speleological Society of America indicates that more than 100,000 caves exist in the whole earth. Such as Kartchner Caverns - Arizona, USA, Cango Caves - Western Cape, South Africa, Harrison’s Cave - Allen View, Barbados, Dongzhong Cave - Guizhou, China, Fantasy Cave - Dannervirke, New Zealand, Phong Nha Cave - Minh Hoa, Vietnam, Barton Creek Cave - Cayo, Belize, Škocjan Caves - Trieste, Slovenia, Deer Cave - Borneo, Malaysia and Onondaga Cave - Missouri, USA are some of them. There are several limestone caves in Sri Lanka and most of them are located in provinces of Sabaragamuwa, Uva and the Central. Several studies have proved that the caves located in wet zone are more prone to form speleothems than the dry zone caves. These solution caves reaching up to 10 or 20 feet in height and sometimes found in marble bands (Cooray, 1984).

METHODOLOGY

The limestone cavern at Waulpane is located in Kumburugamuwa Grama Niladhari Division in Kolonna Divisional Secretariat at Ratnapura district, Sabaragamuwa province. It is located 278m above sea level at the eastern slopes of Bulutota Rakwana Mountain Range, northwest to the Embilipitiya and about 14km from Pallebedda. The approximate position of Waulpane is 6°25.5’N latitude by 80°43.8’E. The name Waulpane or the ‘cave of bats’ is probably derived because of the enormous number of bats that inhabit this cavern. It is estimated that approximately 800,000 bats live there.

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The surrounding area of the Waulpane cave is located inside of a tropical rain forest with 100 feet high trees. The forest has spread over nearly 30 acres. This forest is blessed with number of species including endemic flora and fauna species such as birds, mammals, lizards, butterflies, fish, reptiles, herbal plants and wild rice species can be found in the Waulpane area.

As the nature of this research the sample was selected from the Waulpane village. So, the sample of this research is the entire Waulpane limestone cave and its surrounding area. Apart from that, respondents of the village were selected to get the data and information of the cave and its surrounding randomly. As well as, relevant officers and scholars were interviewed to get further information. And also, water samples, soil samples and rock samples were collected from several places of the cavern premises. There is no any particular statistical technique or method to select these samples. Therefore, all the samples were selected randomly.

Hardness of the collected water from the brackish water spring was calculated by using EDTA method. First 10.00 cm³ of the given sample was taken to a titration flask. And then 0.5 ml of pH 10 buffer solution and 3 drops of Eriochrome Black 7 indicator were added to it. Then it was titrated with 0.001 moldm⁻³ EDTA solution until the colour changed from wine red to blue colour. This titration was duplicated.

Basically, data were gathered in two ways. Primary sources and secondary sources were used to collect data and information. Accordingly, as secondary sources relevant books, reports and articles from the internet, research reports published by institutions and academicians were referred. Many kinds of maps and photographs were referred and clarified. Accordingly, Metric maps, GIS maps, Google Earth maps and Google images were studied. As primary sources observation, and informal in-depth interview methods were mainly used to gather information. Unstructured interviews were done with the villagers, grama niladhari of the village (village officer) and academicians to gather information about the history and other details about the cave and its surrounding. And also, water samples, soil samples and rock samples were collected to conduct laboratory tests. Water quality tests were conducted to study about the pH value, temperature, dissolved materials, dissolved oxygen, conductivity and turbidity of the water. Measuring methods were used to measure length, width and height of the features of the cave and karst landforms (speleothems).

When considering about the data analysis, several methods and techniques were used to analyse the data. Methods and techniques such as quantitative methods used in basic statistics and advanced statistics were used. Basically, the findings were presented through photographs and maps and descriptive manner also used according to the relevant occasions.

**RESULTS AND DISCUSSIONS**

The nature of the distribution of karst landforms

According to the researches done by several scientists, it is revealed that the rough estimate of the age of the cave is said to be 500 million years and stones belong to Precambrian period. It is believed that, this is the oldest and biggest cave in Sri Lanka; would be the oldest in the world. Geologists believe that this limestone deposit is spread out 20 square miles (Weerasekara, 2001). The cave is sited from east to west ward direction. The cave itself is to the south east of the village and lies across a drop valley cut by the Hulwini dola and obstructing its passage. The cavern consists of about 12 side caves of varying sizes inside and the outside of the main cave. The main cave is about 150 feet (45.72m) in length. The main entrance is about 12 feet in height and 11 feet in breadth (Figure 5). And there is another entrance (small hole) on the right side of the main entrance. These entrances are separated by a 5-6 feet diameter limestone column between them. The upper entrance (entrance in the left side) is wide and about twice as high while the lower one is narrow. Through the lower entrance, the water of Halwini dola enters to the cave at an elevation of about 900 feet. Then it emerges after an underground course of almost quarter of a mile at an elevation of about 800 feet above mean sea level.

