Multi-Level Maze Cave Development in the Northern Territory

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Introduction

In 1991 the Top End Speleological Society discovered a three dimensional maze cave (BAA38) at Limestone Gorge, Northern Territory. This cave is unique in the region in its extent and developmental complexity. The cave has been extensively explored, and surveyed in detail, but this is still far from complete. In this paper features of the cave system are described. Based on analysis of survey data and observations made over the course of many field trips, some concepts regarding the development of the cave are presented and discussed. It is anticipated that as more of the cave is explored and surveyed, these concepts will be further developed and modified.

Limestone Gorge is located 60 km south of Timber Creek in Gregory National Park, Northern Territory. Limestone Gorge is situated on the Victoria River Plateau and is developed within the Skull Creek Formation which is composed of blocky crystalline dolomite with minor interbeds of siltstone (Sweet 1973). The formation is 220 metres thick with a bedding plane which locally dips South East 2°. Limestone Creek and the East Baines River have cut directly through the formation, revealing the lithological sequence.

The topography is characterised by rounded stepped hills formed from the Upper Skull Creek Formation. The most prominent layer in this formation is the Supplejack Member, which has been measured at a thickness of 18 m, and lies approximately 135 m above the base of the Skull Creek Formation. The Supplejack Member is thick and relatively uniform in composition, and it is more resistant to weathering. Typical tropical karst topography has developed on exposed sections of Supplejack Member, with examples of rillenkarren, trittkarren and kamenitza. The Lower Skull Creek Formation forms a series of thick beds below this (Sweet et.al. 1971).

Exploration of the caves has revealed a more detailed lithology of the Lower Skull Creek Formation. The upper boundary is a layer of dolomitic mudstone 0.5 m thick. Beneath lies a 2 m layer of shale followed by another layer of mudstone 0.5 m thick. A 10 m thick layer of dolomite, 2 m of shale and two more sequences of dolomite (2.4 and 7.2 m) are evident at the limit of exploration (Figure 1).

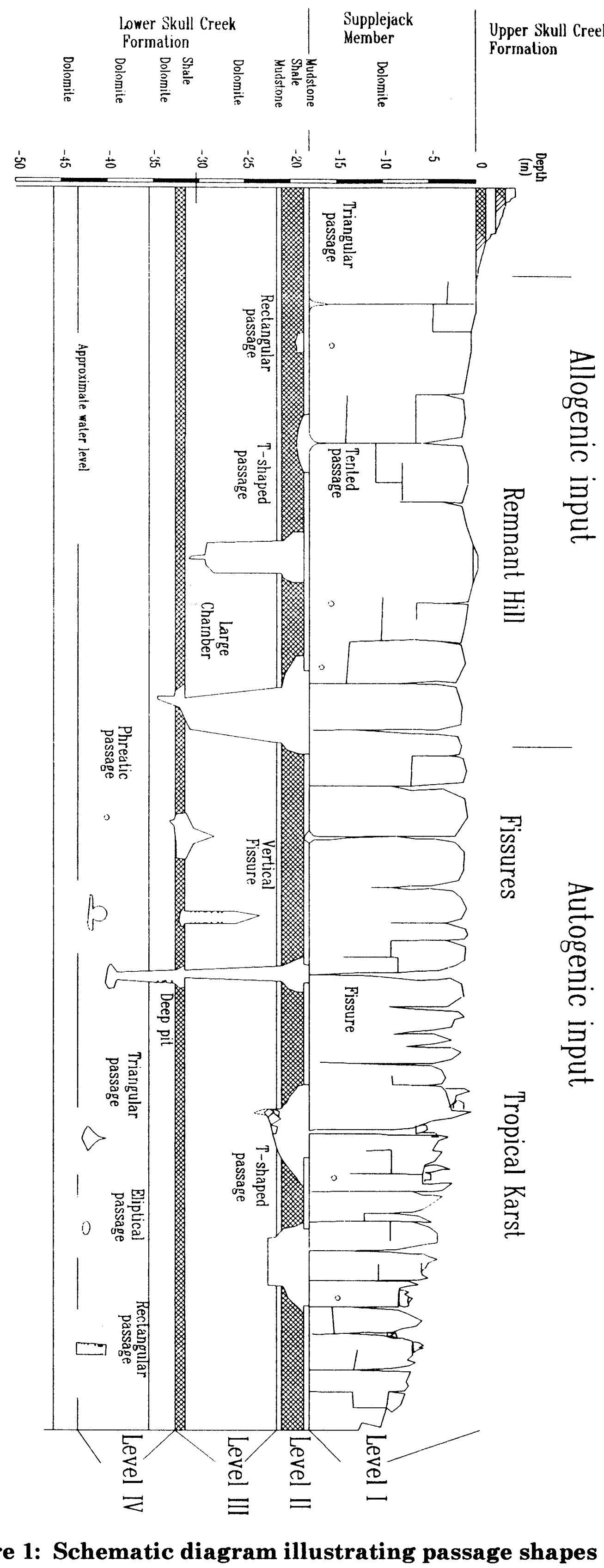

Figure 1: Schematic diagram illustrating passage shapes and their relationship to the lithology

