CHAPTER TWO

METHODOLOGY AND PROJECT SITES

2.1 Preparatory work in the field

Reconnaissance surveys were first conducted to locate the fossils exposed on the surface of remnant cave deposits in the caves. The caves were then mapped and the locations of the fossils were carefully documented both in the maps and cross sections of the caves that cut across the fossiliferous sediments. Field sketches were also made to show the relationship of the fossils to the entombing sediments.

The fossils were photographed *in situ* before being extracted with the aid of a variety of hand –held hammers, chisels, and mechanical drills to free them from the sediments. Some bulk samples were also collected for processing with acid for smaller vertebrate remains such as the teeth and bones of bats and rodents and for making thin sections of the associated stratigraphic layers.

2.2 Preparatory work in the laboratory

2.2.1 Macrovertebrate fossils

The fossils were first scrubbed with brushes, rephotographed if necessary and then further cleaned with an electric engraver vibro-tool. The fossils were carefully labelled with information with the specimen number, locality, date of collection and collector. The cleaned fossils were photographed and measured according to standard measurements as

applied to animal bones from archaeological sites following Schmid (1972) and von den Driesch (1976). All the measurements were taken in millimeters (mm) with digital vernier calipers (Duwell model for smaller specimens of less than 150 mm with a resolution of 0.01 mm and error of ± 0.03 mm to ± 0.04 mm and larger Precise model for bigger specimens up to 300 mm with a resolution of 0.01 mm and error ± 0.02 mm). The maximum length, width and height were measured for each tooth and bone described and recorded.

2.2.2 Microvertebrate fossils

It was not possible to carry out a detailed study of both the micro and macro vertebrate fossils because of time limitations for this project due to the large number and variety of specimens. The major focus in this study was on the large-vertebrate fossils. However, the limited micro vertebrates studied attempted would be a useful lead for further studies in the future.

Eight bulk samples of sediments from the different caves studied were processed for microfossils. The cemented sediments were dissolved in 70% of dilute formic acid mixed with 30% buffer (made by reacting of with acid) and leaving them overnight. More solution was added until the fizzing reactions stopped. The residue left from dissolution was washed under running water then put it in the oven for dry. The dried residue was screened with sieves of 35 and 60 meshes and picked under binocular microscope.

If the sediments were unconsolidated like some from the muddy parts in Villa Cave/Batu Caves, then washing several times under running water after soaking in fresh water and sieving was sufficient to extract the fossils.

Hydrogen peroxide (H_2O_2) of less than 10% was used to disaggregate the sediments such as those from Dark Cave/Batu Caves if deflocculation with fresh water was not enough. Micro-photographs of the fossils were taken by using the Scanning Electron Microscope (Leica S440) in the Physics Department and Dissecting Microscope (Leica MZ9.5) in the Biology Department in the University of Malaya and by the Polarizing Microscope with a camera attached (Leica DMLP) in the Geology Department.

2.3 Comparison and identification

The cleaned fossils were then identified by comparison with reference collections of Malaysian species in the Zoological Museum in University of Malaya, Sabah Museum, Zoology Museum in the University Malaysia Sabah, and Museum of the National Zoo of Malaysia, and species from the adjacent countries housed in the Natural History Museum (London), National Museum of Natural History (Leiden, Netherlands), and photographs of specimens from University of the Philippines. The results were tabulated in a Microsoft Office Excel database.

Information on the distribution and habitat of mammals of this region was mainly extracted from *The wild Mammals of Malaya (Peninsular Malaysia) and Singapore* (Medway, 1983), *The Mammals of The Indomalayan Region* (Corbet and Hill, 1992), and *Mammals of South-East Asia* (Francis, 2007, 2008).

2.4 Results

During more than two years of field work, abundant macro and micro vertebrate fossils were discovered and collected from cave breccias and calcite cemented remnants deposits mixed with cave sediments in several parts of west Peninsular Malaysia.

The fossils found were mostly disarticulated teeth and bone fragments. Most of them were embedded in isolated clusters except for solitary teeth and scattered bones which were found attached to the wall and roof in some parts of these caves. No articulated post-cranial remains have been found. These finds show a highly diversified mammalian fauna ranging from large carnivores and herbivores to small species like bats and rodents. Most of the teeth could be identified to the species level while the greater portion of the bone materials was too highly fragmented for identification.

2.5 Dating

Peninsular Malaysia houses a number of caves that have preserved some of the most important cave deposits or cave formations. This include: stalactite, stalagmite, flowstone, columns, and a number of other things. All these deposits defined under term speleothem. During the past years there have been substantial advances in dating and paleoenvironmental reconstruction using cave interior deposits, especially speleothems.

Samples of the matrix hosting the fossils from caves studied sent to Dr. Kira E. Westaway, Department of Environment and Geography, Macquarie University, Australia, for dating by using luminescence and U-series methods.

This is the first attempt in Peninsular Malaysia to date cave materials using Luminescence techniques (both thermoluminescence (TL) and optically-stimulated luminescence (OSL)). Breccia material can often prove problematic for dating cave deposits associated with the fossils and requires the use of more than one dating technique. Multiple techniques provide independent age estimates and a greater confidence in the final results, therefore, the U-series dating techniques were used also to confirm the results.

Luminescence dating techniques were employed to provide a chronology for the sand-sized quartz grains within the matrix of the breccia deposits, while U-series dating of the overlying flowstones provides a minimum age for the deposition and cementation of the breccia. (See Appendix A for detailed dating procedures).

2.6 Fossil localities

Caves are common in the limestone hills in Peninsular Malaysia. Some of these caves are of archaeological, cultural, social, and religious interest.

Within the caves have been found a variety of the deposits including secondary calcareous coating and cave formations such as stalactites, stalagmites, flowstone, guano deposits, limestone breccias, and alluvial river and flood deposits. These deposits have also given us the best Quaternary fossils materials.

The material studied (teeth and bones) comes from eight limestone caves located in three different parts in west Peninsular Malaysia. Four caves (Cistern Cave, Swamp Cave, Villa Cave, and Dark Cave) are from within the Batu Caves Massif in Selangor, central part of west Peninsular Malaysia, two caves (Badak Cave C, and Ngaum Cave) are from the Lenggong Valley, Perak, north Peninsular Malaysia, and two caves (Naga Mas Cave, and Datok Cave) are from Kinta Valley, north of Peninsular Malaysia (Figure 2.1).

Most of the vertebrate fossils collected from these sites are new discoveries. Although some of them were discovered and reported before, like those from Badak Cave C (Ros Fatihah Muhammad and Yeap, 2000a) and the two caves in Kinta Valley (Hooijer, 1962a; Adi Haji Taha, 1993; Tjia, 2000) this is the first attempt at studying them in detail.

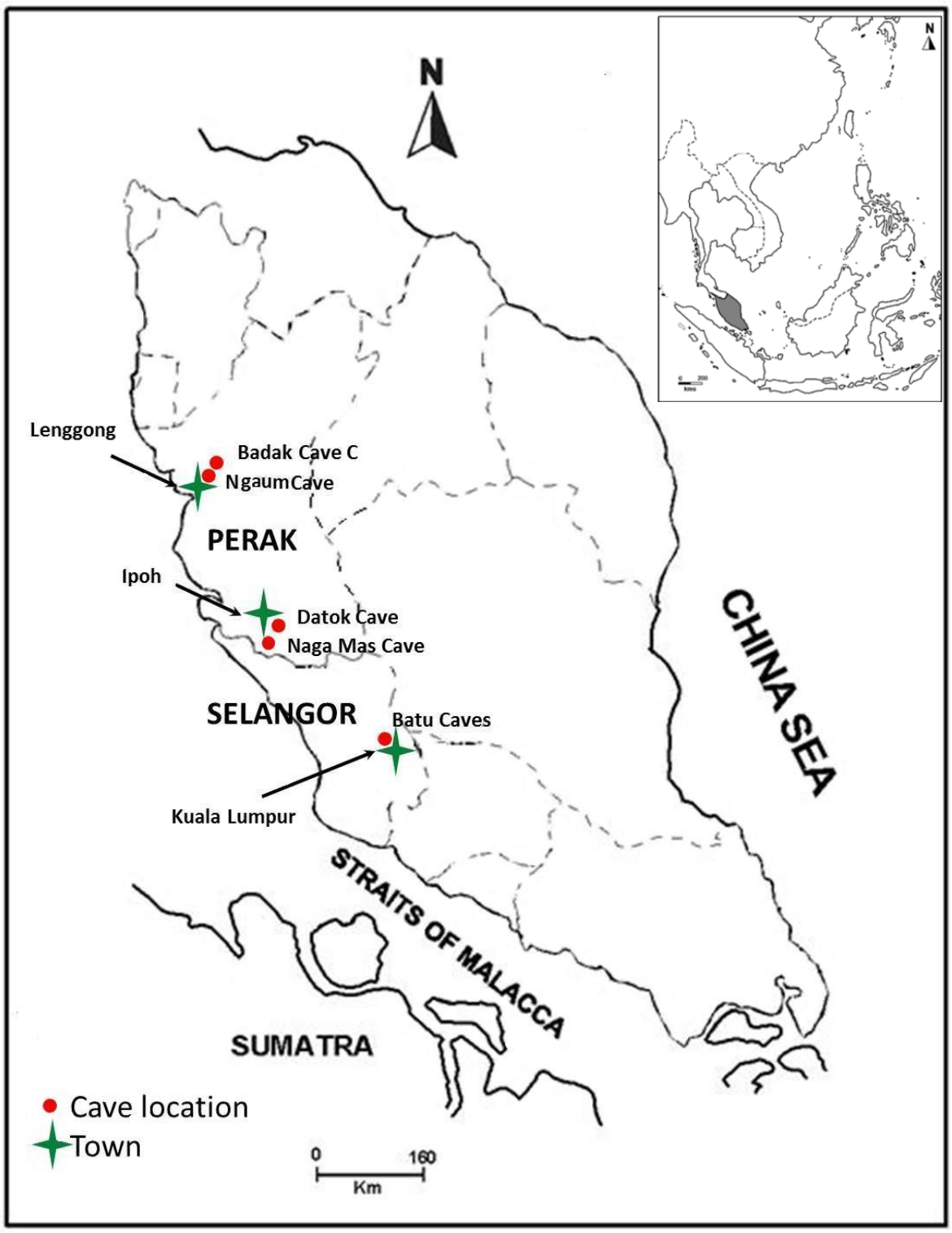

Figure 2.1 Location map of the caves studied in Peninsular Malaysia.

