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The Characteristics and Origin of Some Limestone Caves in the Sungai Perak Basin

ROS FATIHAH & YEAP EE BENG

Department of Geology,University of Malaya
50603 Kuala Lumpur

Abstract

Caves are commonly found in limestone hills throughout Sungai Perak Basin as a result of the action of various factors such as structure, drainage and previous climate, which control the rising and lowering of previous sea levels and determines the level of the groundwater table. Their characteristics such as the levels of the caves, shape, cave deposits as well as the origin are significantly related to the surrounding rocks and climate during the Quaternary. These caves were interpreted to have been formed by the action of freshwater. The active caving in Gua Tempurung is made possible by the constant allogenic water source from the neighbouring granitic hill. Some chambers are still being enlarged by percolating meteoric water through cracks and joints and form vertical and horizontal scallops.

Sifat dan Asalan Sebahagian Gua Batu Kapur di Lembangan Sungai Perak

Abstrak

Gua merupakan fitur yang biasa ditemui di kawasan perbukitan batu kapur sepanjang Lembangan Sungai Perak hasil tindakan pelbagai faktor seperti struktur, saliran dan iklim awal yang bertindak mengawal kenaikan dan penurunan aras laut yang menentukan tahap permukaan air bawah tanah. Sifat seperti kedudukan gua, bentuk, endapan gua termasuk asalannya merupakan unsur penting berkaitan dengan sekitaran batuan dan iklim semasa Kuaterner. Gua-gua ini ditafsirkan terbentuk kesan tindakan air tawar. Aktiviti penguaan yang aktif di Gua Tempurung disebabkan oleh sumber air alogenik dari perbukitan granit yang berdekatan. Sesetengah kebuk masih membesar melalui 'percolating' oleh air meteor melalui rekahan dan kekar dan membentuk 'scallops' menegak dan melintang.

INTRODUCTION

Limestone hills occur in three regions in the Sungai Perak basin; the Lenggong area, Padang Rengas and the Kinta Valley. These limestone hills are the remnants of the much larger exposures of limestone which have been denuded and are presently under the cover of the Quaternary alluvium. The limestone hills show well-defined mogote topography consisting of steep to vertical walls and rounded tops.

Geologically, the Kinta Valley is underlain by the Kinta Limestone which shows an age range from Devonian to Permian (Suntharalingam, 1968). Much of the limestone is found beneath the general surface where it underlies the tin ore bearing alluvium for which the Kinta Valley is famous. The Kinta Valley Schist occurs mainly below the limestone though some parts are found to interbed with the former. The limestone and schist were probably folded and metamorphosed during about the end of the Permian. After the folding and metamorphism, these Paleozoic rocks (limestone and schists) were intruded by the Kledang and Main Range Granites during very Late Triassic. Some Jurassic igneous events had been detected as well. After the folding and intrusive events they are slowly became emergent. Calculated rates of emergence were given as 0.1 mm per annum (Krahenbuhl, 1991). The trends of the structures of the Kinta Valley are largely north-south. A number of geologists have ascribed the formation of the Kinta Valley to block faulting occurring at the contacts between the granites and the meta-sedimentary rocks (Gobbett, 1975). The Padang Rengas limestone is interpreted to be the northern most extension of the Kinta Valley Limestone and its surface expression takes the form of Gunung Pondok.

The largely banded fine to medium-grained marble of the Lenggong Limestone is Lower Paleozoic in age and is intruded by the Bintang Granite of Triassic age. Calc-silicate veins and patches are found locally in the marble not far from the contacts with the granite. The Lenggong Limestone is seen as several low, densely forested mogote hills with conical tops.

CAVES AND CAVITIES

Thornbury, 1961 defined cavern or cave as a natural subterranean runway void. According to him, caves can be simple in plan or have complex ramifications. It may extend vertically or horizontally and may occupy one or more levels. Caves can be dry or streams may occupy the cave floors. On the other hand Ford and Ewers, (1978, p. 1784) define a cave in a very broad sense as "a solutional conduit or other void that possesses dimensions large enough for turbulent flow of water to occur" i.e. 5-16 mm in diameter as a minimum. It is only under such condition of water flow, that rocks can be effectively dissolved by water. However, in most usage, caves are generally taken to be voids of larger dimension and solution cavities are used for voids that are of smaller dimension.

