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A Classification for Sri Lankan Caves

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Abstract

Sri Lanka is an island with a very high density of caves. The lithology of the country is characterized by mostly Precambrian metamorphic rocks and Miocene limestone in the northern area of the country. Although caves are considered as dark spaces with many legendary tales, the scientific background of Sri Lankan caves were recently discovered after initiating scientific studies by Postgraduate Institute of Archaeology of the University of Kelaniya. During this project of speleology, first ever attempt was made to classify Sri Lankan caves based on lithology, morphology and genesis. This particular classification was done comparing the investigated caves located in Rathnapura, Ruwanwella and Mahiyanganaya and other documented caves of Sri Lanka. Results indicate that common Speleogenesis processes are weathering and erosion of bed rocks and amalgamation of boulders on the surface. It is revealed that the position of caves on the Earth is important to define a cave as surface or underground cave. Lithology helps to classify a cave into two groups as metamorphic origin and sedimentary origin. Metamorphic caves are further divided in to two sub groups as crystalline silicate rock-caves and crystalline limestone rock-caves (Marble caves). According to the genesis and morphology above caves could be categorized in to six types as (I) rock shelter, (II) hollow cave, (III) tunnel cave, (IV) river cave, (V) boulder cave and (VI) crack cave. In conclusion classification of caves is an important aspect in Speleology since it provides information for comparative studies.

Keywords: Sri Lankan caves, classification, lithology, genesis, morphology

1. Introduction

Open cavities on earth are known as Caves which are wonderful geological formations. Caves are diverse in morphology and genesis and formation of a cave is matter of time, rate of weathering and erosion, climate and type of bed rock (Bosak, 2008; Palmer, 2003; Piccini, 1995; Hill, 2000). Caves have long been interest of archaeologists since they are paleo occupations for prehistoric people (Jankovic et al, 2006; Karkanas et al, 2007) and they preserve extraordinary records of past humans, their evolution and paleo-environmental changes (Goldberg and Nathan, 1975; Barber and Hubbard, 1997; Yong et al, 2007). Caves are places of mineral resources and people have harvested those resources since long time (Kennedy and Watson, 1997, Osborne, 1997). Recently cave tourism is becoming a popular adventure in the world (Lobo and Moretti, 2009).

Based on rock formations/lithologies different kinds of caves have been originated (Hill, 2000; Karmen et al, 2001). Most famous caves in the world are Karstic or Limestone caves due to the

fact those karstic caves are wonderfully decorated with speleotherms (Baskar et al, 2007; Osborne, 2007) and most of studies have been carried out on those Karstic caves. In addition

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Sandstone caves were also recorded (Waltham and Chubby, 1997). It seems that genesis of such sedimentary caves is common and the process is known as paragenesis and dissolution (Pasini, 2009). Dissolved materials of the limestone bed rock are precipitated somewhere else to form spleotherms such as Stalgmites and Stalactites which are the natural sculptures of caves (Woo et al, 2005). Such caves are dominant in countries of northern hemisphere. Magmatic process and/or volcanic eruptions also can create underground cavities (Lava tubes) by quick cooling and leaving of the lava inflow from the solidified tube with time (Simons, 1974; Ferguson, 1991). However, the areas of world that cover with Precambrian metamorphic rocks also have immense number of caves. But, there are very little or no literature on such metamorphic rock caves. This can be due to many reasons; such as, less attention of people, small cramped formations, lack of beauty etc *.

Classifying of caves is important in many ways. It is important mainly in cave management and conservation. Also it helps to cataloging the caves. Classification is needed in educational and research purposes. Cave classifications have commonly been introduced for sedimentary (mainly Limestone) caves. It can be based on many criteria such as types of rock (Limestone, Gypsum or Lava caves), morphology/geometric shape (Fissure, Horizontal, Vertical caves, Cave systems and Cracks) and by the time of forming - primary like Lava tubes, secondary by weathering (http://www.showcaves.com/english/explain/Speleology/Classification.html). Caves are also classified by the way they formed (Solutional caves or Karstic caves, Lava tubes, Tufa caves, Sea caves, Talus caves etc). Caves also can be grouped according to the age of rocks such as Recent, Jurassic or Devonian caves. In special occasions caves can be classified according to the sensitivity, endangered species and natural hazards etc. For an example caves of Missouri are classified as Class I, II and III. This has been done for the sake of management purposes. Also American caves have been grouped as Class A, B, C and D. Class A caves have exceptional value, Class B has national importance, C has local importance and Class D includes the caves that do not meet the criteria of A, B and C. In most cases, caves have been grouped as Caves and Rock shelters in very simple manner (Jankovic et al, 2006; Jayasingha et al, 2009a).