2.6.1 Batu Caves Massif (central part of West Peninsular Malaysia)

The Batu Caves Massif (Figure 2.2) is the southernmost above ground limestone hill in Peninsular Malaysia. It was first described by Europeans in 1878 when a hunting party lead by Captain H. C. Syers, Selangor's first Superintendent of Police. An American, William T. Hornaday later recorded the visit as part of his experience in Southeast Asia (Yussof, 1997; Price, 2001). It is located 13 km north of Kuala Lumpur at an elevation of about 75m above sea level. It is a 300 m high hill made up of Ordovician-Silurian limestone.

The Batu Caves Hindu temple complex with its 272 steps is a popular tourist attraction and of great religious significance to the local Indian community who go there to worship especially during the yearly Thaipusam festival. The limestone which makes up the hill has been metamorphosed to marble and is a part of the thick calcareous rock unit named the Kuala Lumpur Limestone or Kuala Lumpur Marble (Cheong, 1976) that underlies much of Kuala Lumpur where it had been eroded and covered by Quaternary alluvium. The lithology of this limestone is of grey to cream color calcitic and dolomitic banded marble with minor schist and phyllite interbeds (Lee *et al*., 2004).

Figure 2.2 Batu Caves Massif.

The largest caves in this area were probably formed by flowing water beneath the water table that sculpted the irregular shapes on their eroded floors and walls as the streams cut downwards with the gradual lowering of sea levels through time. The caves above ground level are dry at present because they are higher than the present ground water table (Stauffer & Morgan, 1971). The Batu River passes through this area presently and flows from north to south on the west side of the limestone outcrop whereas the Gombak River is located further away on the east side of the outcrop (Telakavati, 2008).

There are quite a number of researches done on Batu Caves but none was on vertebrate fossils from the caves in this massif. One of the earliest reports on mammals in the Batu Caves area was by Ridley (1898) who reported that large wild animals including tiger, bear, wild ox, pig, muntjac, deer, and elephant were all found in the forest around Bukit Batu during that time but he also noted the general absence of any bones of these animals in the caves. Roe (1953) reported the discovery of the third upper molar of Indian elephant tooth (*Elephas maximus*) under about 20 ft. of tin-bearing alluvium resting on the granite bed rock in in the Batu Valley near the Batu Caves. Williams-Hunts (1952) found a few pieces of pottery in a ground level cave at Batu Caves with no mention of fossils. Wycherley (1972) recorded Ridley's exploration in several caves in Bukit Batu. Some of these caves were completely destroyed even before Ridley left Malaya. Yussof (1997) remarked that the trogloxenes such as Bears, Leopards, Porcupines, and Wild Pigs, have not been recorded in and around Batu Caves recently. This is not unexpected as the surrounding forest around Batu Caves has been cleared for development in the rapid urbanization of Kuala Lumpur. Stauffer (1979) recovered a fossilized honeybee hive from a quarry face on the north side of Bukit Batu.

There are many caves around the limestone hill at different levels in Batu Caves including the studied caves. Several of them were recorded in the past under different names which are no longer in existence due to quarrying (Medway, 1977b) or mining. Some of them are developed into Hindu shrines and for tourism. The major attraction is the Temple Cave with 272 steps leading up to its entrance. Caving tours are available for the Dark Cave and an art gallery, mini zoo and cultural centre in a cave called the Villa Cave that has been built at the foot of the steps while the rest are undeveloped caves. The first research published on vertebrate fossils from some caves in the Batu Caves complex was by Yasamin *et al*. (2012).

Abundant vertebrate fossils were collected from four caves of the Batu Caves Massif named the Cistern Cave, Swamp Cave, Villa Cave, and Dark Cave (Figure 2.3). Except for the Dark Cave, the rest were located at the foot of Bukit Batu. The vertebrate fossils were found in cave breccias and calcite cemented remnants of cave wash deposits mixed with cave sediments left by former guano diggers. These fossils are disarticulated teeth and bone fragments found embedded in isolated clusters except for a few solitary teeth which were found attached to the wall and roof in some parts of these caves. No articulated post-cranial remains have been found. Some of these clusters of fossil were located at different levels within some caves while others were located at the same level in others.

2.6.1.1 Cistern Cave (N 3° 14' 15.6", E 101° 41' 08.4")

It is a small undeveloped cave at ground level located about 30 m east of the foot of the Batu Cave Temple steps. After sections of the cave were mined for guano, it was abandoned but original in situ deposits remain towards the rear of the cave. Price (1996, 2001) reported it as an ancient cave among the cluster of caves in Selangor.

Figure 2.3 Satellite image of four caves studied in Batu Caves Massif.

The cave extends about 20 m from the main entrance. The main orientation of the cave system is generally in an east-west direction with shorter connecting passages oriented north-south. Based on the morphology, there are three levels of cave deposits observed in the cave, belonging to the lower, intermediate, and upper chambers. There are three openings south of the cave, two of them at the upper level chamber which were not accessible. Only the main entrance is accessible at about 9 m above ground level. A flat roof in the intermediate chamber indicates a phreatic origin of the cave when the water table was higher than at present. Patches of cemented breccia are observed on the walls and ceilings.

Nine clusters of fossils of mammalian remains were found in the Cistern Cave. All the fossils were only recovered from the lower and intermediate level chambers at heights of between 1 m near Cluster 5 to 2.8 m near Cluster 2 above the cave floor and also in the rock rubble on the floor believed to be left behind by the guano diggers. No fossils were found in the upper level chamber. (Figure 2.4) shows the plan view and cross sections for Cistern Cave with the locations of the fossil clusters.

Clusters 1, 2, 4, 5, 7 and 9 were located in the intermediate level chamber while clusters 3, 6 and 8 were located in the lower level chambers. Cluster 1 was located about 6 m to the east of the entrance. The fossils were found at 1.7 m above the cave floor. They consist of fragmentary bones and molar of Eurasian Wild Pig (*Sus scrofa*) embedded in a strongly cemented hard sedimentary layer of brownish coloured coarse grained sandy deposit. Cluster 2 was located 2 m away from Cluster 1 to its southwest within the same layer. Two specimens were recovered from Cluster 2, one of which was the lower jaw bone of Microchiroptera Bat with four teeth attached and the other a tooth fragment. Cluster 3 was located 5 m to the southeast of Cluster 2. It is in the lower chamber which is about 2 m below the level of the cave floor that has been partially dug up for guano extraction. This cluster contains several small fragmentary bones and large teeth including that which belonged to a Red Muntjac (*Muntiacus muntjak*) and an Orangutan (*Pongo* sp.) tooth which is an exciting new discovery from Peninsular Malaysia.

Cluster 4 was located about 5 m north-northeast from Cluster 3 in the northern part of the cave. Stalagmites and gour pools are present next to it. Remnants of this bed are found sticking to the roof of the crystal chamber. Two species of mammalian fossils previously not found in Peninsular Malaysia were discovered in this cluster.

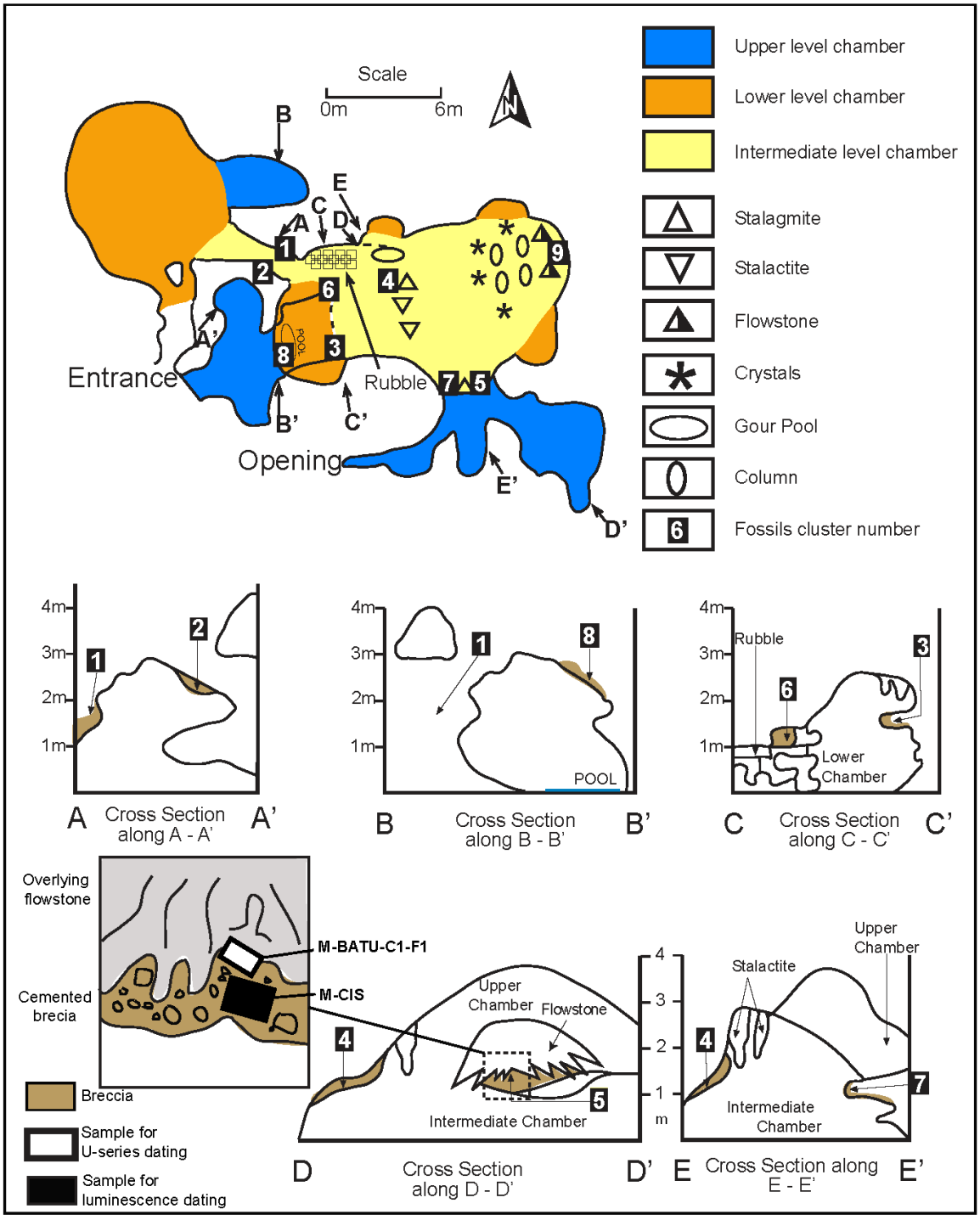

Figure 2.4 Map and cross sections for Cistern Cave.