Passage Morphology

The cave is developed within a major peninsular of karst. The southern section of the outcrop has the greatest relief, and passages have developed on four levels over a depth of approximately 47 m. The majority of passages are formed within the Lower Skull Creek Formation and jointing occurs predominantly at 220°. This region of the cave has been used to explain the developmental sequence of the system. Four levels of cave passage have been identified; each level is characteristic of the lithological unit in which it is predominantly formed:

- Level I Phreatic and vadose development within the Supplejack Member.
- Level II Vadose development just below the Supplejack Member.
- Level III Joint controlled vadose passages in the Lower Skull Creek Formation.
- Level IV Phreatic and vadose stream way at the lowest level.

Level I

Passages with phreatic characteristics occur near the base of the Supplejack Member and meander for 2 - 10 m. The origin and development of these passages is unclear. Vadose passages at this level are controlled by joints developing within the Supplejack Member exclusively. These narrow linear fissures develop into a distinctive triangular form as a result of lateral corrosion at the base of the joint. Passages in this level control and concentrate autogenic water to the cave below.

Level II

Erosion of the mudstone floor of the level I passage allows entrenchment into the shale layer below. Dominant lateral erosion increases the width of the passage within the shale interface. Two types of passage can be distinguished. Those which have developed from the level I, **tented passages**, and those which have are developed only within the shale interface, creating **rectangular passages**. The latter have a characteristic flat roof, and they are not influenced by the joints of the level above. Both types of passage ultimately cut deeper into the Lower Skull Creek Formation creating joint controlled vadose streamways. This creates distinctive **T shaped passages**, which increase in depth and basal width through mechanical erosion and breakdown.

Level III

Vadose passages cut deeper into the Lower Skull Creek Formation, and create a lower level following a different jointing pattern localised to level III. **Deep vertical fissures** (6 - 10 m), **meandering streamways** and **canyons** are frequently encounted. Extensive collapse of the lower dolomite passages give rise to **large chambers**. Where there is an intersection of major joints deep pits 14 - 23 m descend through the length of the Lower Skull Creek Formation to level IV.

Level IV

This level is the deepest and most constricted region of the cave. The passages vary from **triangular** or **rectangular** to **elliptical** in shape. The passages are generally joint controlled, except in a few areas where it appears that recent phreatic passages have developed in regions where old passage has been blocked by collapse. Many are partially filled with gravel and fossil breccia. The sediment depth in these passages has not been determined. Sediments also suggest active flooding and flowing water in the wet season.

Hydrology

The region has a monsoonal climate with a short intense rainy season (December - March) and a long dry season. Slopewash off the Upper Skull Creek Formation conducts allogenic recharge into focal inputs at the junction of the Upper Skull Creek Formation and Supplejack Member. Diffuse recharge is also added by autogenic water falling directly onto the exposed Supplejack Member. The existence of mudstone and siltstone layers form aquitards, making the sequence less permeable and more directly controlled by the lithology (Ford & Williams 1992, Palmer 1984).

The mudstone layer at the base of the Supplejack Member causes water to lateralised along jointed passages, developing level I into a two dimensional maze. At points where this aquitard is breached, recharge is focused into the shale layer beneath, and the process of lateralisation is repeated in level II. Autogenic water usually falls directly into the levels below as both layers of mudstone have been eroded. As each subsequent level develops there is convergence of the water into fewer, more constricted passages below ultimately causing flooding in level IV. All the water moving through level IV passage flows towards the only known point of discharge in the cave. The convergent drainage system appears to direct all water towards the efflux. The volume of allogenic and autogenic recharge entering the whole outcrop (± 1.5 km^2), appears inconsistent with the small size of the level IV drainage system and the efflux. This suggests that an extensive amount of new passage remains undiscovered.

