The geomorphology and origin of Gua Tempurung, Perak, West Malaysia

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Abstrak — Gua Tempurung is 1.2 km long cave in Gunung Tempurung, a limestone hill in the Kinta Valley, Perak. Constant allogenic water is being fed into the cave from a river that flows from the granitic area in the east, cutting through the limestone hill along the cave. Studies have shown that the cave has undergone a complex and long history of development. Its formation can be related to the evolution of the Kinta Valley landscape with evidences preserved in the cave.

Keywords: Gua Tempurong, geomorphology, limestone cave, karst

Abstrak — Gua Tempurung adalah satu gua yang mempunyai kepanjangan 1.2 m, terletak di dalam Gunung Tempurung, iaitu satu bukit batukapur di Lembah Kinta, Perak. Bekalan air allogenik yang berpanjangan dihasilkan oleh satu sungai yang mengalir dari kawasan granit di sebelah timur, memotong batukapur sepanjang gua. Kajian menunjukkan gua ini telah melalui sejarah pembentukan yang kompleks dan panjang. Pembentukkannya boleh dikaitkan dengan evolusi pembentukan lanskap Lembah Kinta dengan bukti-bukti yang terpelihara di dalam gua tersebut.

Kata kunci: Gua Tempurong, geomorfologi, gua batukapur, kars

INTRODUCTION

Thornbury (1961) defined a 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 & 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 conditions 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 geological 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.

Ford & Williams (1989) have classified caves according to the type of water that forms them. They indicate that the type which is formed by normal meteoric water is the most common. Caves that are observed in this study fall in this category. As suggested by Palmer (1991) that of 3 types of recharge of meteoric water, the caves in the study area were observed to be drained by allogenic and authigenic water. Allogenic water was supplied to the karstic area from granitic hills that surround the area in the east, north and part of the western part of the valley. Small tributaries of these streams that flow into the karst area and either drain the plain or are lost in underground caves. In the authigenic type, rainwater which falls directly on the top of limestone terrain seeps through joints and cracks to further enlarge the caves. Meteoric water becomes diffuse when it falls on the alluvium cover of the plain. This water then diffuses through the permeable alluvium and dissolves the subsurface limestone. No cave has been observed by the author in the subsurface area but reports on numerous sinkholes (Zahari Muda, 1985; Shu, 1986; Chow, 1995) especially in the Bukit Merah area near Jelapang in the Kinta Valley indicate that underground cavities are common there.

Caves are best developed in humid climates where the dominant antecedent pore network consists of fractures and bedding plane partings in strata with minor matrix porosity (Palmer, 1991).

GUA TEMPURUNG, GUNUNG TEMPURUNG, SOUTH KINTA VALLEY

Location and gross charateristics

Gunung Tempurung is the largest surface limestone mass of the Kinta Valley. In plan view it takes the shape of a three-pointed Y-shape (Figure 1). Gua Tempurung is located in the middle part of Gunung Tempurung. Sungai Tempurung which is a tributary of the Sungai Kampar flows westward from the granitic hill of the Main Range and carves its way through Gua Tempurung to the east. The alluvium that surrounds Gunung Tempurung is approximately between 40 m to 60 m above mean sea level.

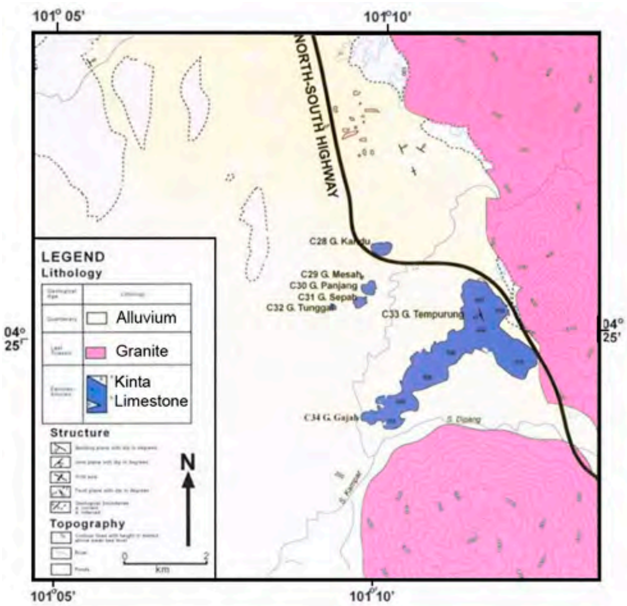


Figure 1: The location of Gunung Tempurung that house Gua Tempurung.