2. Background

Sri Lanka is an island of which land mass is composed of oldest known rocks on earth known as Precambrian shield rocks (Cooray, 1984). Eighty percent of the Sri Lankan land mass is comprised of high grade metamorphic rocks. The rest is covered with limestone of Miocene age and small patches of sandstones of Jurrasic age (Figure 1). During the study it is well noticed that Sri Lanka is rich in different types of caves and its cave density is high. It can be believed that it is mainly due to the different lithological distribution and their structural variations. In addition climatic condition of the country may also support for the diversity of caves. Sri Lankan caves are familiarized with country's people and culture for long time of the history (Mahavansa, 300 A.D.; Thupawansa, 300-600 A.D.). Most of the caves have archaeological importance for the academics and researchers while some of them are of historically and religiously important for people of the country. Although cave exploration is being done since a long time by adventurous youths proper scientific explorations were started recently. Deraniyagala (1965) has published about cave exploration and the importance of

** Metamorphic rocks are less erodible specially with regard to chemical weathering hence very little precipitated materials are found in such caves.*

Speleological research. During the last 70 years only few publications have being done about scientific cave studies among them many are dedicated for cave fauna (Bringoli 1972; Shilhavy, 1974; Mauries, 1981; Weliange, 2009; Weliange & Namalagamuwa, 2009). Caves have become an interesting topic for researchers recently (Jayasingha et al, 2009b).

With this trend more people would be attracted to the caves for research, studies, fun, adventure, treasure hunt and also for vandalism. Hence the need of cave management and conservation will be a great issue in the present. As a part of the process of conservation and cave management, documentation and cataloguing is an essential step in characterizing each cave specifically.

3. Speleological studies of Sri Lanka

The history of spelology of Sri Lanka is driven back to sixty's century (Deraniyagala, 1965; Bringoli, 1972; Silhavy, 1974; Mauries, 1981). But the studies had been terminated afterwards and in 2009, after long period of time and with the understanding of the present day requirement, the scientific studies of Sri Lankan caves were discovered after initiating scientific studies by Postgraduate Institute of Archaeology of the University of Kelaniya (Weliange, 2009; Weliange & Namalagamuwa, 2009; Jayasingha et al, 2010;). A team which is comprised of specialists of different scientific fields (Biology, Geology, Archaeology, Architecture etc.) carried out preliminary investigations of selected wet zone caves. During the field surveys it was understood that the cave density and diversity is very high. Some of the caves have special values in mineral resources, biodiversity, tourism, and research. Hence to identify and to compare the significance of each cave a classification is essential. Therefore, during this project which was done under the postgraduate Institute of Archaeology of University of Kelaniya first ever attempt was made to classify Sri Lankan caves based on lithology, morphology and genesis. This particular classification is based on caves investigated at Rathnapura, Ruwanwella and Mahiyanganaya and also the documented caves in literature and popular but unpublished caves of Sri Lanka were included.

4. Physiography of the country

As a tropical country located in northern hemisphere just above the equator (6-10˚ N, 80-82˚E), Sri Lanka is experiencing wet warm climate with high rainfalls and high temperatures. Sri Lanka is small in extent (65,621 km^2) but ecologically very diverse island in the Indo-pacific region. The country gain rainfalls from SW (May to October) and NE (December to March) monsoons and inter-monsoons throughout the year. During most of the daytime, it gains sunlight. But temperature variation in the country is mostly determined by elevation rather than season. Higher elevated areas are experiencing cooler temperatures and the average monthly temperature ranges from 13°C to 20°C. The lowland areas receive higher temperatures and the average monthly temperature ranges from 26° to 31°C year-round. Considering geomorphology in Sri Lanka it is distinguished by central highland and it is surrounded by lowland area which is wider in northern area and narrows down in southern area. According to the monsoon pattern and geomorphology the country is characterized by four climatic zones; wet zone, intermediate zone, dry zone and semiarid zone.