A cave in the glossary of geology as well as the American Speleology Association is defined as natural underground open space, generally with a connection to the surface and is large enough for a person to enter. The most common type of cave is formed in limestone by dissolution.

PREVIOUS STUDIES

Gale (1983) recognised four major phases of hydrological development from the studies of the morphology and sedimentary infill of abandoned drainage networks in Batu Caves. Tjia (personal communications) in his study on the development of tropical karst topography was of the opinion that caves were formed when limestones were dissolved laterally following the water table and fractures. Caves then increased in size by further solution and episodic collapse of their roofs and walls. Wilford (1964) had accepted Davies' two cycle theory for the formation of the Sabah and Sarawak caves. On the other hand, Gobbett (1965) in writings on the caves of Malaysia, noted that the caves in Peninsular Malaysia are rather complex and may have undergone a long history of vadose and phreatic solution phases. He believed that the caving process might have gone on for several tens of millions of years, since the Peninsular Malaysia landmass was exposed for a considerable length of geological time.

THE PRINCIPLE OF KARST FORMATION AND LIMESTONE DISSOLUTION

The actual genesis of karst features is intimately tied up with the hydrological conditions prevalent in an area whereby the regional groundwater is used to define the vadose zone (above the water table) and the phreatic zone which is below the water table. In general the regional water table may be curved, since a steady state will develop between the supply of atmospheric water and the outflow into the nearest stream.

Several theories regarding the formation of caves have been developed. These can be classified as to 'phreatic', 'vadose' and 'water-table' theories, corresponding to the groundwater zone in which the cave is assumed to be created. All theories start with minute channels in the limestone rock, which are supposed to be due to original heterogeneity that eventually enlarge into caves.

In the phreatic theory (Grund (1910) and supported by Davies (1960)), a cave is formed through leaching in the phreatic zone where the flow velocities are highest in the biggest channels. When the water table sinks owing to the entrenchment of nearby streams the solution will be directed downwards.

The supporters of the vadose theory (Matson, 1909) assume that the leaching occurs mostly in channels through which the atmospheric water flows to the ground water table. Solution in the freshwater vadose zone and at the freshwater vadose-phreatic interface is the most important for karst formation in the early stages following the emergence of carbonate rocks. This evidence is supported by the observation of intensive karstification occurring in emerging islands, atolls and reefs, carbonate platforms and terraces. Caves commonly form the top of the freshwater phreatic zone and may extend over a vertical range of hundreds of metres depending on the position of the water table and the rate of saturation with $CaCO_3$. The marine mixing phreatic zone appears also to be a place of pronounced solution (Panos, 1976; Rudnicki, 1980 in Bosak, 1989). Swinnerton (1932) assumed that cave formation occurs exactly at the water table because it is here that the flow velocities are supposed to be highest. Bretz (1942) observed both, vadose and phreatic features in many natural cave systems.

Ford and William (1989) through their extensive studies on caves have classified them according to the type of water that had acted upon the limestone: (1) normal meteoric waters, (2) deep enriched waters, (3) brackish waters or combinations of (2) and (3) with (1).

CAVES IN SUNGAI PERAK BASIN

Observations have been made throughout the karstic limestone in the Sungai Perak Basin that covers an area of approximately 30 km x 70 km. Caves are found, especially, in areas where the larger mogote hills occur.

Occurrences

Massive limestone hills occurring in the tropics usually take the form of steep sided hills known as the tower karst. In the Kinta valley, the tower karst is regarded as the mature type consisting of isolated small to large mogote hills rising above an alluvial plain which is largely underlain by the Kinta Valley Limestone. The mogote hills are largely found at the eastern to northeastern part of the Kinta Valley for an area measuring 30 km long and 5 km wide. A number of mogote hills also occur in the northwestern part of the Valley (Tasek area). The mogote hills in the Kinta Valley are observed to continue vertically downwards till the platform levels of the buried karst which underlie most parts of the Kinta Valley underlain by the limestone.

Many caves have been mapped by one of us (Ros Fatihah as part of her Ph. D. studies) and five examples that show differences in characteristics and origin are discussed here. Figures 1 to 5 illustrate the caves in plan view and in cross-sections.