1 km of passage has been mapped at level IV in the southern region of the outcrop. Water reaches this level by vadose canyons, deep pits and fissures as described above. Many of the junctions have branches which have breccia on walls and floor, suggesting recent passage development in older passages filled with fossiliferous clastic sediments. Exploration of level IV has also revealed four water-filled sumps indicating the presence of a perched or deeper and permanent watertable. The presence of Stygobiont amphipods suggests that there could be a connection to a larger permanent body of water.

Development

The topography of the Upper Skull Creek Formation is distinguished by low hills and valleys. This provides a variety of fronts along which the Supplejack Member becomes exposed. The Upper Skull Creek Formation converges allogenic recharge into valleys and depressions where premature erosion of the Supplejack Member occurs. Cave formation appears to begin at the intersection of the Upper Skull Creek Formation and the Supplejack Member, where many adjacent but isolated caves develop as small networks of various sizes in level I.

Occasionally these are connected to each other via one or two small passages. Continuing development results in erosion of the aquitard. When the aquitard is penetrated there is a drop in the piezometric surface and development continues into level II. In addition, erosion of the lower mudstone aquitard causes recharge to be concentrated into the deeper levels. As the Upper Skull Creek Formation is sequentially eroded, the points of allogenic recharge are redistributed. The rearrangement of recharge points and the development of deeper passages from former ones represent sequential phase development (Ford & Williams 1992).

Surface karst erosion is related to the length of time the karst has been exposed. Thus the oldest points of recharge correlate with the most eroded regions in the outcrop and are now represented by collapsed valleys and dolines. These areas are thought to be associated with the initial phases of development in the outcrop. The most recent phases are represented by level I passage developing at the newly exposed regions of the outcrop as well as the deepest passages forming along the hydrological gradient towards the edge of the outcrop.

Where allogenic recharge has entered the outcrop, phase development predominates, but once the caprock has been removed completely, the Supplejack Member is exposed to autogenic (or diffuse) recharge, and maze development is initiated. Diffuse recharge is supplied uniformly to all joints within the caverniferous zone, so that each fissure experiences comparable rates of solution, creating an angular grid of interconnecting passages of similar size (Palmer 1975).

A network maze develops upon the existing phase system, creating high narrow passages along the major joints (fissures) in the Supplejack Member. Isolated caves are commonly joined together through the enlargement of these fissures. Deeper passages are thus influenced by both allogenic and autogenic recharge. This results in a complex network of passages whose origin is a combination of both phase and maze development. Maze development has its greatest influence on levels I and II, whereas deeper levels are largely the result of phase development. Attributing the origin of any particular area in the cave to one of these types of development is difficult because both act simultaneously and continuously at all regions of the outcrop.

In addition to phase and maze development, there is evidence that clastic sediments also influence the development of the cave. In areas with high relief, superficial sediments appear to be rapidly moved into the cave where the aquitard is penetrated close to the recharge points. Sediment loads accumulate in the lowest passage and effect development in these levels. In areas of low relief, clastic sediments slow the penetration of the aquitard close to the recharge points. The sediment load becomes confined to level I. Arched passages are formed through lateral erosion of fissures in Supplejack Member. These sediments also enhance the lateralisation process within the level II aquitard, promoting lateral erosion in the shale layer by diverting streamways to characteristically undercut the Supplejack Member, create wider passages and chambers.

Discussion

The cave is an example of an ideal water table cave as described by Ford and Ewers (1978). Close to the outcrop where the caprock is being stripped away fissure frequency is low and the piezometric surface is intact. Passage is initially under the influence of phreatic development and controlled by the aquitards on three levels. As fissure frequency increases, a drawdown vadose system develops to the lowered piezometric surface. Allogenic water entering the Supplejack Member attacks all the layers vertically and simultaneously until it reaches the depth of the water table, below level IV.

The influences of topography, slope and sediment load on the hydrological controls of the cave appear to account for many of the karst features which can be observed in this case. These factors also explain why this cave has developed differently to other maze caves in the region as outlined by Smith & Storm (1991) and Dunkley (1993). If the slope is small and the sediment load high, passage formed through allogenic inputs lateralise above the aquitard maintaining development within the Supplejack Member (Palmer 1984).

Passages initiated by allogenic recharge then lateralise until they join the rest of the cave. This results in maze cave formation at level I, rather than vertical development to lower levels. Autogenic input then widens the fissures above enhancing entrenchment into the level II aquitard. High sediment load will also fill deeper passage masking any evidence initial phase development. On the other hand, where the relief is high and sediment levels low, as in this example (where the outcrop is a peninsular of karst). The amount of sediment entering the cave from the surrounding caprock is considerably smaller. Phase development is initiated, followed by maze development, resulting in the creation of a three dimensional maze cave.

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