5. General Geology of the country

Sri Lankan basement is characterized by mainly high grade metamorphic rocks of Proterozic age. According to the geochronological and petrological studies, high grade terrain is sub

divided in to four main lithological units (Raith and Hoerness, 1994; Hansen et al, 1987; Kroner et al, 1991; Holzl et al, 1991). They are Highland, Wanni, Vijayan and Kadugannawa Complex (Fig.1). Highland Complex (HC) is the largest and oldest rock unit dated 2000 Myrs (Kroner et al, 1987; Holzl and Kohler, 1989) and composed of granulite facies rocks such as Charnockitic Gneisses, Quartzofeldspathic Gneisses, Quartzite, Marble, Calc Gneisses and Migmatitic Gneisses. North subdivision is known as Wanni Complex (WC) is dated 1100 Myrs (Kroner et al, 1987; Holzl and Kohler, 1989) and consists of Amphibolite to Granulite metamorphites such as Charnokites, Charnokitic Gneisses, Granitic Gneisses, Garnet-Silimanite Gneisses, Marble, Calc Gneisses and Quartzites. The area of the East and Southeast to the Highland Complex is the Vijayan Complex (VC) dated similar to WC. The rocks of VC were undergone Amphibolite facies metamorphism. It consists of mainly Hornblende Biotite Migmtites, Hornblende Biotite Gneisses, various Charnockitic Gneisses, Granitic Gneisses, Garnet Biotite Gneisses, Quartzites, Quartzofeldspathic Gneisses, Calc Gneisses and Marble. The smallest lithotectonic unit, Kadugannawa Complex (KC) aged 1400 to 1600 Myrs (Milisenda et al, 1988; Kroner et al, 1991) and is composed of Biotite-hornblende and Biotite Gneisses, Amphibolites, Quartzofeldspathic Gneisses, Pelitic Gneisses Quartzites and Granitic Gneisses.

6. Speleogenesis of Sri Lanka Caves

Many processes of spleogenesis in Sri Lanka have been identified during the study. Among them weathering and erosion is the most dominant process (Weliange et al, 2010; Jayasingha et al, 2010a; Jayasingha et al, 2010b). In addition amalgamation of boulders by precipitated minerals was also recorded (Jayasingha et al, 2009b). With the higher degree of weathering rate due to high rainfall and warm temperature, Sri Lankan basement has given better opportunity to form different types of caves. Physical or chemical weathering has dominated with time, climate, location and lithology. Also, interior morphology have been controlled by the hydrogeology, lithology, structural pattern and weathering rate. High weathering rate with specific lithological features has combined to form deep tunnel like caves (also can be known as true caves) and/or multi chamber caves. Large size boulders originated from physical weathering rest on bed rocks to form rock shelters. Also rock shelters have been formed from weathering of exposed bed rocks in steep slopes. Crystalline limestone (Marble) is a metamorphic rock in Sri Lanka and it can be easily weathered and eroded chemically. The large boulders of marble have been amalgamated each other by precipitation of calcium carbonate dissolved in water to form chambers of caves. In most cases marble cave is characterized by a stream running inside it. Metamorphosed silicate rock boulders are not connected with such a chemical precipitation but they are jointed together to form a open cave. Hence weathering and amalgamation cause different cave formations in the subsurface and on the surface of the earth

7. Terms, Definitions and Classification

For the classification we consider the following aspects of a cave.

1. Position on the Earth (on the surface and in the subsurface)
2. Lithology
3. Morphology (interior)
4. Genesis

Figure 1: General Geology of Sri Lanka and its subdivisions. Solid lines show the main subdivisions and dotted lines show the climatic zones. HC: Highland Complex. VC: Vijayan Complex. WC: Wanni Complex. KC: Kadugannawa Complex. ML: Miocene Limestone.