The first is the teeth of the Bearded Pig (*Sus barbatus*) (Figure 2.5, A), and (*Sus* cf. *barbatus*) which was found from the Batu Caves locality. The second is the tooth of an Asiatic Black Bear (*Ursus thibetanus*) (Figure 2.5, B) which had also never been recorded in Peninsular Malaysia and any other country in the Sundaic subregion. The present discovery is thus significant in extending the historical range of both these species (more details in next chapters).

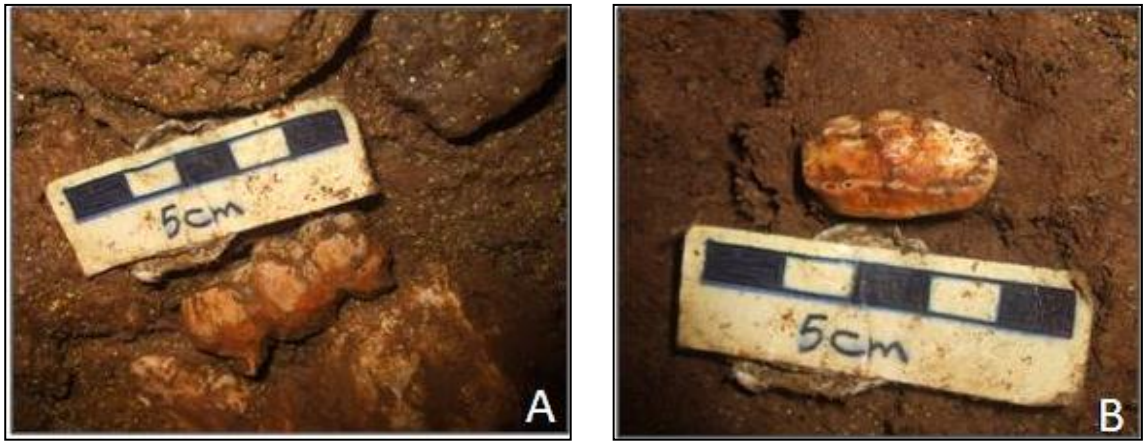

Figure 2.5 Lower molar of *Sus barbatus* (A) and upper molar of *Ursus thibetanus* (B) samples from Cluster 4, Cistern Cave.

Other fossils recovered from this bed were teeth of the Eurasian Wild Pig (*Sus scrofa),* (*Sus* sp.), Red Muntjac (*Muntiacus muntjak*) and unidentifiable fragmented bones. Cluster 5 in a layer that was dated was located 1.16 m below a mushroom-shaped stalagmite about 7 m to the southeast of Cluster 4. This cluster yielded ten samples teeth of Megachiroptera and Microchiroptera Bats, Eurasian Wild Pig (*Sus scrofa),* Bearded Pig (*Sus barbatus* and *Sus* cf. *barbatus*), Serow (*Capricornis sumatraensis*), Asiatic Black Bear *(Ursus thibetanus)* and Long-tailed Macaque (*Macaca fasicularis*), and fragmented bones.

Cluster 6 is 4 m north of Cluster 3 in the lower chamber. Three samples found in the rubble near this cluster were identified as the upper premolar of the Eurasian Wild Pig (*Sus scrofa*), the lower incisor of a Malayan Tapir (*Tapirus indicus*) and the upper molar of an

Orangutan (*Pongo* sp.). Cluster 7 is about 1.5 m west of Cluster 5 and was located inside a small hole 1 m above the intermediate chamber cave floor. The fossils found in Cluster 7 include molars of the Eurasian Wild Pig (*Sus scrofa*), and premolars of Bearded Pig (*Sus barbatus*) and Sambar (*Cervus unicolor).* Cluster 8 was located at the lower chamber with Clusters 3 and 6 near a small pool of water formed by running water. A small bone (bat?) was found *in situ* with other fragments of bones in this cluster. Cluster 9 was located at the end of the cave to the east side after the crystal chamber. Only one upper premolar tooth belonging to the Malayan Civet (*Viverra tangalunga*) was collected from the wall. Fourteen samples of *ex situ* fossils were found in loose material in the Cistern Cave in addition to the *in situ* fossils recovered. These fossils had most probably dropped from the roof during weathering or more likely had been dislodged during guano extraction. The *ex situ* materials include fossils that had not been recorded before in any cave in Peninsula Malaysia like the Bearded Pig (*Sus* cf. *barbatus*), Brush-tailed Porcupine (*Atherurus macrourus*), Sumatran Rhinoceros (*Dicerorhinus sumatrensis*) and Tiger (*Panthera tigris*) together with other previously reported fossils such as Eurasian Wild Pig (*Sus scrofa*), Red Muntjac (*Muntiacus muntjak*), Long-tailed Macaque (*Macaca fasicularis*), Canid (gen. et sp. indet.), (*Sus* sp.), and fragments of upper canines of Insectivorous Bats.

For dating, Luminescence samples (M-CIS) were collected from the matrix of a breccia ledge located between Clusters 5 and 9, while U-series samples (M-BATU-C1-F1) were collected from an associated overlying flowstone (Figure 2.4).

2.6.1.2 Swamp Cave (N 3° 14' 18.9", E 101° 41' 38.5")

It is located at ground level about 1 km east of Temple Cave. Swamp Cave has only one level of cave floor after preserved due to excavations to develop it as a tourist cave except for some small areas still covered by remnant cave floor sediments about 1 m above the present cave floor. The cave floor has been cemented with concrete and the cave itself has been severely modified, however, there are some passages that are still undisturbed. The cave ceiling is almost flat, again indicating phreatic origin. The cave derived its name from a swamp that partially fills low-lying sections of its passages. A sluggish stream runs through the cave and swampy conditions prevail especially during the rainy season. Alluvium and cave wash were believed to have filled the cave originally but were later eroded by the stream, leaving only remnants of conglomerate and breccia that were protected by calcite cementation. There are four entrances located in the north, northeast, southeast and south of the cave. Patches of cemented conglomerate sediments occur near the south entrance extending 7.7 m from the gated entrance along the wall into the cave at a height of 1.6 m above the cave floor along with free hanging columns of cemented breccia where former stalactites have joined with flowstones to form half columns of calcite. The bases of these depict the former surface of the cave soil, and soft cave wash remains attached to the ceiling at some places.

All the fossils from this cave were taken from the free hanging breccia embedded in a thick layer of deposits located about 1 m to 2 m below the cave roof. A much larger mass of the sediments is believed to have filled the cave previously but was later eroded by the stream and only remnants of this are left behind. Six fossil clusters have been recovered from this cave. Clusters 1, 2, 3, 4 and 5 were located in the main passage to the west with its axis oriented in a north-south direction (Figure 2.6).

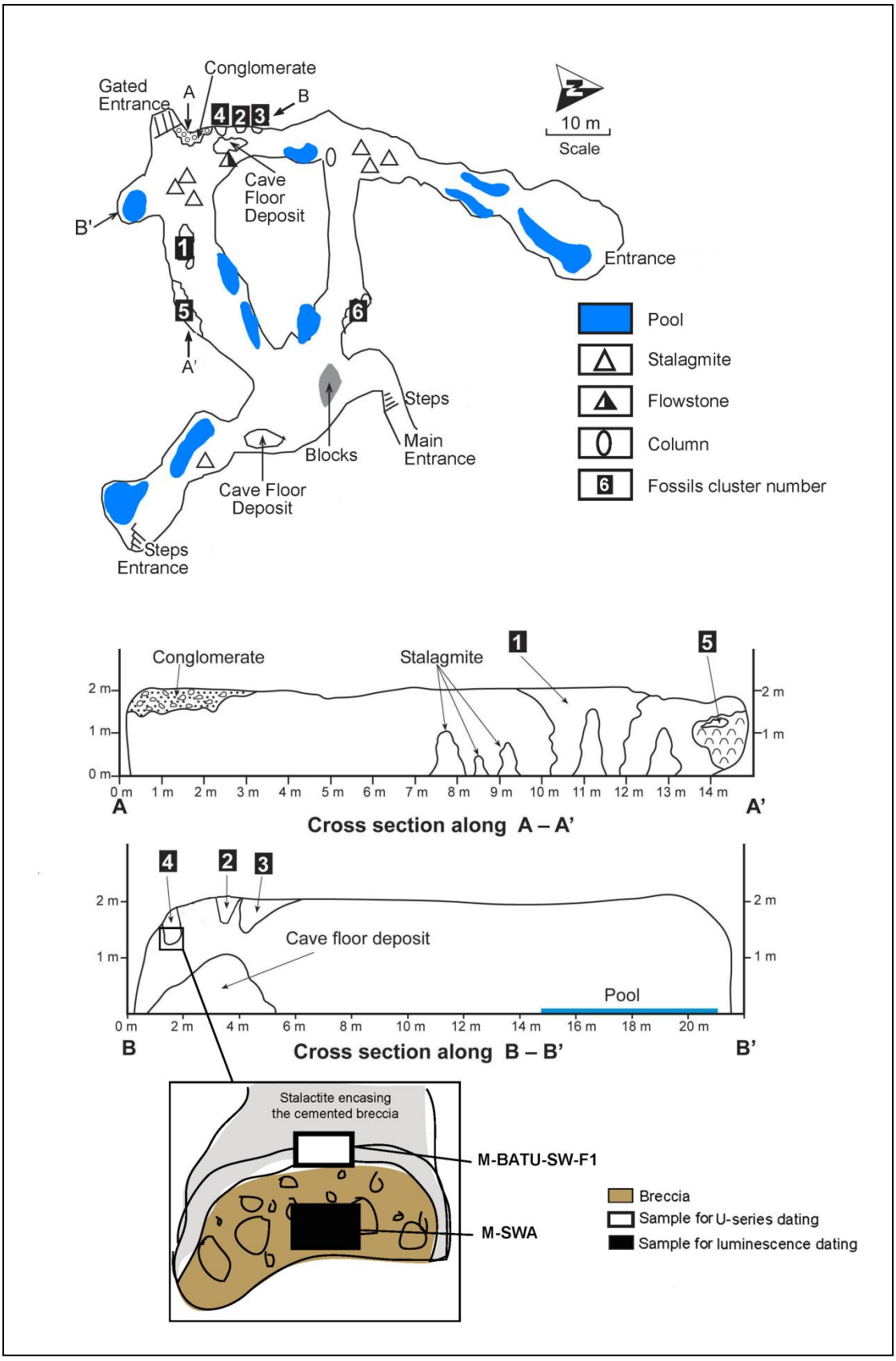

Figure 2.6 Map and cross sections for Swamp Cave.