The height of the cave differs from place to place. The height of the cave is approximately 108 feet (30.5m). Near the entrance the vertical height is about 15.8m while at the end of the cave it is about 16.9m. The exit doorway is located at the end of the cavern and the height is about 13 feet and it is separated by a large broken limestone. But it has a higher roof level that slopes in to the cave. Halwini dola flows out through the hole on the right side of this exit door and now the cave roof has collapsed by the time. According to Sir Arthur C. Clarke, the water flow of the Halwini dola has flowed not as the same level which it flows now, but in a much higher level.
He further says, due to the weathering and the erosion, the route of the water flow has eroded as the time passes. Evidences can still be seen from the cave premises.

This Waulpane limestone cave consists with second longest brackish internal waterfall of the Asia which is known as ‘Waulpane Ella’. It is 150 feet (45m) in height and located in the center of the cavern. The waterfall cascades down on to a pillar which has acquired a roundness and smoothness on top as a result of centuries of falling water (Figure: 6). This subterranean waterfall is made by a stream which gushes out from the hill side by the cave and falls through a sink hole in the limestone layer-roof of the cave. This hole is wide enough for a man to go through and the water falls in a series of three steps. This small brackish water stream which contains high amount of CaCO$_3$ is the main factor of forming the landforms inside of the cave.

When considering about the general form of the cave, it can be described as three separate areas; the front area, the middle area and the behind area of the cave. In the front area, on the sides surrounding the mouth of the cave, the face is covered with secondarily deposited carbonate material in the form of incrustations forming layer after layer of calcium carbonate. Some of this material hangs down in the form of stalactites but the growth of these is not continuing. But the limestone wall of the front area seems bit older and the rocks are about to collapse due to the weathering of rocks (Figure: 7).

The reason behind the lack growth of landforms in this area could be the condition of the slope. The underground water way is the prominent factor to form landforms, but the underground water way flows downward according to the slope. Here the slope angle is also affected for the absence of landforms.

When considering about the central part of the cavern, several types of landforms can be seen from this area. Accordingly, stalactites, stalagmites with different shapes and cave pools are important among them (Figure: 8). And also, small sized caves are located in the middle area which varying 14.4m to 12m in vertical breadth. The reason for the abundant distribution of landforms in this area is the underground water way. Comparatively this area holds several types of karst landforms in a substantial amount. Besides, several broken stalagmites and stalactites can be seen on the floor of the middle of the cave. Some are 16 feet long and 6 feet in breadth.

Behind area of the cave also consists of several types of landforms. It seems that the current outer appearance is different from earlier as lot of changes have occurred due to overflowing of water ways. It is believed that the behind portion of the cave was longer than now. Evidences which prove this fact can be seen few meters away from the back door. Few broken stalactites are seen approximately 15m away from the back doorway. These are varying in few centimetres (5-11cm) to meters (9m) in height. But still the outer walls of the behind cave area are decorated with magnificent karst features (Figure: 9).

**Factors affected for the formation of karst landforms**

When considering about the main factor that has affected to form these karst landforms is the Calcium laden water spring; locally known as ‘kiwul diya ulpatha’ (Figure: 10). According to some sources, this water spring produces 26 l per second and the hardness is comparatively high. Basically, the percentage of CaCO$_3$ and iron hydroxide content is high in the water. Some
other researches have revealed that this spring releases 0.7083 cubic feet per second (20l per second). It is believed that this spring flows constantly even in the dry season. Villagers stated that the water flowing velocity is higher in the dry season than in the rainy season.

Apart from that, in the past this spring entered to the cave from another sink hole and now it is buried under ground leaving only a small hollow. So, the water flow direction has totally altered and dried up the previous path at present. This change is important to study because these alterations directly affect to the formation of the karst landforms.