Measurement of the stream flows during the months April and early July, 2000 are between 0.06 m^3 / s and 0.12 m^3 / s respectively. The whole cave system is about 1200 m long. The east entrance is located at about 4 m below ground level which is about 60 m above mean sea level (msl) while the outlet of the stream is at about the 40 m level on the western side. This gives a gradient of 1:53 (Muhammad, 2000).

Cave entrance and exit

The cave entrance is located at the eastern side of the Gunung Tempurung facing the North-South Express way (Figure 1). The floor is located at about 4 m below the general level and the roof is about 7 m high. This is where Sungai Tempurung first enters the cave. The exit is located on the western side of the Gunung Tempurung. The cross-section of the exit has a broad base and an inclined sharp roof reaching to a height of 17 m. Flowstone marks the northern floor of this exit while a higher level exit located at about 45 m above the ground level is observed above the inclined roof (Figure 2).

Cave chamber orientation

Overall the cave chamber is a bow shaped curve towards the north while the direct line from the entrance on the east and the exit on the west is almost East-West. At the entrance end the cave axis runs along the 110°/290° direction and turns to 060°/240° at the last 500 m of the western end the cave. Studies on the structure are detailed in Muhammad & Tjia (2003).

Present status

Gua Tempurung has been operated as a tourist cave since 1997. It has become one of the major tourist attractions in Perak because of its magnificent chambers and beautiful speleothems. All these are easily accessible as stairways and lighting have been installed.

Cave chambers

Detailed mapping of the cave has been carried out and shown in Figure 2. The plan view of the cave is givien in Figure 2. Thirteen cross sections across of the chamber from the entrance on the east to the exit on the west are given in the map as well Figure 2. Chambers have been given names such as “Gergasi Chambers”, “Alam Cavern”, “Fallen Warriors” and others by earlier explorers of the cave and these are used by the operator of the cave tour. The writer, for easy identification of each of the chambers, also retains these names. Mapping was based on maps produced earlier by the developer of the cave and Rashidah (1998). The detailed mapping took several months to complete and started at the visitors’ entrance which is actually the exit of the cave with respect to the flow of the Sungai Tempurung. Traversing was done along the cave and river using measuring tape, compass, inclinometer and laser range finder.

Cross-sections were constructed as work progressed and thus the section at visitors entrance was labelled as A-A’ while the last section constructed (M-M’) actually represents the cave entrance on the east. Part of the explanation of A-A’ to F-F’ was published in Muhammad & Yeap (2000) while the mapping was in progress.

The Gunung Tempurung peak is 578 m above the mean sea level. There are numerous levels of cave entrances on the east wall especially along the 800 m long collapsed wall of the northern arm of Gunung Tempurung. The average levels of these entrances are shown below:

Average cave roof / floor entrance heights with respect to the flat ground level

1. +156.7 m (Highest)
2. +73.8 m
3. +45.1 m
4. +0.0 m
5. -3.0 m (Lowest)

The present entrance to Gua Tempurung is at the lowest level detected for the western wall of the Gunung Tempurung. The cave chambers along the first 300 m of the eastern entrance is curving in plan view and widens from about 4.8 m to 30 m. The Sungai Tempurung is located on the northern wall of the chamber indicating that it is still in the process of eroding the cave chamber wall towards the north direction. The stream that flows on the north side had carved a deep notch with a height of about 1 m (J-J’). The deepest notch in the Gua Tempurung is located at the Alam Chamber and measures about 15 m deep and 1.5 m high.