Cluster 1 was embedded in remnant layer about 1.6 m thick of strongly cemented, brown coloured medium to coarse sandy sediment near a few stalagmites at 5.6 m from Cluster 5. The lower molar and canine of Bearded Pig (*Sus* cf. *barbatus*), and upper molars of Serow (*Capricornis sumatraensis*) with fragmentary bones were found in this cluster.

Clusters 2, 3 and 4 were located on a different patch of beds attached below an overhang in the original wall extending from the small gated entrance located to the south of the cave. Cluster 2 located at 20 m southwest of Cluster 1 contained the lower premolar of a rhinoceros (*Rhinoceros*/*Dicerorhinus* sp. indet.), lower molar of Bovinae (gen.et sp. indet.), and the fragment of a tooth of a Sambar deer.

Cluster 3 was the best preserved fossil cluster in this cave. The fossils were embedded in less than 1m thick layer of cemented breccia hanging below the cave wall. This cluster contained: teeth of the Eurasian Wild Pig (*Sus scrofa*), lower canine of a Long-tailed Macaque (*Macaca fascicularis*), and two Orangutan (*Pongo* sp.) teeth identified as a lower premolar and lower incisor.

The incomplete tooth of a Malayan Sun Bear *(Helarctos malayanus*) and the molar of the Eurasian Wild Pig (*Sus scrofa)* were found in Cluster 4 which located at about 3 m south of Cluster 3 which is 7 m from the gated entrance. The lower premolar of a Eurasian Wild Pig (*Sus scrofa*) was found in Cluster 5 located to the east of Cluster 1.The upper premolars of a Serow (*Capricornis sumatraensis*) and of an Orangutan (*Pongo* sp.) were found stuck to the roof of the cave at 1 m above the cave floor in Cluster 6 located north of Cluster 5 in a northwestern branch of the cave system.

Only one upper molar from a red Red Muntjac (*Muntiacus muntjak*) was found *ex situ* because this cave had already been scrapped clean or cemented for development as a tourist cave.

Luminescence and U-series samples (M-SWA and M-BATU-SW-F1) were collected for dating from the matrix and flowstone, respectively, from Cluster 4 (Figure 2.6).

2.6.1.3 Villa Cave (N 3° 14' 16.7", E 101° 41' 04.9")

The cave is located about 83 m to the west of the Batu Cave Temple steps accessed by a bridge across a pond. The cave was previously known as Museum Cave and Art Gallery Cave (Yussof, 1997; Price, 2001) and may be a site visited earlier (Wycherley, 1972).

Now, after the development as a tourist place, the cave is packed with Hindu statues and named as Villa Cave (this name will use in this study), Valluvar Kottam, or Eye on Batu Caves. Despite this obvious human interference there are still some undeveloped side passages that contain undisturbed deposits. A few pieces of pottery might have been found on the floor of this cave (Williams-Hunt, 1952) and from what the author has been told in discussion with the custodians of the present Villa Cave.

All the vertebrate fossils were found embedded in brownish clay or silty sand that were remnants of alluvial deposits, found in four deeper parts of the cave not opened to visitors and untouched by the on-going construction to develop the cave.

The first cluster fossils was located in south east part of the cave (Figure 2.7) in a cave sediments patch at about 2.7 m above the cave floor where remnants of this bed extended about 7.7 m across a concrete platform. This cluster consists of fragmentary bones and teeth and a lower canine of the Bearded Pig (*Sus* cf. *barbatus*).

Cluster 2 was located about 70 m northeast of Cluster 1 at the end of the northeastern branch of the cave system. A fragment of a rib bone and an upper molar of the Eurasian Wild Pig (*Sus scrofa*) were found in this cluster located between 1 m – 2.8 m from the cave floor attached below a big stalactite.

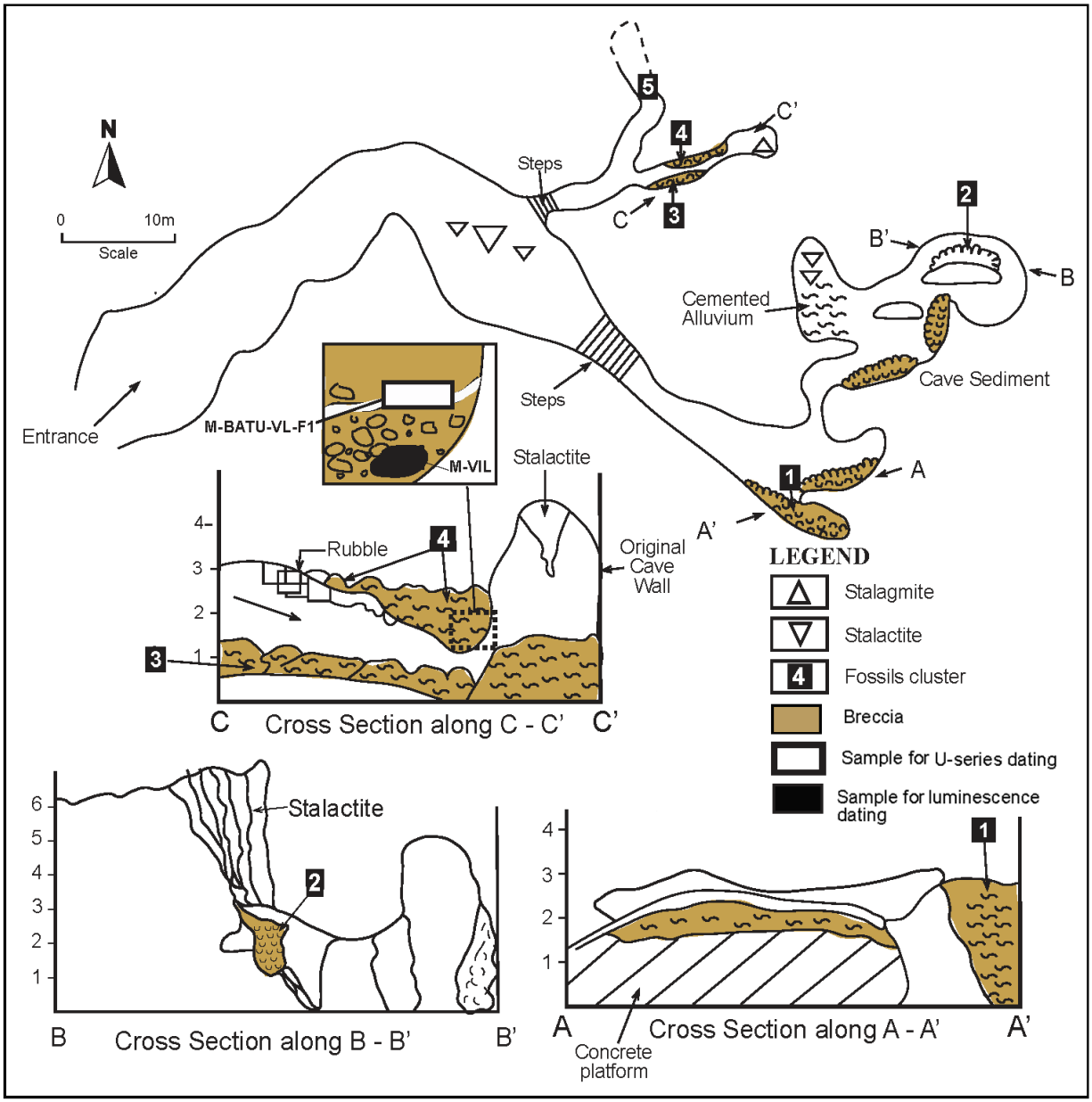

Figure 2.7 Map and cross sections for Villa Cave.

Clusters 3 and 4 were found on both sides of the same deep inner part forming a small muddy room extending about 6 m in length and between 2 m - 2.5 m in width located at the east to this cave system. This part is ended by a1.5 m uplift in ground level of the original cave wall. The upper and lower molars of the Eurasian Wild Pig (*Sus scrofa*), an upper molar of a Sambar deer (*Cervus unicolor*), a lower premolar of Bovinae (gen.et sp. indet.) and the anterior part of a lower premolar of a rhinoceros identified as (*Rhinoceros*/*Dicerorhinus* sp. indet.) were collected from the right side of this cave from clay sediments attached to the wall extending about 5 m at about 0.8 m above the cave floor making up Cluster 3.

Cluster 4 was found in the left side from the same inner part with cluster 3 in muddy clay sediments and in rubble left behind by guano diggers. A high diversity of fossil teeth was collected from Cluster 4 ranging from Eurasian Wild Pig (*Sus scrofa*), Bearded Pig (*Sus barbatus* and *Sus* cf. *barbatus*), Orangutan (*Pongo* sp.), Red Muntjac (*Muntiacus muntjak*), Pig-tailed Macaque (*Macaca nemestrina*), Malayan Sun Bear (*Helarctos malayanus*), small part of tooth fragment of wild cattle , small rodent, and fragmented bones. Most specimens collected *ex situ* from Cluster 4 belong to the Eurasian Wild Pig (*Sus scrofa*) as teeth with tooth belong Bearded Pig (*Sus* cf. *barbatus*), and bone fragments.