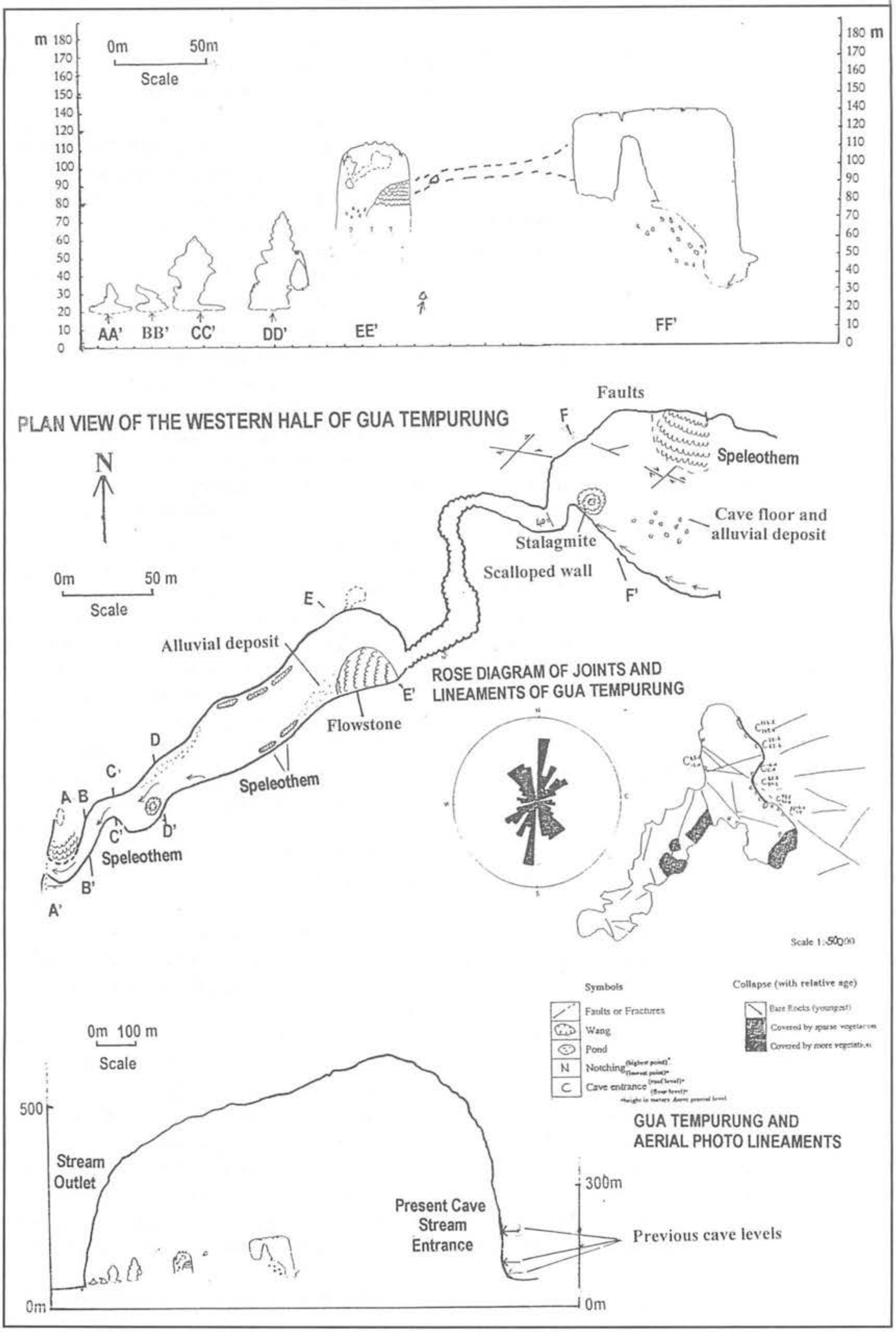

Figure 1: Gua Tempurung cave system, south Kinta Valley.

