CHAPTER SIX

SUMMARY OF RESULTS AND DISCUSSION

6.1 Interpretation and discussion

Most of the limestone bedrock in the Kinta Valley in Perak and Klang Valley in Selangor in west Peninsular Malaysia is buried beneath the tin-bearing alluvium and are exposed only by alluvial tin mining. The rest are exposed as spectacular tower karst hills or mogotes around Ipoh and at Batu Caves near Kuala Lumpur. The bulk of the Kuala Lumpur Limestone to which Batu Caves belongs is under the alluvium (Lee & Chow, 2004).

The Batu Caves complex has a series of caves developed in the Silurian limestone hill during Pleistocene times. The limestone in Lenggong Valley is of Lower Paleozoic age (Rushdan, 1994). Evidence from recent drillings has suggested the former existence of a lake in the Lenggong Valley (Nor Khairunnisa Talib *et al*., 2010) when the Perak River through which it flowed was temporarily dammed up by a landslide.

The lack of clear sedimentary structures in the layers of cave deposits at the sites studied makes palaeoenviroment analysis of fossiliferous layers of the cave is difficult to explain. It is generally believed that the cave deposits were laid down by several episodes of interrupted sedimentation of as cave wash and breccias from this lack of sedimentary structures such as cross-bedding that would be more indicative of subterranean alluvial deposits.

6.2 Morphological and micro morphological analyses

Locally, some field characters show similarity in both sites (Batu Caves and Lenggong Valley caves) like: the distribution of the sediments in both sites appeared heterogeneous in deposits with no clear boundary layers, all the fossils of different sizes were found embedded in the accumulation of unsorted deposits including fragmented bones oriented in different directions. Most of them were cemented to the roof especially those in Badak Cave C. All the fossil teeth collected from all the cave sites were loose samples. No complete skeletons had been found and the only articulated specimen was the incomplete skeleton from Naga Mas. Finally, all the sites studied had been disturbed by human activities either by guano mining or developed for tourism or religious purposes that left only remnants of the fossiliferous layers and reduced their morphological information.

Most of the micro morphological characters that were distinguishable in the thin sections (Figures 6.1 & 6.2) show similarities at both sites such as:

- Small amounts of quartz grains were present in two forms, as angular quartz disseminated throughout the soil matrix in Cistern Cave (Cluster 6), Swamp Cave (Cluster 2 & 3), Badak Cave C (Cluster 4 & 5), (Figure 6.1, A), and big grains of polycrystalline vein quartz with lots of inclusions as found in Swamp Cave (Cluster 3) (Figure 6.1, B).

- Sparry calcite occuring as dense crystalline grains infilling voids and veins was observed in most of the thin sections (Figure 6.1, C).

- Fragmented bones and shells were very common at both sites not from the same layers as the fossil deposits (Figure 6.1, D).