The passage of Clusters 3 and 4 divided into a north-northeast branch leading to another inner branch with height of about 1.5 m above the cave floor and the original cave wall containing Cluster 5. A fragment of rodent tooth and turtle shell were found *ex situ* in this part.

Samples for Luminescence dating (M-VIL) were collected in soft cave deposits by Cluster 4 and a U-series sample (M-BATU-VL-F1) from an overlying flowstone (Figure 2.7).

2.6.1.4 Dark Cave (N 3° 14' 14.9", E 101° 41' 07.1")

This is one of the most famous caves in the Batu Caves complex. It is located about 170 m above the ground. The Dark Cave consists of six major chambers located at different levels with an estimate total length about 2000 m of passageways. Stalactites from the cave's ceiling and stalagmites rising from the floor form intricate formations such as flowstones, and scallops which took thousands of years to form. Visitors can easily access the Dark Cave from the stairs reaching up to the Temple Cave at the branch near the top of the stairs. The cave was discovered and explored by the Europeans like H. N. Ridley, in 1898 who made the first major scientific exploration of the cave. He found some bits of Chinese pottery, fragments of ox bones, and bat bones in the floor near the entrance through his excavation in the Dark Cave. He noted the absence of evidence of human usage in the cave and the presence of many bat bones near the entrance. He believed the bat bones came from bats that had died and fallen from directly above but bats prefer to roost in the darker parts of the cave away from the cave entrance. He also thought that a large stream flowed through the cave when the surrounding area was at a higher level than it is at present and the stream washed and deposited a very large amount of carbonate sediments on the surface and the entrance of the cave. These evidences lead him to suggest that the cave entrance in its present location was not the prehistoric cave entrance which he suggested to have been some distance further south.

Most of the scientific research that has been conducted on this cave has been on the extant fauna such as insects, bats and possibly small mammals like rats. No detailed palaentological work was done in the Dark Cave which holds a lot of potential for future work.

All the vertebrate fossils collected from this cave were found at about 12 m northwest of the present main entrance in 0.6 m remnant block sediments (Figure 2.8). The fossils found in this cave are small and stuck to each other and using hand tools to extract them all was very difficult. Blocks of the material were collected and soaked in dilute hydrochloric acid for three days to extract most of them.

Figure 2.8 Hammer on limestone block from which sample was collected near entrance of Dark Cave.

The main composition fossils from this cave are microvertebrate fossils of bats (Megachiroptera and Microchiroptera) beside fossils collected by hand tool include the lower molars of Long-tailed Macaque (*Macaca fasicularis*), a fragment of an incisor tooth, two pieces of articulated (mammalian?) vertebrae, (mammalian?) vertebra, fragment of a bat jaw bone, and fragmented bones of different sizes.

2.6.2 Lenggong Valley, Perak (northern West Peninsular Malaysia)

Lenggong is located in the Perak River Basin 300 km north of Kuala Lumpur. It is underlain by limestone which had been metamorphosed to fine to medium grained calcitic marble and other and composed of Lower Palaeozoic rocks.

There are eight small to medium limestone mogote towers in the area constituting about 30 percent of the land surface of the Lenggong Valley while the subsurface bedrock limestone is covered by alluvium. These hills housed caves and rockshelters at different levels of various shapes and sizes formed by phreatic and vadose processes. Both mechanical erosion and chemical erosion mainly by underground streams played important roles to create the chambers and caverns of the Lenggong Valley (Mokhtar Saidin, 2005). Some of the dissolved calcite was gradually redeposited over many thousands of years as speleothems such as stalactite, stalagmite, and columns.

Lenggong valley is one of Peninsular Malaysia's most important areas for archaeology. It is the site of the oldest known place of human activity in the peninsula and the people at that time were the first makers of stone tools who lived by hunting and gathering (Zuraina, 2003). By the Neolithic period (beginning about 10,200 years ago) the tools had been improved, pottery was used, and the people practiced farming. Most of the archaeological remains found in Lenggong have been associated with caves which provided important prehistoric evidence. The researchers were aware of this fact since ancient times and therefore the first excavation for the caves started in 1918 done by Mr. I. H. N. Evans. The most important discoveries are from Gua Gunung Runtuh which was used as a burial ground for the Perak Man discovered in 1991. He lived at the end of the Pleistocene or early Holocene 10,000 and 11,000 years ago and is the only complete human skeleton found in Peninsular Malaysia from this time period. The Perak Man was buried with stone

implements and thousand of shells were found associated with him (Zuraina, 1994, 2005). Vertebrate fossils were collected from two caves of the Lenggong Valley site named Badak Cave C and Ngaum Cave (Figure 2.9).

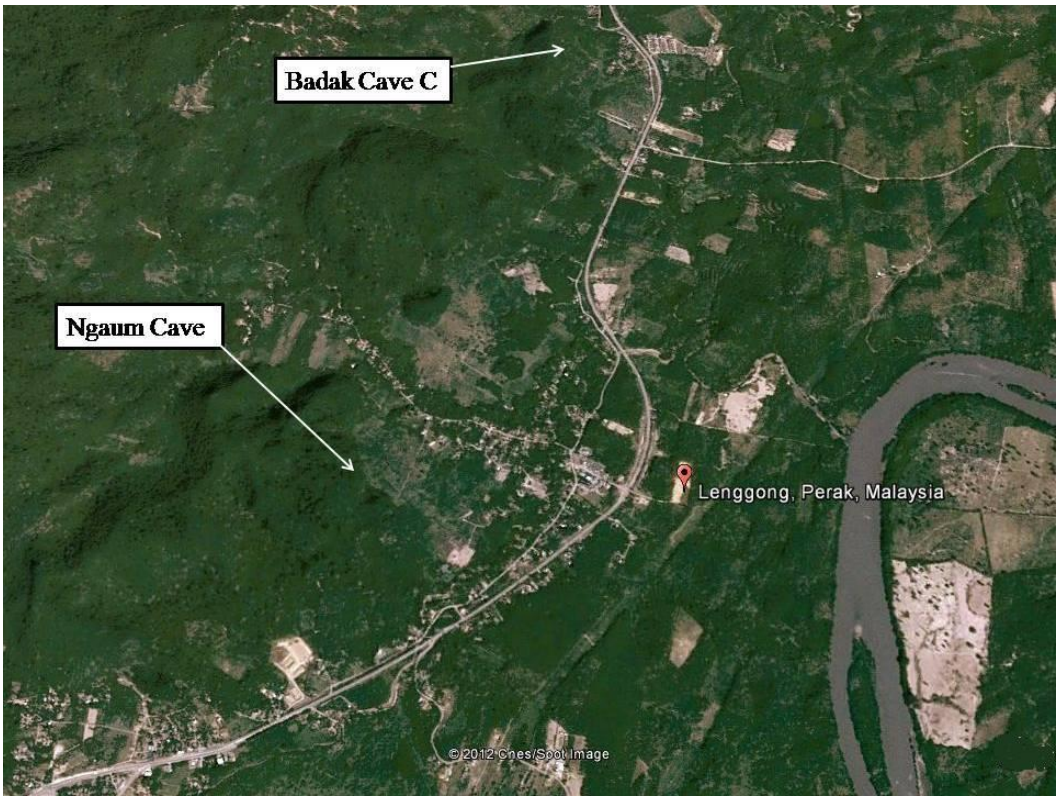

Figure 2.9 Satellite image of two caves studied in Lenggong Valley, Perak.

2.6.2.1 Badak Cave C (N 5° 08' 984 ", E 100° 59' 101")

This is a small cave at the foot of an irregularly shape N-S limestone hill known as Bukit Gua Badak or Gua Gunung Badak where the Perak River crosses the area about 2 km east of the cave site (Figure 2.10).

The cave is located approximately 5 km N-NE of Lenggong town. There are several small caves given the same name (Gua Badak), in the Lenggong Valley, Perak (Price, 2001).