Kinta Valley Caves

The characteristics and origin of the five caves found in the Kinta Valley are discussed below:

Gua Tempurung

Gunung Tempurung is situated 25 kilometres south east of Ipoh. It is a large limestone hill with the highest peak at 546 metres. In plan view it is T-shaped and has a 9.2 km^2 base (Figure 1). Its elevation is from 40 metres above mean sea level in the east to 20 metres in the west. The Main Range granite on the east has just been topographically detached from the Gunung Tempurung and is located about 80 m farther towards the east. A few streams from the granite in the east provide constant allogenic water to the active caves in the hill. Up to 5 well-defined levels of cave entrances have been observed especially on the northeastern face of the hill which is marked by a 1.2 km long collapsed cave face that strikes along 340°-160°. A photo lineament study of the Gunung Tempurung has been carried out (Figure 1). Plots of these photo lineaments and joints of the Gua Tempurung indicates major trends of fracture system along 010° - 190°, 160°-340°, 030 -210° and 060°-240°.

Gua Tempurung is the largest cave in the Kinta Valley. The present active part of the Gua Tempurung is fed by the westward flowing Sungai Tempurung (Figure 1). Measurement of the stream flows during the months February and early July, 2000 are 0.14 m^3/s and 0.28 m^3/s respectively. The whole cave is about 1200 m long. At the entrance end the cave runs along the 110° direction and at the last 500 m western end the cave runs along the 060° direction. The east entrance is located at about 3 m below the ground level which is about 40 m above the mean sea level (msl) while the outlet of the stream is at about the 20 m level on the eastern. This gives a gradient of 1:53.

Detailed mapping of the cave is being carried out now and the mapped western half is shown in Figure 1. Six cross sections from the far west to almost the centre of the cave system are given.

The lowest level of the cave is situated at the west exit is about 20 m above msl with the cave roof height of 17 m. For a distance of about 50 m from the allogenic stream outlet, the cavern chambers are rather small (see cross-section A-A' and B-B'). They have wide base and narrower inclined roof. These were formed rather late. Assuming that the external denudation rate (taken to be 0.1 mm / year) controlled the solution of the caves, then this section of the cave was carved out not more then 170,000 years BP.

From the 50 m to the 210 m segment from the outlet, the cavern is represented by another stage of cave development. Cross-sections C-C' and D-D' show tree-shaped outline (Figure 1). The cave roofs generally show several ledges indicating that the recession of the ground water which controlled the formation of the cavern was held steady for several periods of the time. Ledges that are symmetrical on both walls and are located at 17 m, 27 m and 35 m above the present stream bed. Large-scaled vertical scallops were found on the side walls below the 17 m ledge. This indicates that meteoric water was active after the formation of these chambers. The highest point reached by the cave roof is 59 m from the present stream level. Based on the assumption that the groundwater recession outside the cave had controlled the solution, then the solution of this section of the cave chambers could have started about 590,000 years BP.

In plan view the chamber along E-E' appeared similar to C-C' and D-D' however, the curving roof with a number of bell shaped chambers and near vertical sidewalls indicate a different phase of solution. The E-E' chamber shows more similarity to the F-F' chamber in terms of solution characteristics, that is, with vertical walls and curve or flat roofs. These two larger size chambers are connected by a narrow perched chamber of 220 m. The connecting chamber is suspended at between 60 m to 90 m above the present stream bed. This connecting chamber has a cross-sectional measurement of 7 m width by 4 m and it shows broad sinuous vertical scallops which results from solution by percolating water descending from the roof.

The E-E' and F-F' chambers are quite large. E-E' is a hanging chamber though the F-F' chamber is only partially hanging. The "Gergasi" chambers is located at about 600 m plus from the outlet that is west of the F-F' chamber. The Gergasi' chamber houses the highest level floor ("Top of the World") and has a measured roof height of 112 m from the stream level. The floor of the "Top of the World" is covered with alluvium and collapsed blocks. The widest section of this part of the cave chamber is about 71 m. The Gergasi chamber roof is rather flat with many small stalactites hanging from it, aligned along fractures striking along 170°-350°.

The E-E' chamber has a roof height of about 93 m above the present stream bed. Many bells with heights of up to 7 m were formed above this curved roof. A number of large stalactites hang from the 93 m roof as well as the bells.