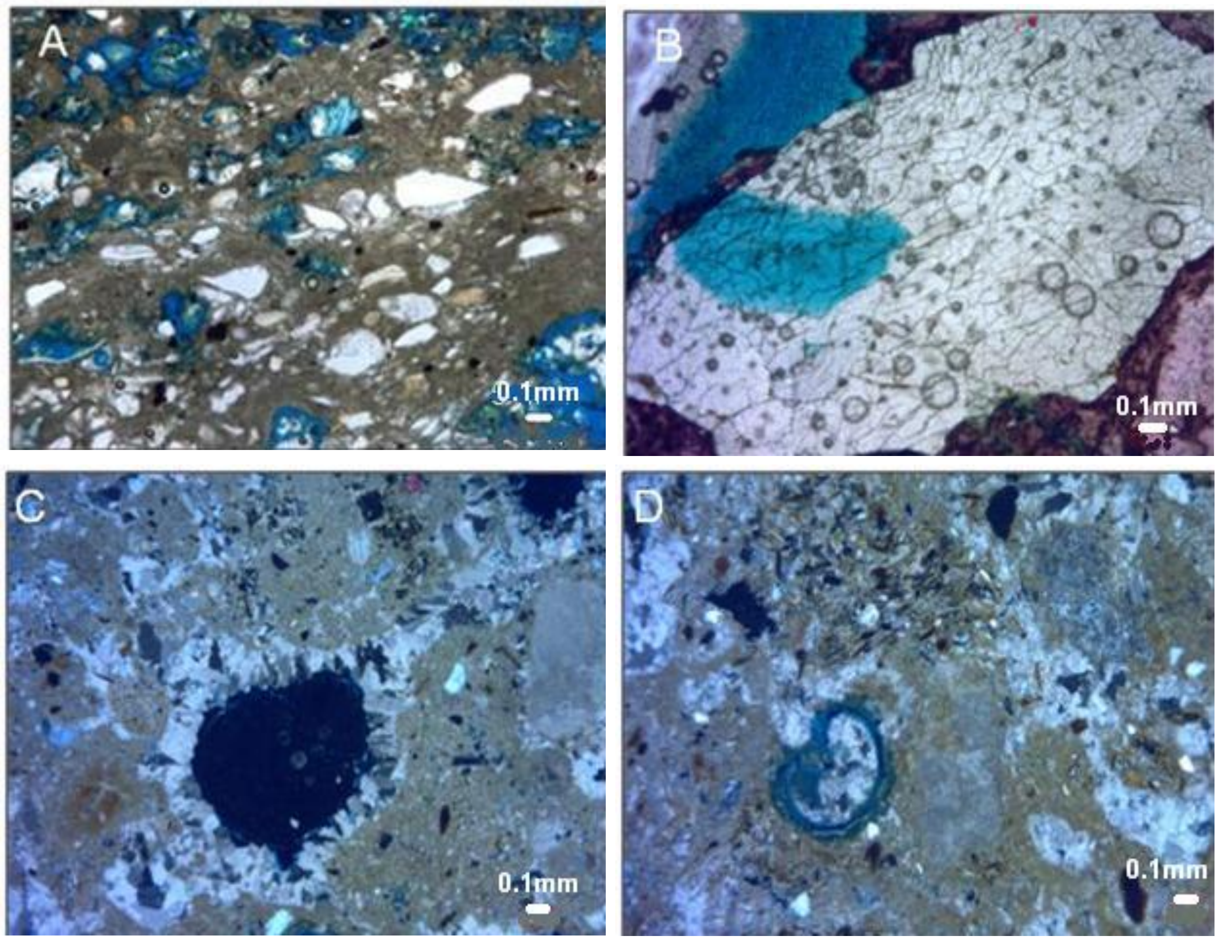


Figure 6.1 Thin sections of treated samples through Badak Cave C and Swamp Cave Clusters.

A: Angular quartz scattered throughout the soil matrix in Badak Cave C (Cluster 4).

B: Big grains of polycrystalline vein quartz with abundant inclusions from Swamp Cave (Cluster 3).

C: Dense crystalline calcite infilling voids from Badak Cave C (Cluster 5).

D: Shell fragment in soil of Badak Cave C.