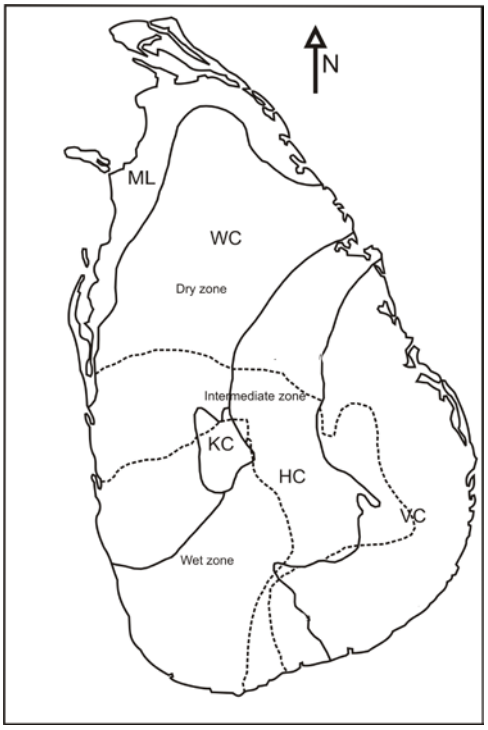
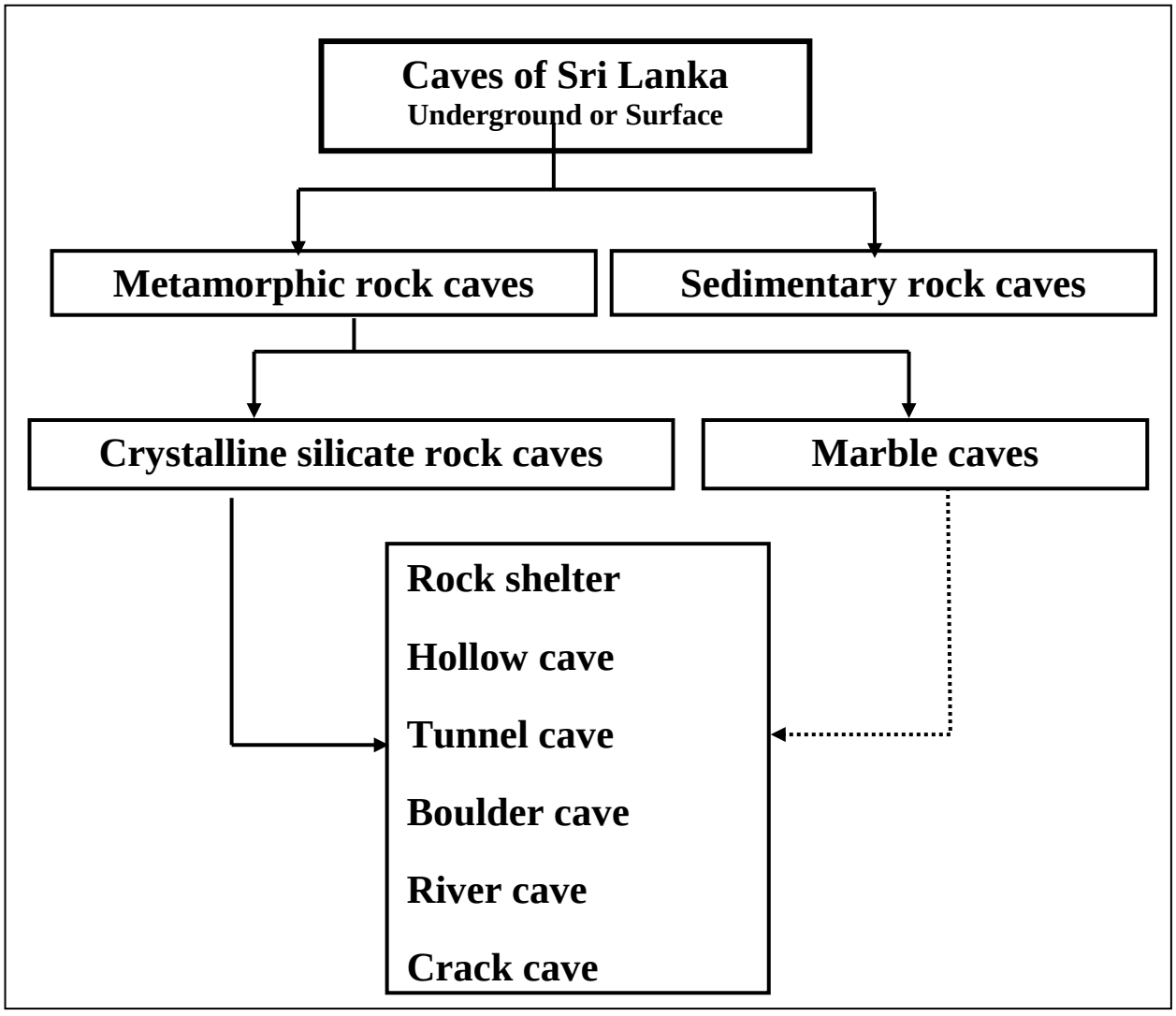


Figure 2: Classification of Sri Lankan Caves (below)



7.1. Position on the Earth

It is revealed that the position of a cave on the Earth is important to define as "*a surface cave*" or "*a underground cave*". A surface cave can be defined as cave that exist on the surface and all the chambers are formed on the earth surface and receives substantial amount of day light. This kind of cave is resulted from physical weathering, transportation over land, followed by chemical and sediment precipitation. An underground cave is located in the subsurface of the earth where all cave space is below the surface of the earth. Those subsurface spaces are connected via an opening to the surface, which is known as the cave mouth.