The cave passages (L-L’ and M-M’) are relatively small and at the entrance it is about 7 m high and 4.8 m wide. A few small stalactites hang from the roof and the curved walls at the entrance.

After traversing for about 150 m into the cave from the actual cave entrance, the cave chamber enlarges to form the Alam Chamber which measures 320 m long and about 200 m wide (I-I’). The highest point of the cave roof is about 101 m above the stream level. The northern parts of the chamber consist of wide spaces while the southern floor is built up by speleothems and fallen blocks. Piles of blocks can be seen on the south side with large speleothems decorating the side of the wall and roof. Several geomorphologic features in the Alam Chamber have been named. The flat area at the eastern part of the Alam Chamber had been named the Battelefield (K-K'). Further west of the Battlefield, many blocks of rocks are found scattered on the floor. The majority of these blocks comprise of magnificent speleothems that had fallen from the ceiling. This site has been named the Fallen Warriors, after the shapes of speleothems which resemble a troop of soldiers (J-J'').

Piles of blocks up to meters in diameter had fallen near the riverbank causing a narrow passage. Here, speleothems are almost absent except for small stalactites hanging from the notch roof. Along the passage, up to H-H', alluvium and recently deposited sands together with blocks of collapse form a bench at the south side with the stream running on the north. The low passage ends approximately after forming a narrow passage of about 140 m long.

All passages and chambers are connected to the river from the Gergasi Chamber (GG') till the end of the cave at the east. Notches of up to 2 m high are being formed in the river following the meandering direction of the river. This can be seen all along the river until the end of the passage. Following the river to the east, at the end of the Gergasi Chamber, there is another small passage measuring about 35 m wide and 5.5 m high. Profile H-H' shows part of the passage. The river bed is filled with gravel and sands. The roof is decorated with small stalactites. Further east, notches can be seen at the north wall. The real height cannot be determined due to the amount of sand on the river bed. At the end of the small passage, remnants of some alluvium, believed to be Old Alluvium (Walker, 1955) is found to be stranded at upper north wall. The direction of the stream suddenly turns from ESE towards the NNE. The writer is of the opinion that some structural element played a role here but unfortunately, evidence could not be found in the bedrock. However, evidence can be seen from projecting lineaments into Gunung Tempurung (Muhammad, 2003).

The E-E' and F-F' chambers are quite large. Both are hanging chambers though the F-F' chamber is only partially hanging. The "Gergasi" chamber is located at about 600 m plus from the outlet that is west of the chamber as shown in Section F-F'. The Gergasi' chamber houses the highest level cave floor (given the name as "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 hanging stalactites that are aligned along fractures striking along 170°-350°. The distinct flat roof is believed to be an indication of a phreatic passage that has been firstly etched following a fissure as explained by Ford & William (1989) for a similar occurrence.

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 (Figure 3). A number of large stalactites hang from the 93 m roof while the bells project into the roof above the 93 m level.