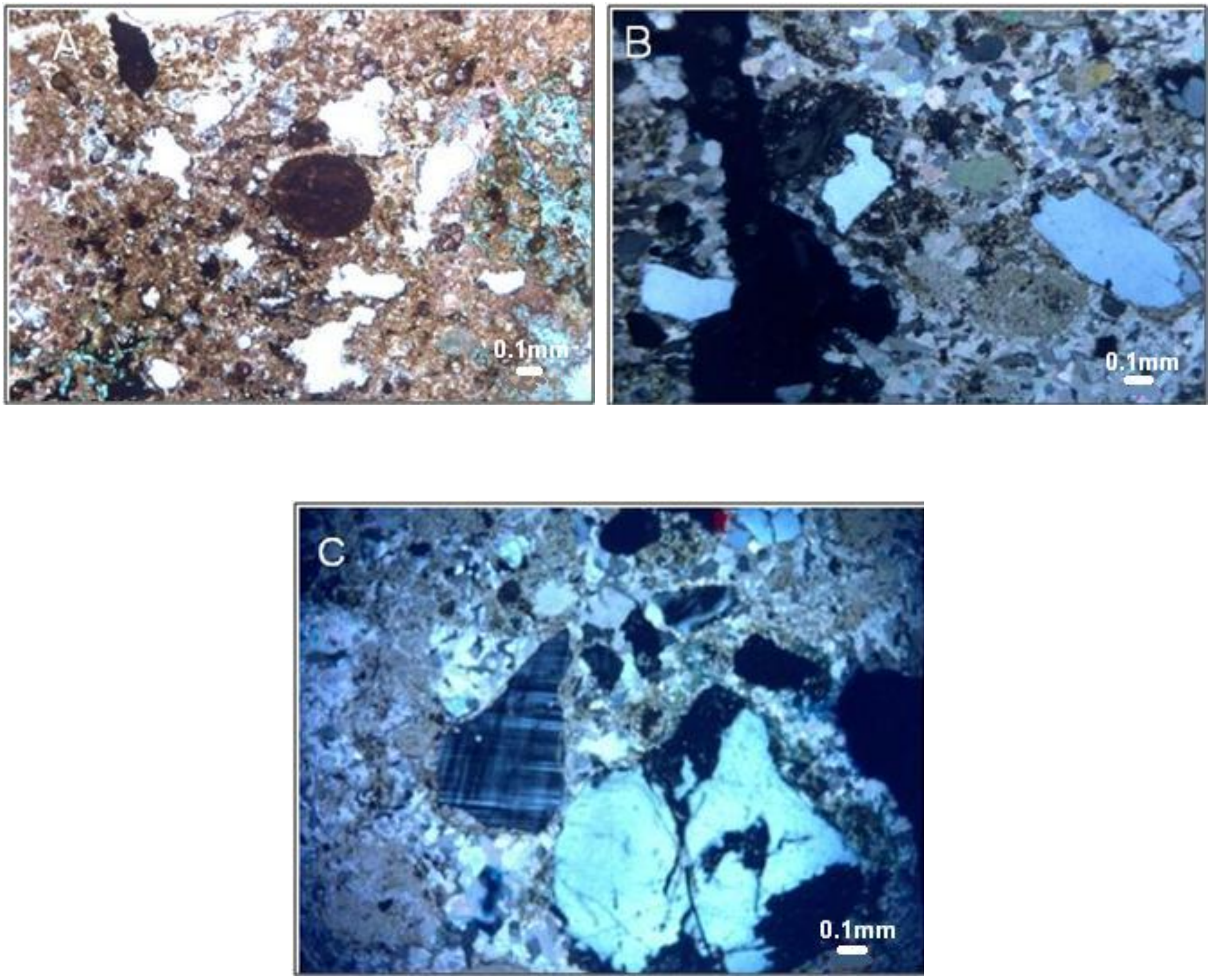


Figure 6.2 Thin sections of treated samples through Cistern Cave and Ngaum Cave Clusters.

A: Iron oxyhydrate nodules in Cistern Cave (Cluster 3).

B: Bipyramidal shape of angular monocrystalline volcanic quartz from Ngaum Cave (Cluster 1).

C: Angular grain of fresh feldspar with clear twinning from Ngaum Cave (Cluster 2).

- Reddish brown grains of iron oxyhydrate nodules which are disseminated in the fine matrix these grains were observed in most of the Batu Caves (Cistern & Swamp Caves) (Figure 6.2, A), and Lenggong Valley sediments (Badak Cave C & Nagum Cave).

- Bipyramidal shape of some angular monocrystalline very clear volcanic quartz with no inclusions were found in the Lenggong Valley sites (Badak Cave C and in Ngaum Cave) (Figure 6.2, B).

- Angular grains of grayish colored fresh feldspar with clear twinning were found in Lenggong Valley sediments from Badak Cave C and in Ngaum Cave (Figure 6.2, C).

Most of the caves in Batu Caves and Lenggong Valley were thought to have developed either phreatically or vadosely from the shape of the the passages and ceilings shape and were later partially filled with alluvium (Yussof, 1997; Ros Fatihah Muhammad &Yeap, 2000; Ros Fatihah Muhammed, 2003; Mokhtar Saidin, 2005). Ros Fatihah Muhammad & Yeap (2000) and Ros Fatihah Muhammed (2003) who studied Badak Cave C had concluded that the beds with the fossils inside the cave had been brought in as alluvial deposits by floodwaters at different times probably in the Late Pleistocene.

The characteristics of poorly sorted deposits containing angular and vein quartz grains, isolated teeth and fragmented bones deposited without preferred orientation, suggest that these deposits were a mixture of colluvial sediments, cave sediments and bat guano cemented in situ by calcite precipitated by percolating water to the floor, roof or wall of the caves. Some of the more angular coarser deposits were cave breccias while the finer material was cave wash deposited by intermittent flash floods. The angularity of the clasts, poor sorting and lack of sedimentary structures like cross bedding rule out alluvial deposition by rivers.