According to the villagers, lot of pure white stalactites and stalagmites can be seen on the cave roof near the water flow. They further mentioned that ropes are needed to go down through the hole to discover these unspoiled karst landforms. This can be sighted even from inside of the cavern. The abundant distribution of these perfect formations proves the fact of significance of the calcium laden spring. Because the karst landform distribution has amply scattered over the cavern ceiling nearto the previous and current sink holes where the CaCO₃ rich water is ample. Accordingly, one side of the inside of the cave is formed and still growing due to the CaCO₃ rich water.

Not only the spring, some other factors such as the climate, topography, vegetation cover, hydrological pattern, limestone distribution and the soil have affected to form these landforms. A tropical forest has grown above the roof of the cave. Therefore, the outer part of the cave is covered with a thick soil layer and 100 feet high trees. The leaves fallen from the trees have covered the soil and it further accelerate the rate of the karst formation when the leaves are decaying. So, the leaf litter and soil together with the brackish water contribute to form the karst landforms. On the other hand, the roots of trees cause to cracks on the limestone when they grow (mechanical weathering). Water seeps through these cracks or cavities to form karst landforms inside the cave.

**Diversity of Micro Karst Landforms in Waulpane cave**

The Waulpane Cave safeguards an enormous multitude of appealing and artistically captivating stalactites and stalagmites and is renowned for these formations. Not only stalactites and stalagmites and also several other types of karst landforms such as columns and few other micro scale karstic landforms can be captured from the cave premises. When considering about the stalactites, which are abundantly available in this cave are formed in several shapes. These awesome stalactites pointing downwards from the roof of the cavern. Such types are;

- Bulbous stalactites (bulb-shaped or circular shape)
- Scattered stalactites
- Joint-scattered stalactites (dispersed but combined with each other)
- Flat stalactites (not elongated)
- Pillar shaped stalactites (linear and elongated)
- Leafy stalactites (cultured like an umbrella)
- Cone shaped stalactites

At the entrance there stand limestone figures of the most weird and awesome shapes and sizes. These formations are circular shaped and some are looks like leaves. They hang from the ceiling of the portico (porch) in front of the main entrance. Circular bulbous stalactites have formed like half bloomed flower buds. Leafy stalactites are clustered like an umbrella, resembling a parasol. These formations are in brownish white colour. Stalactites with whiter colour seems to have formed recently. And also, at the left side of the entrance there is another type of flowstone hanging downward from the walls.

**Table 1 Dissolved materials in water ways**

<table>
<thead>
<tr>
<th>Dissolved materials in</th>
<th>Dissolved materials in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halwinila dola</td>
<td>Katukumbura dola</td>
</tr>
<tr>
<td>pH value</td>
<td>7.3</td>
</tr>
<tr>
<td>Iron</td>
<td>0.2 ppm</td>
</tr>
<tr>
<td>Chloride</td>
<td>9 ppm</td>
</tr>
<tr>
<td>Sulphate</td>
<td>2 ppm</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>20 ppm</td>
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</tbody>
</table>

Source: Adapted from Perera (1970)

High amount of chemical compound concentration was identified during the field survey as well. The total hardness of the brackish water of the spring is recorded as the 309 ppm. It is much higher than the amount recorded in the previous records. Total hardness is the Ca⁺² plus Mg⁺² hardness in solution. If the CaCO₃ amount in water is >180, the hardness of the water is very high. Anyhow, it can be observed that the water is highly rich with chemical materials even by tasting the water.

Apart from that, in the past this spring entered to the cave from another sink hole and now it is buried under ground leaving...
These wavy somewhat huge formations can be identified as draperies. All these formations have combined together to form the front ceiling and walls of the cave (Figure: 11). But these formations are near to collapse as most of them are rather old.

In addition, on the right side near to the main entrance (nearly 10 feet away), there is another, somewhat huge stalactite hanging from the wall. It is brown in colour and nearly 60 feet in height and 5½ - 6 feet in circumference (Figure: 12). There are some other 4 or 5 stalactites near to the aforesaid stalactite. They are dispersed but combined with each other. These stalactites vary in 20, 30 and 40 feet in height. Some other stalactites with uneven shapes can also be seen with these huge stalactites (Figure: 12). On the left side of the entrance, nearly 8 feet away, another type of stalactite formation can be seen. These are recognized as bulbous stalactites and clustered together like small wall lamps (Figure: 13). They elongated towards the ground with about 5 feet.