It is interpreted that the carving of the E-E' and F-F' chambers could probably have started about 930,000 years BP. Bells were then developed on the E-E' curving roof. On the other hand faster solution is indicated to have taken place in the F-F' chamber leading to much collapse and forming the "Top of the World" level. Subsequently, percolating water from the roof led to the formation of many small sized stalactites along certain fracture systems running parallel and transverse to the axis of the Gergasi chamber.

At the collapsed wall at the northeastern side of the hill, 4 levels of caves are exposed. The average position of each level above the present ground are 156.7m, 73.8 m, 45.1m and –3m. Assuming a denudation rate of 0.1 mm to 0.085 mm per annum (Crowther, 1986), it is interpreted that the first cave of allogenic water origin could have started developing about 1.57 to 1.84 million years BP. At that time the Gunung Tempurung limestone mass is assumed to be still covering the granite mass on the east and the allogenic Sungai Gua Tempurung is assumed to have entered the limestone at a level of at least 156.7 m above the msl on the east of the present entrance.

Kek Look Tong (temple), Gunung Rapat

The Kek Look Tong is situated at the northern part of Gunung Rapat which is situated at the south-east of Ipoh town. The highest peak is 318 m high and it has basal area of 4.6 km^2. The alluvial plain is about 80 m above the mean sea level around Gunung Rapat. In plan view it is highly irregular in shape with many appendages sticking out of the whole hill like an amoeba. Geomorphologically, Gunung Rapat shows a cockpit type topography – with many peaks and a number of collapsed, dry and water-filled wangs (or sometimes known elsewhere as dolines if they are of significant size). In some parts, where mining operations have stripped off the alluvial cover, it is evident that the original limestone platforms have been reduced to pinnacle topography by sub-surface solution. In some parts, mining activities of rich iron-bearing alluvium have exposed some important sub-surface morphology such as the planation of buried limestone at about 9 m below the plain level which can be seen in an open wang in the middle of the hill. Five levels of caves measured in this hill are located at about 184.9 m, 138.4 m, 102.4 m, 87.7 m and 80 m above mean sea level. Kek Look Tong's general floor level is about 86 m above the msl.

Kek Look Tong cave opens on the northern part of Gunung Rapat and exits southwards into a large wang where the western face has been eroded. The slightly curved chamber trends approximately 160° (Figure2). It is a small cave believed to be the remnant of a much larger cave, which had been eroded. The whole length of this passage shows evidence of being dissolved by turbulent allogenic water. The main chamber at the northern end is dominated by a dome which has a number of bells projecting above this main dome. A rock window located at a height of about 105 m from the plain level is located northwest of the northern entrance of Kek Look Tong. The presence of a number of bells on the cave roof without evidence of fractures indicate that these could have originated as the result of corrosion by condensation from a warmer allogenic water source flowing through the caves (Ford and Williams, 1989). Such warmer than normal water source could be a hot spring. In such a circumstance, condensation could be from the steam coming from the hot spring at site or carried in by the allogenic water source.

Unnamed Cave in Gunung Kuang

G. Kuang is located at Chemor which is about 16 km northeast of Ipoh. It is a small hill with the highest peak 270 m located at the northern part. It has a base area of less than 0.5 km, elongated N-S with rounded sides.

The unnamed cave is located on the western side of the N-S trending Gunung Kuang. It has a small chamber measuring 18 m in length elongated in the N-S direction (Figure 3). This cave probably started as vadose chamber which tapped a 250 m high cliff wall controlled along fractures which striking along 030° and dipping at about 70° towards the northwest. This fracture controlled chamber contains speleothems of large size. The bedding planes also controlled another solution direction. A small subsidiary chamber towards the east of the main chamber is controlled along the bedding planes which strike 110° and dip at about 70° towards the southeast. It is interpreted that the cave initially originated as several small sub-parallel vadose chambers. When the vadose chambers were intercepted by the groundwater surface, the chambers were enlarged by accumulating meteoric water discharged by the fractures tapping descending autogenic water. The receding groundwater level allowed the main chamber to be excavated. The main chamber is young (related to the groundwater surface), though the vadose part of the cave (which contains significant amounts of speleothems) could be very old.