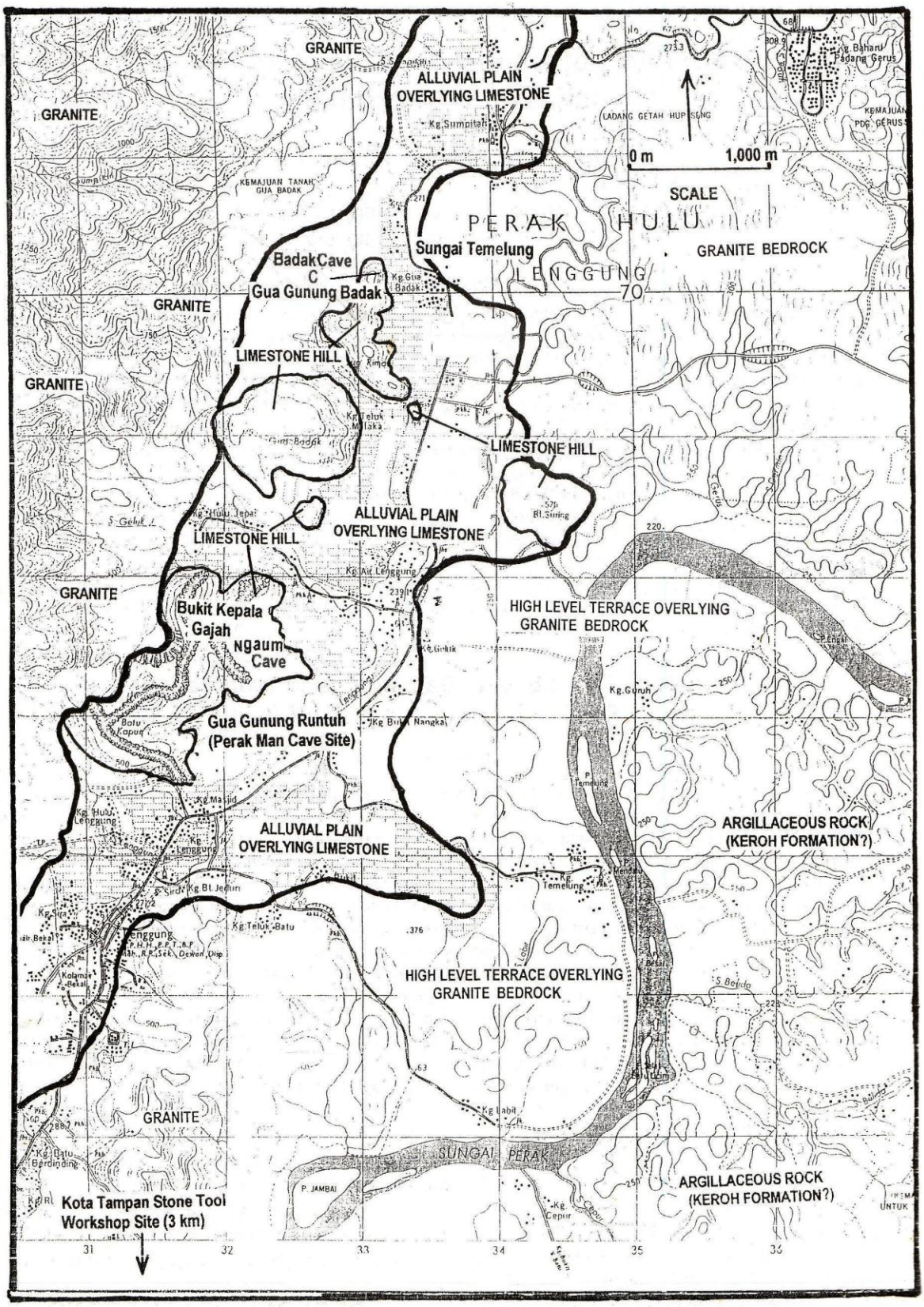

Figure 2.10 Regional geology and location of the limestone hills in the Lenggong Valley with locality of Badak Cave C and Ngaum Cave modified from Ros Fatihah Muhammad and Yeap (2000a).

Evans (1927) noted charcoal drawings in a small cave in Lenggong Valley at Gua Badak. The oldest of these aboriginal paintings found is only about 120 years at Lenggong (Price, 2001). They were then thought to have been destroyed and lost by quarrying. Aboriginal charcoal paintings (Figure 2.11) were found in a rock shelter called Badak Cave A located about 250 m - 300 m northeast of Badak C where vertebrate fossils were found.

Figure 2.11 Charcoal paintings in Badak Cave A, Lenggong Valley, Perak.

Badak Cave C is an elongated NNE-SSW cave that extends about 50 m with two distinct narrow northeast-southwest branches parallel to the western flank of the hill (Figure 2.12). Its entrance is located at about 3 m above ground level which is about 75 m above sea-level. Stalagmites are a rare occurrence and are located at a few places while stalactites and columns were more commonly found especially in the southern part of the cave. A swallow hole was seen in the western wall of the cave. This points to where concentrated inflows of water underground used to be in the past (Ros Fatihah Muhammad, 2003) with evidence of

roof collapse (rubble) leading to the opening of this swallow hole on the cave ceiling. Abundant vertebrate fossils are found in remnant breccia deposits attached to the wall which appears to be a mixture of colluvial sediments with cave sediments and bat guano cemented by calcite while the original cave floor has been removed by guano diggers. Ros Fatihah Muhammad and Yeap (2000a) first documented some of the fossilized teeth and bones of mammals in Badak Cave C.

A very high diversity of fauna was collected from this cave that consisted of isolated teeth and bone fragments found embedded in isolated clusters in several parts of the cave. No articulated post-cranial remains have been found. Seven clusters of fossil were located in three different levels of the cave (lower, intermediate, and upper level chambers) (Figure 2.12). Most of the fossils were recovered from the intermediate level chamber except for one cluster from the upper level chamber and one from the lower level chamber.

Clusters 1,2,3,4 and 7 were found in intermediate level chamber which is the main part of the cave located at about the same level as the cave entrance.

Cluster 1 was located about 20 m to the northeast from the entrance. The sediment housing the fossils is composed of coarse sand mixed with granite wash and calcite cement with isolated patches of limestone breccia scattered on the roof. The fossils were collected from two layers in this cluster designated as the upper layer and lower layer.

The vertebrate fossils are mainly teeth collected from the upper layer about 3 m above the cave floor.

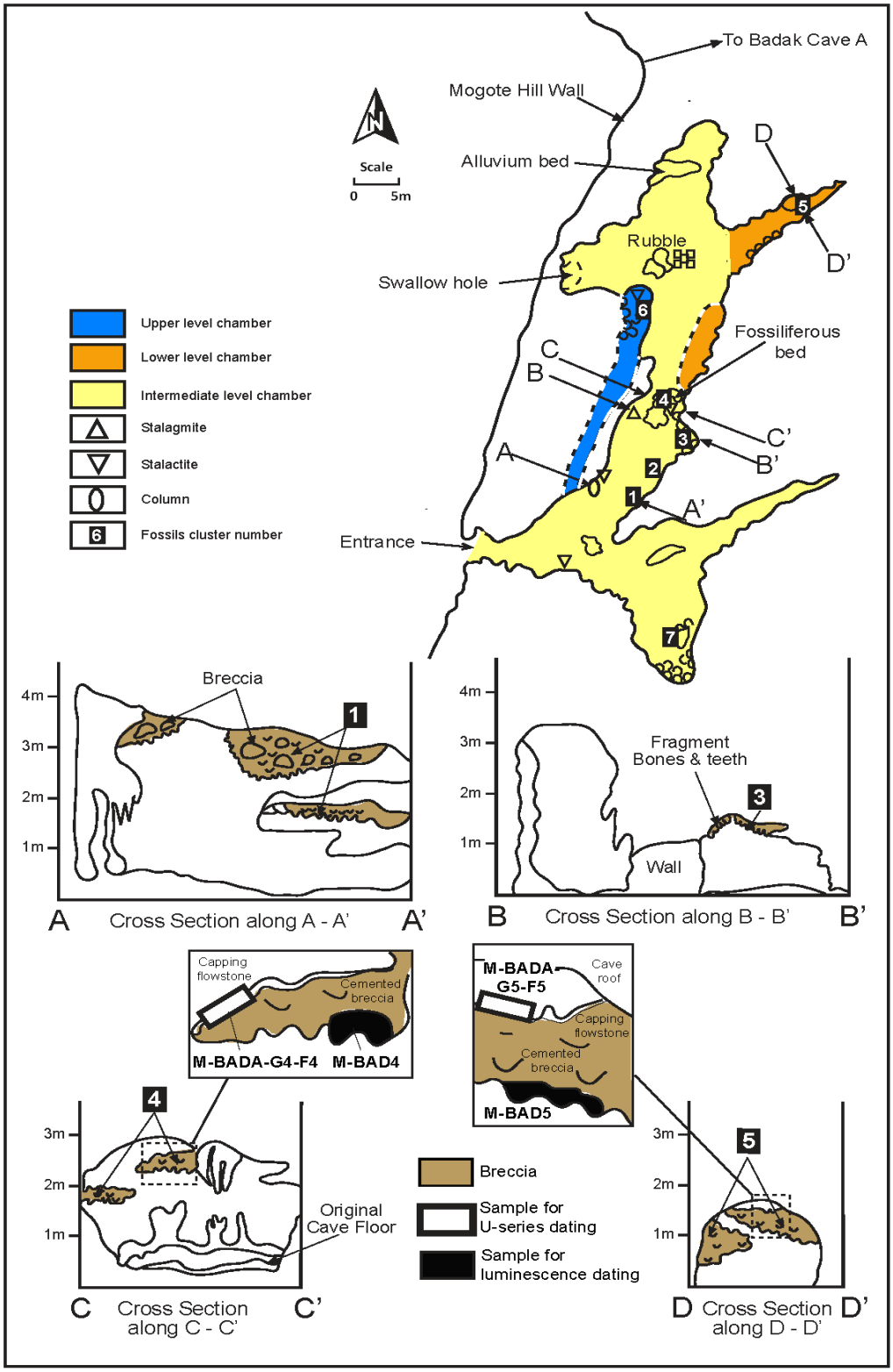

Figure 2.12 Map and cross sections for Badak Cave C.

Teeth of the Eurasian Wild Pig (*Sus scrofa*), pig (*Sus* sp.), Asiatic Black Bear (*Ursus thibetanus*), Bovinae (gen.et sp. indet.), Pig-tailed Macaque (*Macaca nemestrina*), rhinoceros (*Rhinoceros*/*Dicerorhinus* sp. indet.), Orangutan (*Pongo* sp.), Brush-tailed Porcupine (*Atherurus macrourus*), Malayan Porcupine (*Hystrix brachyura*), porcupine (*Hystrix* sp. indet.) and unidentified bone fragments were recovered from this layer. Four specimens consisting of a molar of a pig (*Sus* sp.), a lower premolar of Orangutan (*Pongo* sp.) (Figure 2.13, A), lower molar of Bovinae (gen.et sp. indet.) (Figure 2.13, B), and fragment of a long bone were collected from the lower layer in Cluster 1 which is around 2 m above the cave floor.

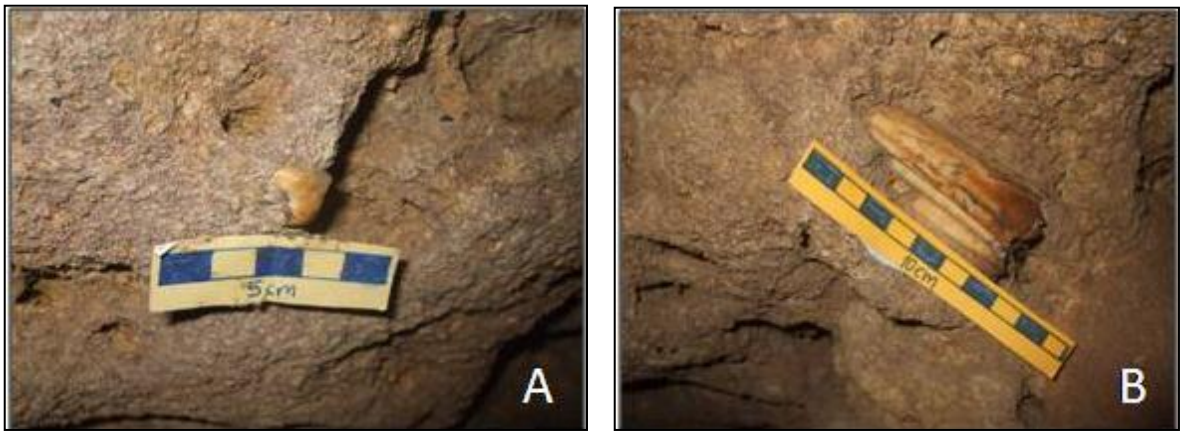

Figure 2.13 Lower premolar of Orangutan (*Pongo* sp.) (A) and lower molar of Bovinae (gen.et sp. indet.) (B), both found in lower layer in Cluster 1, Cistern Cave.