When considering about the ceiling of the entire cave, it is hemisphere shaped (half a sphere). Solidified stalactites dripping from the ceiling making various shapes. Bulbous stalactites, scattered stalactites, leafy stalactites, flat stalactites and pillar shaped stalactites can be seen hanging from the ceiling with various sizes. In most cases these formations look like shields. The ceiling has created as several stages resembling balconies. Within these balconies like platforms, deep cavities have formed. So, the small sized caves have created on the ceiling and bats use these cavities as their habitation (Figure: 15). An inch of these landforms may have taken hundreds of years of natural activity to form. These formations are brown in colour and in some instances yellowish brown.
A.A.R. Thamodi and Sumanajith Kumara, *A Geomorphological Study on the Diversity of Micro Karst Landforms of A Limestone Cave (with Special Reference to Waulpane Cave in Ratnapura District)*

1 - Elongated, pillar shaped stalactites
2 - Bulbous stalactites
3 - Ceiling consists of several platforms and deep cavities
4 - Ceiling near the waterfall
5 - Ceiling near the main entrance
6, 7 - Ceiling in the middle of the cave

Another important feature of stalactites can be seen at the end of the cave. These tiny crystals are made of CaCO$_3$ which is the primary stage of forming soda straws and stalactites. Tiny water droplets dripping through the cracks in the rock and CO$_2$ is lost into the air leaving deposit of calcite. Then a ring of calcite left when water drop falls (Figure: 16). Eventually stalactite straw builds as water continuous to drop from the crack. These formations are very important to study as these formations are the starting point of all these karst landforms.

Though the cave has numerous stalactites, no stalagmites to be found on the floor. May be the speed of the stream flows through the cave has affected to this situation. Because the tree trunks and rock boulders flow with the stream may have affected to erode or to destroy the stalagmites. Several broken pieces of stalagmites, some other limestone boulders and huge tree trunks and rock boulders can be seen on the floor of the cave.

Apart from that few small-scale landforms can be seen on the wall near to the roof top. These are very similar to stalagmites but formed hundreds of feet above the ground. They are only 4-5 feet long and still growing. These landforms are formed in front of the waterfall where the previous waterfall used to flow. Comparatively bigger feature is dark brown in colour and the other feature is yellowish brown in colour (Figure: 17).

1 - Comparatively bigger feature (dark brown coloured)
2 - Yellowish brown feature

Another small size column (pillar) can be seen in the left side of the main entrance. The upper part of the column is covered with calcium carbonate layers. These layers appear like flower
petals or small leaves. This feature is only 3-4 feet in height and formed on the wall similar to a buttress (Figure: 18).

And another column like landform is formed on high walls in front of the waterfall. It seems, it is formed not by joining a stalactite and a stalagmite but eroding or breaking a drapery. Only a pencil like formation is left now. The eroded sheet like fragment shows the various colour of layers which have deposited for years. Likewise, few other columns and column like features can be seen inside of the cave. One is formed in front of the waterfall right next the above-mentioned feature. It is whitish brown in colour. And another yellowish brown colour column can be identified near to the main entrance. It is well developed and covered with bulbous stalactites. (Figure: 19).

Another interesting feature can be seen left side of the main entrance. It is 6-7 inches in size (Figure: 20). These are formed on the wall near to the ground. This feature appears like a sand clock (hourglass). The upper and the lower part of the landform is rounded like two glass bulbs of the hourglass. The middle part is narrow and thin. The upper and the lower parts of the landform is connected vertically by this narrowneck. Several numbers of features have formed by connecting to each other. In between two features a small hole is visible and as the time passes these small holes will be filled by depositing CaCO$_3$ to expand the cave wall. When studying this feature, it could be identified that these features are still growing. The newer whitish colour of the feature is an evidence for that.