Perak Tong Cave, Gunung Tunggal

Gunung Tunggal which houses the famous Perak Tong Temple is located about 6 km northeast of Ipoh. The peak is not more than 150 m high. The main cave floor is situated at about 5 m from the general ground. A swallow hole at the southwestern part of the cave is controlled by a fracture trend towards 315°. Evidence floor collapse leading to the opening of this swallow hole on the western face of the Gunung Tunggal is seen. The main chamber measures 75 m x 24 m x 45 m. The main chamber is accessed by a passage which opens towards the south. Large vertical scallops (up to 3 m long) are seen on the walls of this passage (Figure 4). Some well-defined bells were formed on the roof of the passage. Bells are absent in the main chamber.

The authors are of the opinion that the main chamber of this cave was formed by the action of autogenic water which was issued along the 315° fractures where the swallow hole collpase had occurred. The passage which opens to the south is interpreted to be controlled by N-S fractures and was enlarged at a later period especially when the vadose chamber was intercepted by the goundwater surface. Solution by phreatic water did not appeare to play any role in the formation of the Perak Tong.

Gua Gunung Runtuh, Gunung Runtuh, Gunung Kepala Gajah.

Many caves in Lenggong can be observed in the larger limestone hills for example Gunung Kepala Gajah contain Gua Gunung Runtuh, Gua Siput, Gua Puteri and Gua Gelap. Some of these are small notch caves or rock shelters, probably remnants of much larger caves which have already collapsed.

Gua Gunung Runtuh is located at the western side of the Gunung Kepala Gajah at about 32 m above the ground