Cluster 2 was one meter away from Cluster 1 on the same cave wall at 0.65 m above the cave floor. The upper incisor of a Malayan Porcupine (*Hystrix brachurya*) and the upper left and right molars of Red Muntjac (*Muntiacus muntjak*) were found in it.

Cluster 3 was located about 6 m N-NE of Cluster 2 on the eastern wall and some parts of the cave ceiling. The sediment was strongly cemented by calcite causing most of the samples collected from this cluster to be complete due to difficulty in extracting them.

The fossils include mainly fragment bones with fragmented teeth of rhinoceros (*Rhinoceros*/*Dicerorhinus* sp. indet.), Bovinae, lower incisor of a pig (*Sus* sp.), and fragmentary bones.

Cluster 4 was located about 2 m northwest Cluster 3. The locality of this cluster is at a small passage connecting the intermediate level chamber with the first lower chamber located to the northeast of the main cave.

Locally, two cycles of deposition might have happened in the cave affecting Cluster 4. The older first cycle partially eroded off around 1m of the original cave floor sediments and incorporated some pebbles of limestone fragments in the denuded layers to form the lower part of the bed. No fossils were found in this layer. All the fossils found were from the top part of the deposit which represents the younger second cycle located 1.5 m above the present cave floor. The remnants of this layer extend to cover the southeast cave wall which was extremely rich in fossil fragments (teeth and bones).

A number of broken large vertebrate long bones were stuck to the roof in different orientations while some of them had been partially knocked off and removed by previous visitors. I preferred to leave most of the remaining bones intact for future research at this site as it was difficult to chisel them out and the fragments would not be very useful for identification (Figure 2.14). Teeth from the Eurasian Wild Pig (*Sus scrofa*), pig (*Sus* sp.), Bovinae (gen.et sp. indet.), Serow (*Capricornis sumatraensis*), Red Muntjac (*Muntiacus muntjak*), and large herbivore bone fragments were found here but no articulated bones was observed.

Figure 2.14 Unidentified large mammalian bone fossils in Badak Cave C.

Cluster 5 was found at the entrance to a northeastern branch of the lower level chamber at about 2.8 m below the main cave floor in the intermediate level chamber. The fossils were found in the 0.3 m to 0.8 m remnants of a sediment bed of coarse quartz sand cemented by yellowish clay and calcite. These remnant sediments were stuck to the roof at 1.2 m to 1.5 m above the present lower level cave floor. The presence of this layer at the end of the cave system without any observable opening could be explained by a previous connection that is now blocked or covered up by the cave sediments (Ros Fatihah Muhammad and Yeap, 2000a).

The fossils found from this cluster are teeth of Eurasian Wild Pig (*Sus scrofa*), pig (*Sus* sp.), Orangutan (*Pongo* sp.), Red Muntjac (*Muntiacus muntjak*), Pig-tailed Macaque (*Macaca nemestrina*), Malayan Sun Bear (*Helarctos malayanus*), Serow (*Capricornis sumatraensis*), Sambar deer (*Cervus unicolor*), Malayan Porcupine (*Hystrix brachurya*), and fragmented bones.

Cluster 6 was located about 10 m southwest of the passage that leads to the lower level chamber (locality of Cluster 5). It is at the base of a narrow passage running above and toward the west side of the main intermediate level chamber that leads to the higher level chamber located about 2 m to 3 m above the present cave floor. The original cave wall makes up the major part of the upper chamber. A fragmentary mammal vertebra bone and an upper molar of Eurasian Wild Pig (*Sus scrofa*), were collected from a small accumulation of sediments stuck to the hard original cave wall 1.5 m above the upper chamber floor.

Cluster 7 was located in the southeastern part of the cave where more strongly calcified sediments compared to the other parts covers most of the site. A large tooth identified as the lower molar of a (*Rhinoceros* sp.) has been found in the thick and hard calcified sandy sediments 1.3 m above the present cave floor.

Some vertebrate fossils including fragmentary bones and teeth were found *ex situ* on the floor especially from the intermediate level chambers and from the lower level chamber near Cluster 5. These fossils are teeth of the Eurasian Wild Pig (*Sus scrofa*), pig (*Sus* sp.), Bovinae (gen.et sp. indet.), Brush-tailed Porcupine (*Atherurus macrourus*), porcupine (*Hystrix* sp. indet.), lower jaw bone with teeth attached of Rodents, and pieces of fragmented long bones.

Samples of the matrix for luminescence dating were collected from the upper breccia at Clusters 4 and 5, along with associated overlying flowstones for U-series dating (Figure 2.12).

2.6.2.2 **Ngaum Cave** (N 5° 09' 12.9 ", E 100° 59' 06")

The cave is located at the foot of a hill known as Bukit Kepala Gajah, the largest limestone hill in the Lenggong Valley (Figure 2.10) at about 800 m north with Gua Gunung Runtuh (the Perak Man site). This cave is accessible from other caves like Gua Asar and Gua Puteri (Price, 2001) which are all located in the same limestone hill. The cave is less than 3 m wide and about 15 m long narrowing gradually at the end with very strong growth of stalactites near the mouth. Mokhtar Saidin, (2005) listed this cave among the excavated habitation sites in the Lenggong Valley. Two fossil clusters were found on both walls of the cave a few meters from the entrance in cemented sediments attached to the hard original cave walls (Figure 2.15). The sediments which include some limestone breccia were deposited inside the cave near the entrance were cemented by calcite.

Cluster 1 was found on the right side after about 3 m from the entrance at 2 m above the cave floor and extends about 2 m into the cave. Pieces of big angular breccia were scattered in this layer. The fossils collected from this cluster include: the Eurasian Wild Pig (*Sus*

scrofa), pig (*Sus* sp.), Red Muntjac (*Muntiacus muntjak*), Sambar deer (*Cervus unicolor*), and teeth and bone fragments.

Cluster 2 was found on the left side opposite to Cluster 1 after about 0.75 m from the entrance. Two fossil teeth were collected from a 2 m thick layer of sediment with sub-rounded breccia at about 1.6 m above the cave floor contained one upper molar of a Eurasian Wild Pig (*Sus scrofa*), and an incomplete tooth belonging to a pig (*Sus* sp.). No *ex situ* fossils were found in this cave.

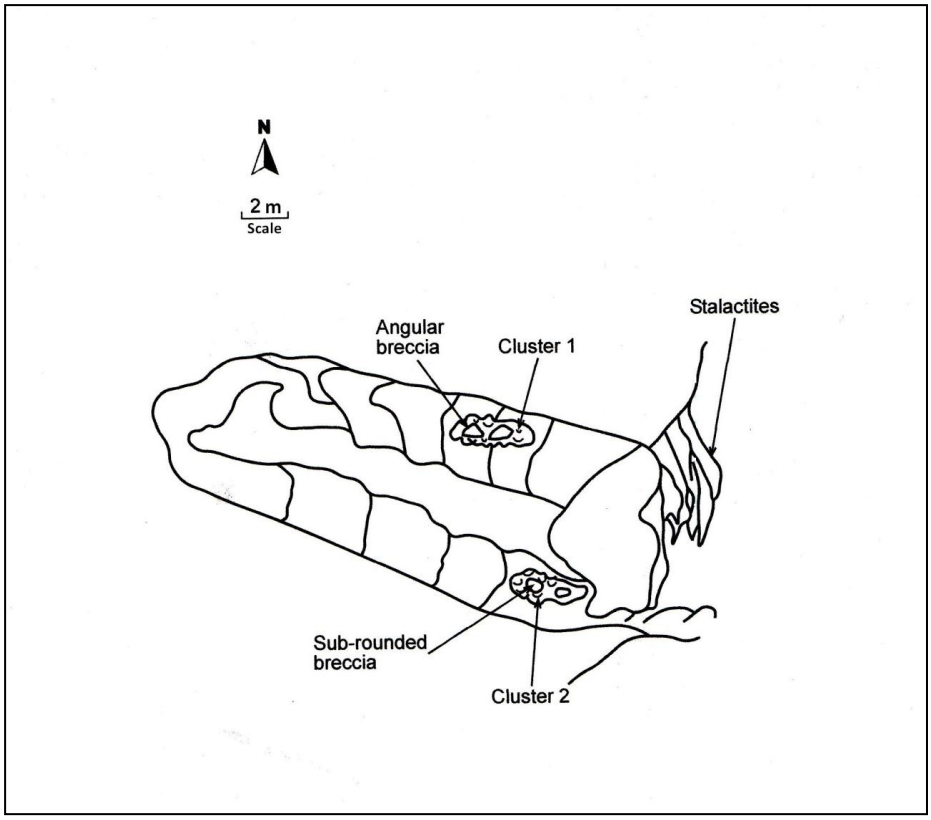

Figure 2.15 Map of Ngaum Cave.

2.6.2.3 Other sites in Lenggong Valley, Perak

Some other caves were briefly examined in the Lenggong Valley area, but no macrovertebrate fossils were observed. They are:

- Gua Badak A (about 250 m – 300 m northeast Badak Cave C).

- Gua Gunung Runtuh (N 5° 07' 43.1", E 100° 58' 180.0").

- Gua Asar (N 5° 07' 33.1", E 100° 58' 54.5").

- Gua Teluk Kelawar (N 5° 09' 34.21", E 100° 58' 57.01").

2.6.3 Kinta Valley (northern West Peninsular Malaysia)

It is a triangular-shaped valley containing the most spectacular limestone hills in Peninsular Malaysia. The valley widens from about 7 km in the north to 20 km in the south over a distance of about 45 km (Ros Fatihah Muhammad, 2003). These hills are of Devonian to Permian limestone's (Suntharalingam, 1968) that had been folded and recrystallised by regional metamorphism in the Late Triassic. Geological structures in the limestone in the Kinta Valley area are dominated by faults and folds oriented north-south which gives a noticeable grain to the landscape especially to the orientation of the hills in the central part of the valley.