They are very small in size of only few centimeters. These features can be seen on the pillar which waterfall falls and in some other places as well. The formation of these features also similar to the aforesaid feature, but some are like pointed or ogival arches in Gothic architecture. These features are also still growing but not rounded like the abovementioned feature. These have formed by pouring CaCO$_3$ laden water on the surface of the walls. Small scale cavities can be seen among these features (Figure: 21). As a whole it can be said that the colours of these micro karst landforms ranges from white, cream, yellow to pink and brown. Pillars and columns of precipitated calcareous substances are everywhere while plentiful at the left side of the cave, balconies carved out of the stone, disappear into the earth. Even now these are constantly in formation by the action of the stream and waterfall.
CONCLUSIONS

Karst is a significant and often undervalued element of geo-diversity, which describes the collection of landforms produced by the action of natural waters on soluble rocks. Karst is formed through the dissolution of bedrock typically limestone, and produces a network of enlarged joints and cavities through which the water can flow. When these cavities are large enough, they are known as caves. In addition, they can have a range of characteristic surface features, and another type of secondary mineral deposits found inside of the caves. These are known as speleothems and formed due to the solutional and depositional process of CaCO₃. These karst and limestone habitats are important and fascinating features which have a tremendous range of interests for many groups. Globally, examples of karst topography can be found at all latitudes and at all elevations. Likewise, Sri Lanka also consists of several limestone caves mainly in the provinces of Sabaragamuwa, Uva and Central. Limestone cave in Kudawe, pannila, Waulpane, Padiyapelella, Sthreepura and Ravana lena are few among them. Waulpane cave in Pallebedda, Ratnapura district is an important limestone cave in Sri Lanka due to its geological importance and geo-diversity.

This cave consists of an enormous multitude of appealing and artistically captivating stalactites, stalagmites, shield and drapery like features and some other macro karst features such as limestone cave itself and sinkholes. According to the facts revealed through the research, this cavern mostly has micro karst landforms than macro and meso scale landforms. Mostly the secondary mineral deposits known as speleothems can be seen inside of the cavern. Only the limestone cave itself and the sinkhole are the large-scale karst landforms that can be identified from the cave premises. The main reason for this could be the area extent of which the limestone deposit has spread out. Some macro karst landforms are large and extended to several kilometres. And also, it is obvious that these karst formations are forming mainly due to the action of the brackish water spring. The water capacity as well as the CaCO₃ content of the spring is not enough to form meso scale landforms. Only speleothems and karren have formed from this spring water. As well as, the other factors such as climate, topography, vegetation cover, hydrological pattern that have affected to form the micro scale landforms inside the cavern may not enough to form the meso and macro scale landforms. It is because most of the meso and macro scale landforms form by the dissolving action of the limestone not by the depositional process.

But basically, this cave comprises with micro karst landforms such as speleothems on the walls and ceilings and karren on the walls and ground. All these micro karst landforms are varying in size and have unique characteristics. Some features; stalactities seem like bulbs, cones, leaves and pillars while some other features appear like pencils, wall lamps, rounded arches, sand clocks and flower petals. Most of these features have scattered in the middle of the cave due to the favourable conditions.

When conducting this research several issues and obstacles such as poor infrastructure facilities and lack access to the destination, insufficient facilities of equipment and a powerful source of light, difficulties inside the cave such as insects, mites (ticks), bat guano, thick darkness and difficulties of walking as the ground is slippery and sloppy in some places were occurred.

Recommendations

Several recommendations can be suggested to improve such kind of researches further.

- Improved equipment and infrastructure facilities should be provided.
- Transportation facilities should be developed further.
- Thenatural, cultural, scientific, recreational, socio-economic and aesthetic value and importance of such places should be distributed among the people as a key to protect this place.
- Declaring this area as a nationally protected and world heritage site.
- The knowledge about this place should be given to the future generations through mass media

Furthermore, it should be noted that these karst features require particularly careful thought and effort to ensure that they are conserved for all to study and enjoy, whilst giving highest priority to the often-fragile geological formations contained within them. These formations are often under threat from visitor pressure. In caves, the issues can be particularly extreme and include inappropriate specimen collecting, erosion of cave floor sediments which hold geological or archaeological importance, roosting of bats and other cave-dwelling species. And also, leaving rubbish here and there is also problematic. According to villagers, people have collected limestone in order to make lime from them and have killed bats for their meals earlier in Waulpane area as well.

In addition to that, contact with even natural skin oil can stop depositing minerals on the formation. These formations grow continually, take thousands of years and are very fragile. So, these should not be disturbed, otherwise that would be harmful for their formation process.

Once the leader of the Suquamish and Duwamish Native American tribes; Seattle stated as “The Earth does not belong to us; we belong to Earth. Take only memories, leave nothing but footprints”. This is the best way of preserving the gifts given by the Mother Nature for the future generations. Because we do not inherit the Earth from our ancestors but we borrow it from the future generations.
References


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