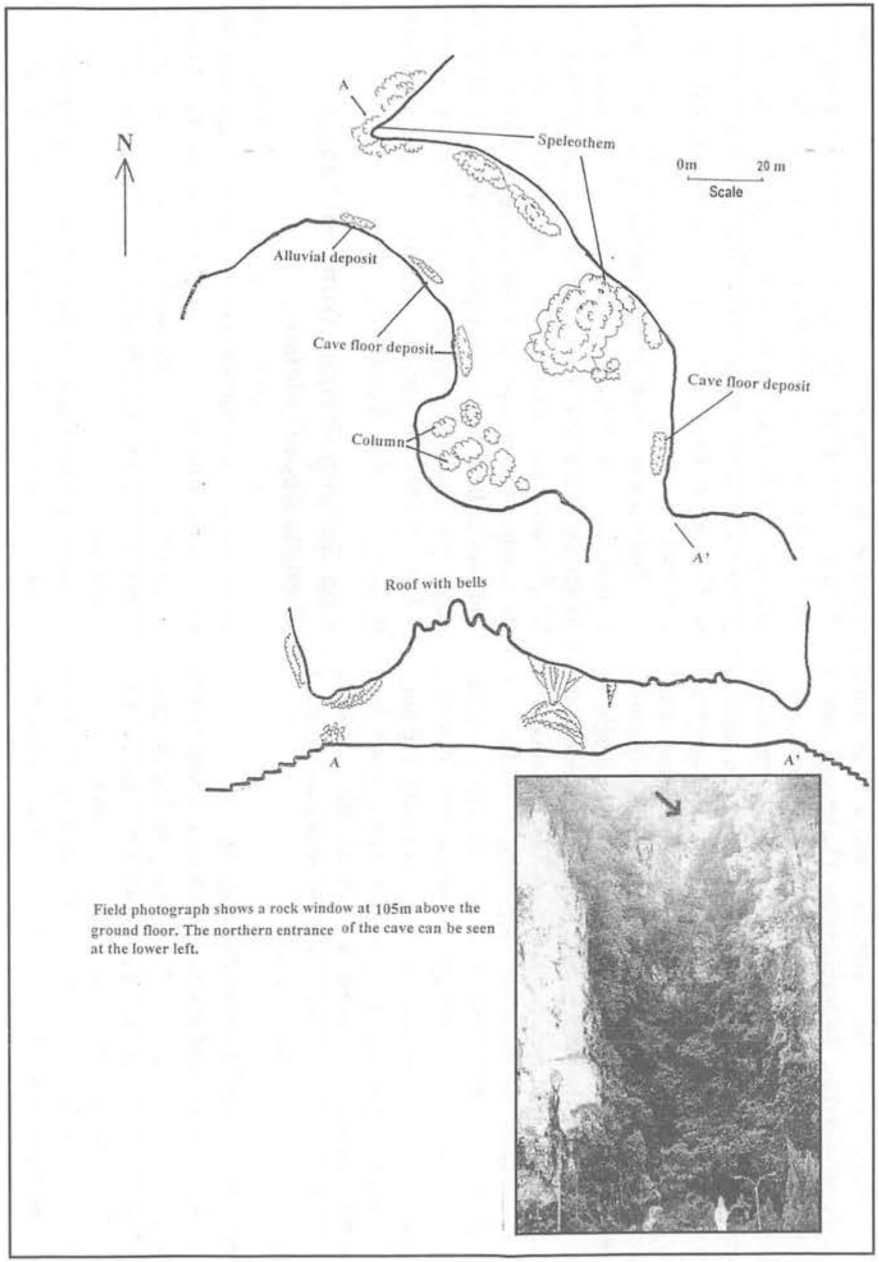

Figure 2: The Kek Look Tong Cave, Gunung Rapat, Ipoh.