Parts of Kinta Valley are bordered by prominent limestone hills rising from the valley floor to over 600 m found chiefly on the eastern side of the valley (Price, 2001). These limestone hills surrounded by the granites of the Kledang Range to the west and Main Range to the east. Part of the limestone has been removed by weathering and erosion. The higher granite ranges are bordered by low hills rising from the floor of the valley or foothills which are made up of schist interbedded with limestone (Ingham and Bradford, 1960). The Perak and Kinta Rivers and their major tributaries drain south-westwards from the mountains and flow across the plain, bringing alluvial deposits which were then deposited over the eroded limestone in the plain and in caves.

This alluvium covered the bedrock floor of the Kinta Valley at various depths with the general thickness increasing southwards. Limestone formed most of the bedrock beneath the alluvium.

The alluvial deposits in Kinta Valley were classified by Walker, (1956) into four layers: old alluvium, young alluvium, boulder bed, and the organic mud and peat. Several studies on these alluvial deposits were done by (Ingham & Bradford, 1960; Sivam, 1969; Newell, 1971).

Many caves are found around the base and higher up in the limestone hills of Kinta Valley. These caves are not simple in form and might have been variously modified since their formation. Most of these modifications happened when the caves were flooded during transgression. Wave action, changing river courses, acid swamp water, and mud deposition in the valley had modified the walls and roofs of the caves (Walker, 1956). Ros Fatihah Muhammad and Yeap (2000b) and Ros Fatihah Muhammad (2003) mapped and described the characteristics and origin of many caves in Kinta Valley.

The Kinta Valley is one of the most important tin producing districts in the world. This is an area that has been under active alluvial tin-mining. The heavy cassiterite ore had been trapped in alluvium-filled pockets within the irregular limestone bedrock after being washed down from the weathered granite and were mined by dredging as well as washing by hydraulic pumps.

A few mammalian fossils had been found in the alluvial sediments in the Kinta Valley beginning with the discoveries of *Elephas namadicus* and *Elephas maximus* teeth reported by Andrews (1905), Savage (1937) and Ingham and Bradford, (1960). Hooijer (1962a) described a most important assemblage of Middle Pleistocene fossils from a cave in the Tambun area in Perak. A large vertebrate skeleton is exposed on the wall in the Naga Mas Cave, just south of Ipoh (Figure 2.16) (all the details in chapter 5).

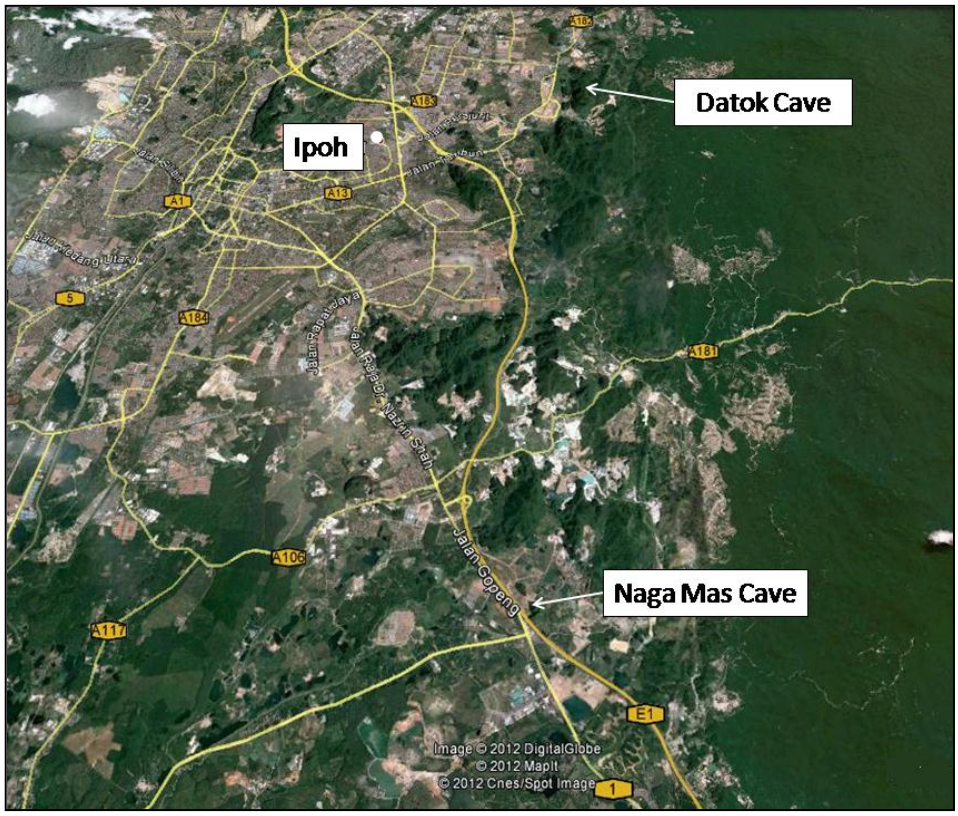

Figure 2.16 Satellite image of two caves studied in Kinta Valley.

2.6.3.1 Tambun (N 4° 37.' 040", E 101° 09.' 480")

In 1962a, Dick Hooijer (Leiden) presented a paper that included interesting fossils found at a depth of about thirty feet in the tin –bearing deposits filling a limestone cave in the Tambun area, in the Kinta district of Perak, Malaysia. The area contains a number of rockshelters and has been developed for a resort named the Lost World of Tambun Water Theme Park (Figure 2.17).

The specimens had been collected by Mr. B. A. V. Peacock, Curator of the Perak Museum, Taiping, Perak, who did not give any details of the location. The materials were probably collected from a high level cave known as Gua Datok or Datok Cave in Tambun (Figure 2.16).

The collections discovered are of special interest because they include mammalian fauna different from that found today that are indicative of a Middle Pleistocene age in the Malaya Peninsular such as *Duboisia* and Hippopotamus. Hooijer in his paper mentioned that the collections were housed in the University of Malaya, Kuala Lumpur, Malaysia and it would be most interesting to find and reexamine these materials, especially in the light of recent developments and advances in Southeast Asian Pleistocene palaeontology (all the details in chapter 5).

Figure 2.17 Limestone pinnacle in Lost World of Tambun where Datok Cave is located.

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2.6.3.2 Naga Mas Cave (Gold Dragon Cave) (N 4° 30' 26.9", E 101° 09' 00.9")

The Naga Mas Cave is located in Bukit Lanno about 14 km to the south of Ipoh, Kinta Valley some 500 m from the Simpang Pulai highway junction to Batu Gajah. The locality consists of two caves located side by side near the summit of a limestone hill named as Gunung Pua (Price, 2001). Price listed these two caves under name Gua Naga Mas Lower and Gua Naga Mas Upper. The first one was an abandoned old Chinese temple located at the eastern base of the hill with rubbish dump in the front.

The latter with the vertebrate fossil is a small western cave with a well developed speleothem deposits on the walls and ceiling located 31 m above ground level. It can be accessed by some crude steps indicated by a sign board erected by the Museum Department. Collapse limestone blocks can be seen scattered on the floor of this cave. The large vertebrate skeleton is exposed in the ceiling at about 7 m above the irregular cave floor. The large vertebrate skeleton is about 98 cm long and almost complete embedded in a near horizontal banded horizon of reddish travertine that is younger than the Devonian limestone forming the hill. Studies done on the site and fossil include:

- Members of the Malaysian Nature Society of Perak (Ipoh) who first discovered this site as a part of their caving activities in the area in 1992 (Adi Haji Taha, 1993; Tjia, 2000).

- Core travertine samples were collected from various place within the cave in 1992, some of the samples near the fossil were studied by using ESR method (electron- spin resonance) in Osaka University, Japan by Professor M. Ikeya and his student Mr. A. Tani, the result was obtained on 1995, need more confirmation and calibration with another measurements.

- Staff of the Archaeology Unit of the Museum Department who were the first to investigate the cave in 1993 (Adi Haji Taha, 1993).

- Dr. Geoffrey Davison of the Singapore National Parks Board visited the site and tentatively identified the fossil as a possible modern tiger (*Panthera tigers*), extinct Middle Pleistocene tiger (*Panthera palaeojavanica*), or modern lion (*Panthera leo*), in 1993.

- Dr. Adi Haji Taha (Director of the Antiquity Division in the National Museum, Malaysia) presented a preliminary report to inform about the discoveries site in 1993 at Journal of the Malaysia Branch of the Royal Asiatic Society.

- The Department of Museum Malaysia/ Putrajaya, made cast of the skeleton (personal communication) and designated the cave as a protected site in the early 1990s.

- Professor H. D. Tjia (a geologist from University Science Malaysia) reported preliminary results of the age for the fossil as more than 700,000 years old, core travertine samples were collected from various spots within the cave to get the geological age using ESR (electron- spin resonance) method with suggestion for need of further confirmation in 2000.

- U- series method using to dated the flowstone embedding the fossil, preliminary results indicate that the cave could have started to form at least 228 ka ago (Ros Fatihah Muhammed *et al*., 2001).

- Ros Fatihah Muhammed *et al.* included the Naga Mas Cave among other caves in the Kinta and Lenggong Valleys to test the U- series technique in 2002, the result show limit the precision with which their ages can be determined.

- Ros Fatihah Muhammed studied this cave in 2003 in greater detail focusing on the origin and the development of the cave but not the fossil.

- A scaffolding built and used by (the writer, her supervisor, and other researchers) to reach the fossil in order to take close up photos and measurements of each part of the skeleton for more certain identification and to collect samples near the skeleton by drilling for dating in 2009 (more details in chapter 5).

2.6.3.3 Other sites in Kinta Valley

Some other caves were briefly visited and quickly searched for vertebrate fossils in Kinta Valley area, but with negative results. They are:

- Kandu Cave (N 4° 26' 49.9", E 101° 10' 54.4").

- Gua Tempurung (N 4° 26' 00.4", E 101° 11' 15.0").

- Six Mile Tunnel (N 4° 37' 0", E 101° 8' 0").