7.2. Lithology

Lithology helps to classify caves in to two groups as "*Metamorphic*" origin and "*Sedimentary*" origin. Metamorphic caves are further divided in to two sub groups as "*crystalline silicate rock-caves"* and "*crystalline limestone rock-caves (Marble caves)"*. Sedimentary rock caves of Sri Lanka is characterized by mainly Miocene limestone rocks found in northern and northwestern area of the country.

7.3. Morphology and Genesis

According to the genesis and morphology above caves could be categorized in to six types as "*Rock Shelter", "Hollow Cave ", "Tunnel cave", "River cave", "Boulder Cave"* and *"Crack Cave"*.

7.3.1. Rock shelter

The caves that have wider mouth and it is open in three sides of it. They have short depth which is not deeper than the twilight zone. Therefore entire cave get sunlight very well. Mostly those caves have a single chamber which is very well aerated. According to the genesis, Rock shelters can be further categorized in to two; as "*Bedrock shelter"* and "*Boulder rock shelter"*. Bed rock shelter is formed in an exposed bed rock on the surface of earth and best examples are given by Pothgul lena, Alawala. Boulder rock shelter is formed from a single boulder resting on a bed rock on the surface and Varana cave complex is a group of bed rock shelters (Jayasingha et al, 2009a). Weliange (2009) has speleologically studied a bedrock shelter located at Alawala village in Attanagalla.

7.3.2. Hollow Cave

This can be considered as a true cave which is formed in underground sub surface. It has smaller mouth with long depth. The mouth is open to a single direction. Hollow cave can be single, double, tribal or multi chambered. Some hollow caves extend into very deep into the Earth such as Sthreepura Cave in Kuruwita. These deep cave are entirely dark but aerated enough for several people to stay inside for hours.

7.3.3. Tunnel cave

A cave which has multiple chambers and these chambers are connected by tunnels. Tunnels are classified as deep hollow/tube of which the depth is longer than the diameter or width of the mouth. In some cases only a tunnel can be observed but it is a small cave. Tunnel cave is definitely an underground cave. Inner chambers of the cave do not receive sunlight; hence it is dark even at daytime. Best example is Pelpola underground tunnel cave in Rathnapura.

Weliange & Namalgamuwa (2009) also reported about a tunnel cave (small scale) located in Alawala village in Attanagalla electorate.

7.3.4. River cave

It does not mean a cave formed on the banks of rivers/streams. The river cave is also like a tunnel cave or a deep cave and essentially a stream flows through it. All though it says "River" again does not mean the stream is a river or a larger water channel. It can be a tributary of a major river, mostly first, second or third grade. A river cave located in Nikawalamulla, Sri Lanka is one of the examples.

7.3.5. Boulder cave

A cave made up of series of boulders (at least more than three boulders) gets connected to form the cave. This category specially form tunnel like caves but those are not true tunnel caves. Jayasingha et al (2009b) has described a marble boulder cave in Mandaramnuwara, Piduruthalagala.

7.3.6. Crack cave

A cave formed due to a large crack developed along a joint/fracture of bed rock is defined as Crack caves. The crack caves can be narrow and vertical where ceiling height could be very high. Two crack caves and one crack cave have been identified located near the Divaguhawa Cave in Kuruwita and in Nuikawalamulla.

According to the classification Sri Lankan caves are simple but in the nature there can be combination of types that we have described. Figure 2 summarizes the types of caves of Sri Lanka.

8. Conclusion

For the first time in the field of Sri Lankan Speleological Science, an attempt is made to classify caves of Sri Lanka. The position of the cave on the Earth is the most important to define caves as surface or underground caves. According to the lithology, caves of Sri Lanka can be categorized in to two broad categories, as Metamorphic and Sedimentary. Sedimentary rock caves or karsts are found in limestone or Karstic areas of the country. Metamorphic caves can be divided in to two as crystalline silicate rock-caves and crystalline limestone rock-caves (Marble caves). According to the genesis and morphology caves could be categorized in to six as; (I) rock shelters, (II) hollow caves, (III) tunnel caves, (IV) river caves, (V) boulder caves and (VI) crack caves. In conclusion classification of caves is an important aspect in Speleology since it provides information for comparative studies, future cave management and conservation. Future studies will be done to find out other cave classification criteria such as sediment types, depositions, chemical composition and structure of speleotherms etc.

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