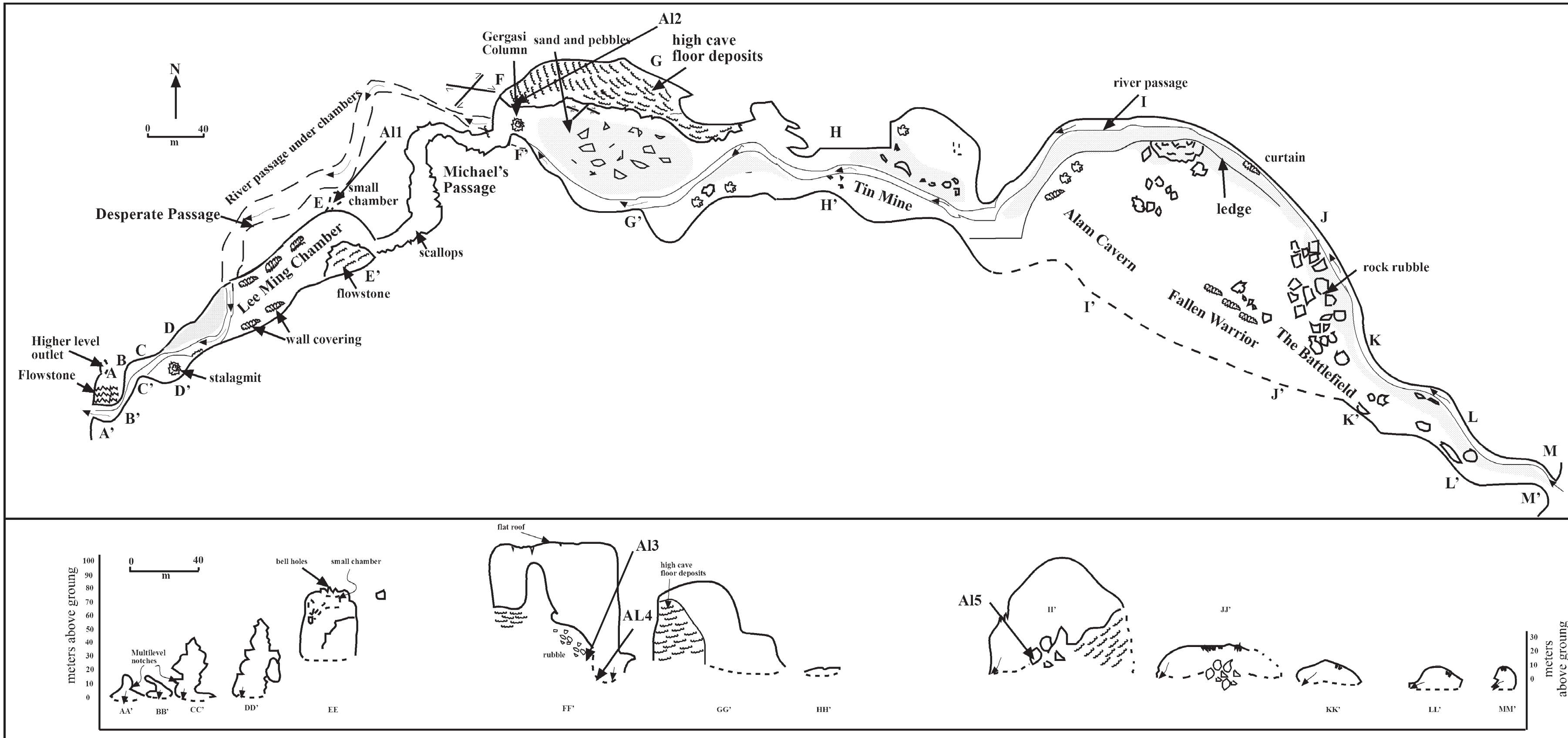
From the 50 m to the 210 m segment from the outlet, the cavern is represented by another stage of cave development. Cross-sections C-C' and D-D' show tree-shaped outlines. The tree-shaped cave roofs generally represent several ledges indicating that the recession of the ground water which controlled the formation of the cavern was held steady for several periods of the time. Ledges that are symmetrical on both walls 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.

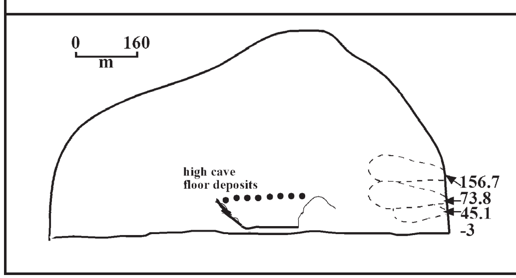
In plan view the chamber along E-E' appeared similar to C-C' and D-D'. However, the curving roof with a number of bell shaped chambers and near vertical sidewalls indicate a different phase of solution. The E-E' chamber shows more similarity to the F-F' chamber in terms of solution characteristics, that is, with vertical walls and curved or flat roofs. These two larger size chambers are connected by a narrow perched chamber which is 220 m long. 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 wide by 4 m tall and it shows broad sinuous vertical scallops which had resulted from solution by percolating water descending from the roof.