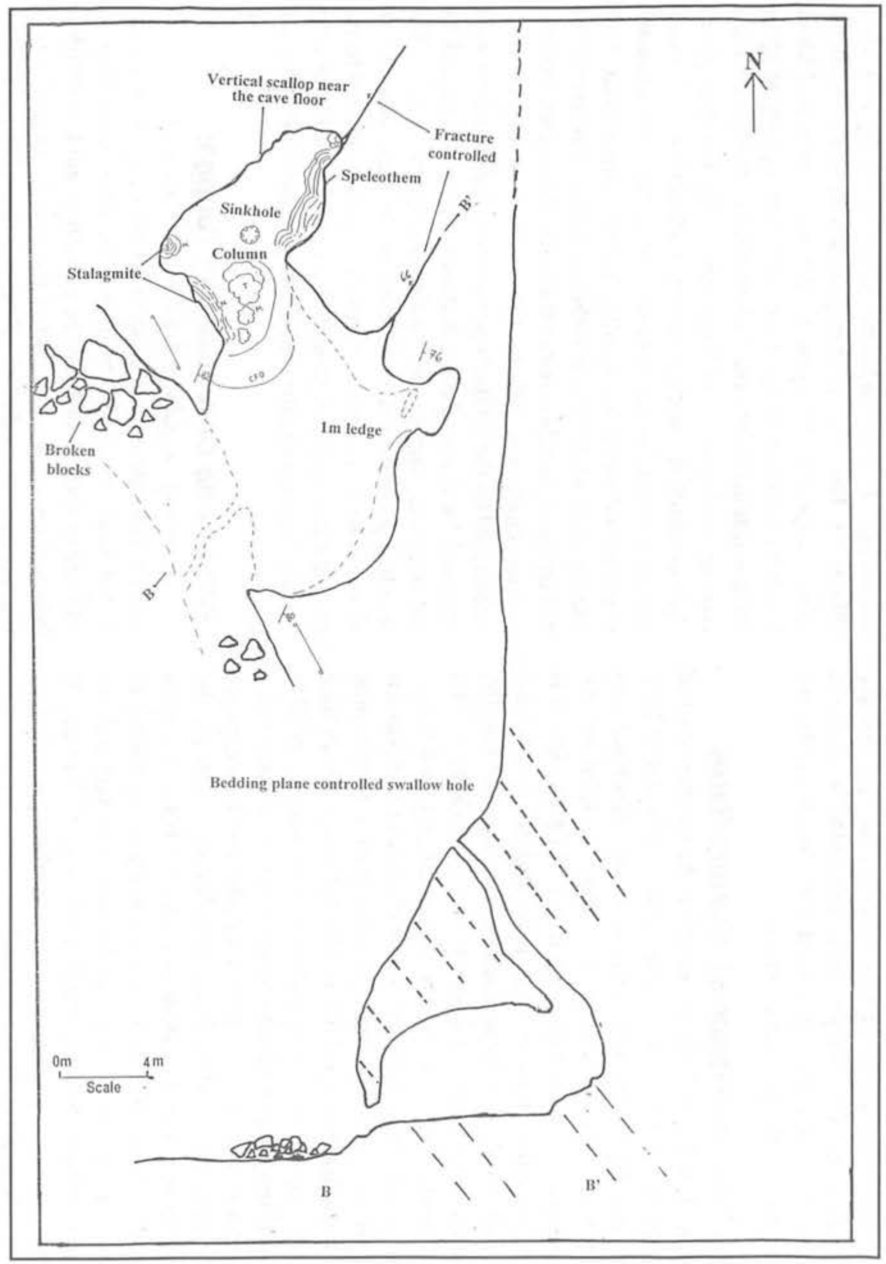

Figure 3: Unnamed cave, Gunung Kuang, Chemor, North Kinta Valley.

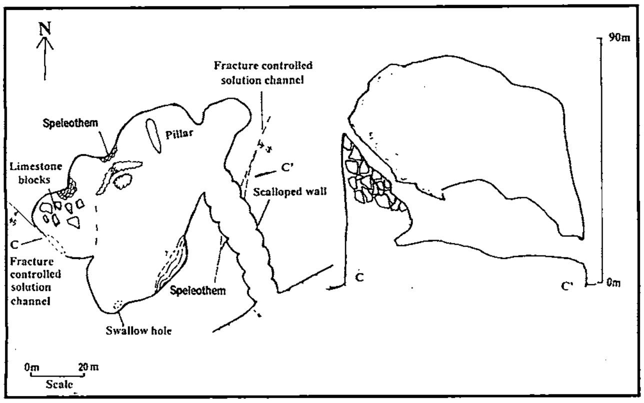

Figure 4: The Perak Tong Cave, Tasek, Ipoh.

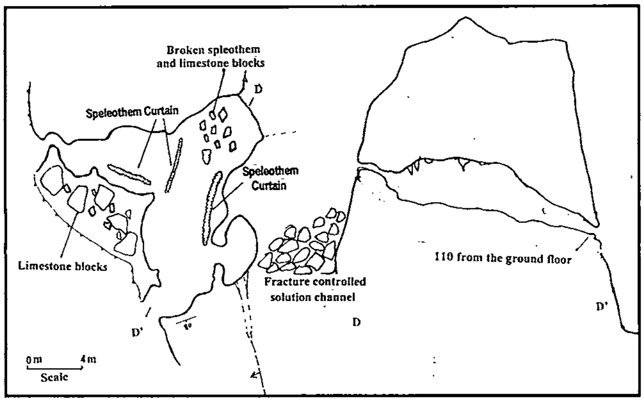

Figure 5:Gua GunungRuntuh, Lenggong, Ulu Perak.

or 110 m above the msl. In shape, it has three wings which are oriented towards northwest, south and northeast. The cave is located almost at the top of the hill surrounded by large blocks of the limestone that have collapsed. The shape of the cave chambers are rather irregular and the roof is decorated by curtains of speleothems deposited along fractures trending N-S and NE-SW (Figure 5). These fractures are believed to have controlled the formation of the Gua Gunung Runtuh. The cave chamber is believed to have been initiated as vadose cavities along these fractures. The cave chamber is believed to have been enlarged through the vadose action (from autogenic meteoric water) and followed by collapse. It is believed that the cave chamber was totally enclosed in the limestone hill and could have been exposed after collapse of several parts of the limestone hill.

CONCLUSIONS

The caves of the Sungai Perak basin are found in the larger mogote hills in this region. All these caves are interpreted to have been formed by the action of freshwater on rather pure crystalline marble found in the Sungai Perak Basin. The Gua Tempurung is formed by allogenic water. An allogenic water source is indicated for the Kek Lok Tong. In this case involvement of a hotter than normal allogenic water is indicated. A hot spring could have contributed to this hot water source. The Unnamed cave at Gunung Kuang and the Perak Tong began as vadose cave chambers controlled along fractures, which were enlarged when intercepted by groundwater. The Gua Gunung Runtuh is interpreted to be a vadose chamber formed by N-S and NE-SW intersecting fractures. Collapse of the cave roofs had contributed to the enlargement of the chamber. The caves were not exposed until a large part of the hill collapsed.

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