The lowest level of the cave is situated at the eastern exit which is about 40 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 chamber is rather small (see cross-section A-A' and B-B' in Figure 2.1b). They show wide bases and narrower inclined roofs.

ORIGIN OF GUA TEMPURUNG

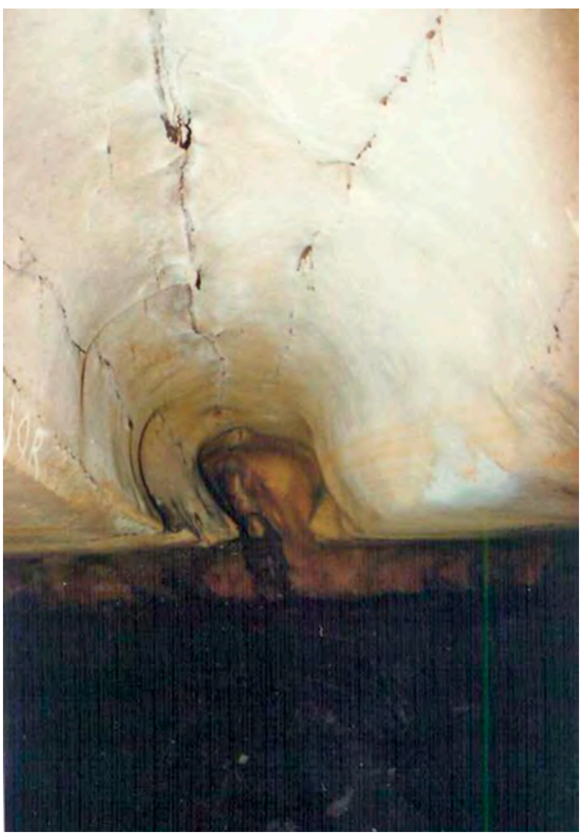
Five cave levels are exposed at the collapsed wall at the northeastern side of the hill. The average position of each level above the present ground is 156.7m, 73.8 m, 45.1m, 0m and –3m (Figure 2.3). The entrances at 0 and -3 m can clearly be observed, however chambers at the higher levels were not accessible and were not explored by the author. Crowther in using geochemical methods had determined the denudation rate of 0.085 mm per annum for the Kinta Valley (Crowther, 1983). Muhammad (2003) has attempt to use the estimated rate of land denudation of about 0.1mm per annum from the correlation between the past climate to interpret the first cave of allogenic water origin could have started developing about 1.57 to 1.84 million years ago. At that time the Gunung Tempurung limestone mass is assumed to be still connected to the granite mass on the east. However, this extrapolation can be hazardous as there is unlikely to have continous channel deepening at a constant rate for such heights (Derek Ford,





Figures 2: (2.1) The plan view of Gua Tempurun. (2.2) Cross sections of Gua Tempurung. (2.3) Cross sections of Gunung Tempurung, showing the level of Gua Tempurung and 3 other higher level caves seen from the eastern wall. Geomorphological features as labelled on plan are: 1 - Higher level outlet – previous high level stream outlet which is presently abandoned after the falling of the base level. 2 - Flowstone – speleothem or secondary calcite deposits formed after calcium-saturated water is evaporated. Normally formed on the floor or inclined wll from a rather uniform flow and accrete roughly parallel to the host surfaces. 3 - Stalagmite – another form of uniform diameter and almost all new growth at the top (not down the side) and are considered to be created by uniform supply of feedwater with uniform solute concentrations. 4 - Wall covering – speleothem that are being formed on the wall of the cave by percolating water from the roof. 5 - Small chamber – smaller chmber formed off the Larger Ming Chamber. 6 - Scallops – spon shaped scoops that are occurring in packed patterns, here seen as vertical scllops that are being from vertical flowa of water. 7 - River passage – coarse or direction that is being taken by the running stream. 8 - River passage under chambers – river coarse under the larger nd higher cave chambers. 9 - Sand and pebbles – materials that are being brought into the caves by the running stream. Mainly consists of sand and pebbles of granitic, limestone and metasedimentary origin. 10 - Gergasi Column – a large stalagmite that are actively being formed by feedwater. 11 - High cave floor deposits – cave floor deposits, mainly consist of alluvial material incorporated with the speleothem deposition. Some remnants can be seen at high levels. 12 - Ledge – ledge separating the river passage from higher level cave floor (mainly consists of flowstone and boulders and reach up to 110m above the msl (Rasidah, 1998). 13 - Curtain – speleothem in the form of stalactite formed along joints or cracks. 14 - Rock rubbles – piles of gravels and boulders. 15 - Multilevel notches – a few level of notches, almost symmetricl are formed on both walls of the chamber. 16 - Flat roof – an almost flat roof in the Gergasi Chamber, an indication of phreatic condition (Ford & Williams, 1989).

Figure 3: Ceiling half tubes found in Gunung Tempurung caused by deep phreatic condition. The half tube is about 0.5 m deep and up to 5 m long (taken from Muhammad, 2003).



Figures 4: Bell holes found on the ceiling in Lee Ming Chamber, believed to be formed by condensation corrosion.

2004 pers. comm.). However, condensation corrosion and rock collapse play a vital role in raising the roof upwards from an original elevation. The most obvious evidence of condensation corrosion can be seen by the presence of the bells (shown in E-E') and rock collapse is dominant in the eastern part of the cave. Observation shows that this cave has undergone a long and complex history throughout its formation. It is postulated that the first etching occurred along fissures in phreatic condition. The 112 m high flat roof in the Gergasi Chamber is evidence of a phreatic origin and this is very well preserved, and is also supported by the presence of half-tube (Figure 4). This may be followed by vadose entrenchment by piles of rock rubble and broken speleothems further enlarge the passage. Later, the modern river starts to feed water and bring together with its flow alluvium, that can be seen stranded in some high chambers such as the Lee Ming and Gergasi Chambers. The walls near the cave entrances in the east and west show that the meander of the river influences the direction or trend of the cave. And several ledges at symmetrical heights show the probable record of past river levels. Studies on multi-level notches on karst hills in Kinta Valley indicate that they could be previous base level (Muhammad, 2003). However, no correlation can be made with these ledges as the notches are found at elevations of below 14 m while the former are formed at 17 m and above. Without the observation at the higher chambers from the higher entrances, it is too early for the author to make further conclusions on the origin of this cave. It is not known when the modern stream has started to feed allogenic water, and subsequently enlarging the cave further.

GUA TEMPURUNG AS A RECORD OF LANDSCAPE EVOLUTION

The long history of how the cave develops, probably even when the limestone mass is still attached to the granite mass may be preserved in the cave. Cemented alluvial material consisting of coarse grains of sands can be found at the higher level of Gunung Tempurung especially in the Gergasi Chamber. Observations on other alluvial material at lower level i.e. 10 m above the river bed show that they belong to a different phase of alluvial deposition, probably prior to deposition of the tin-bearing old alluvium (Yeap, pers. comm.). Though, it is too early to estimate when the cave started to be carved by modern rivers, evidence of tin-bearing alluvium can be seen as high as in the Gergasi Chamber. The author is of the opinion that the alluvium had been brought in by a strong river current or during a flood that had increased the river level. Evidence that this alluvium been mined for the tin is preserved in this cave. Boulder beds with a mixture of allochthonous and autochthonous rocks are also common in other caves in Kinta Valley (Muhammad, 2003). The boulders could have been transported through some of the caves. Further studies emphasize will hopefully give additional insight into the paleo-erosional conditions of this cave. The author hopes to find 'undisturbed' alluvial deposits at the other levels and age determination will be attempted on the samples. This alluvium that had been deposited in the surrounding palaeofloodplain could have been eroded, but preserved in the closed environment inside the caves. The study will give a better understanding on the formation of alluvial deposits in this area, the cave, and the evolution of Kinta Valley karst in general. Ongoing research on Gua Tempurung includes studies on the chemistry of the dripwater, isotope analysis and paleoclimate changes detected from the composition of the stalagmites.

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