Parts of these deposits had been later eroded by streams flowing through the caves. Despite substantial natural erosion occurring in many of these caves, remnants of former cave floor surfaces with the associated fossils, situated above the present cave floor have been preserved undisturbed due to the cemented nature of the layers and the protective presence of overlying flowstones.

The presence of clear angular volcanic quartz with big angular fresh feldspar in both the Lenggong Valley sites (Badak Cave C & Ngaum Cave) indicates that active volcanism might have taken place during the time of deposition in the surrounding region as active volcanism has been ongoing in Sumatra.

6.3 Composition of the Batu Caves and Lenggong Valley fauna

The specimens recovered from the six caves at the two main sites (Table 6.1) consist mainly of isolated teeth of large and medium sized mammals. Some teeth have gnaw marks of porcupine and other rodents. Remains of small mammals, notably bats, are also represented but not identified and worked on in detail in this study.

Generally, there is no major difference in species composition between the mammal faunas from the two sites at Batu Caves and Lenggong Valley. The fauna finds confirm the relative modernity of the fauna by comparison with similar animals still living in Peninsula: *Macaca fascicularis, M. nemestrina, Hystrix brachyura, Hystrix* sp. indet., Canid gen. et sp. indet., *Helarctos malayanus, Viverra tangalunga, Tapirus indicus*, Sus *scrofa, Sus barbatus, Sus* sp., *Muntiacus muntjak, Rusa unicolor,* Bovinae gen.et sp. indet., *Capricornis sumatraensis* (Davison & Zubaid Akbar, 2007).

Table 6.1 Fauna list of vertebrate fossil teeth recovered from Batu Caves and Lenggong Valley sites in Peninsular Malaysia.

Taxa	Common Name	Batu Caves Fauna				Lenggong Valley Fauna	
		CC	SC	VC	DC	BDC	NC
Order Insectivora **Family Soricidae**							
Soricidae gen. et sp. indet.	Shrew	?		?	+	?	
Order Chiroptera							
Megachiroptera gen. et sp. indet.	Fruit Bat	+	+	+	+		+
Microchiroptera gen. et sp. indet.	Insectivorous Bat	+	+	+	+	+	+
Order Scandentia **Family Tupaiidae**							
Tupaiidae gen. et sp. indet.	Treeshrew	?		?			
Order Primates **Family Cercopithecidae**							
Macaca fascicularis	Long-tailed Macaque	+	+		+		
Macaca nemestrina	Pig-tailed Macaque			+		+	
Family Hominidae							
Pongo sp.	Orangutan	+	+	+		+	
Order Rodentia **Family Muridae**							
Chiropodomys gliroides	Pencil-tailed Tree-mouse					+	
Maxomys surifer	Red Spiny Rat			+			
Family Hystricidae							

Table 6.1, continued

Taxa	**Common Name**	**Batu Caves Fauna**				**Lenggong Valley Fauna**	
		CC	**SC**	**VC**	**DC**	**BDC**	**NC**
Hystrix brachyura	Malayan Porcupine					+	
Atherurus macrourus	Brush-tailed Porcupine	+				+	
Hystrix sp. indet.						+	
Order Carnivora **Family Canidae**							
Canid gen. et sp. indet.		+		+			
Family Ursidae							
Helarctos malayanus	Malayan Sun Bear		+	+		+	
Ursus thibetanus	Asiatic Black Bear	+				+	
Family Viverridae							
Viverra tangalunga	Malayan Civet	+					
Family Felidae							
Panthera tigris	Tiger	+					
Order Perissodactyla **Family Tapiridae**							
Tapirus indicus	Malayan Tapir	+					
Family Rhinocerotidae							
Dicerorhinus sumatrensis	Sumatran Rhinoceros	+					
Rhinoceros sp.						+	
Rhinoceros/*Dicerorhinus* sp. indet.			+	+		+	

Table 6.1, continued

Taxa	Common Name	Batu Caves Fauna				Lenggong Valley Fauna	
		CC	SC	VC	DC	BDC	NC
Order Artiodactyla **Family Suidae**							
Sus scrofa	Eurasian Wild Pig	+	+	+		+	+
Sus barbatus	Bearded Pig	+		+			
Sus cf. *barbatus*		+	+	+			
Sus sp.		+				+	+
Family Cervidae							
Muntiacus muntjak	Red Muntjac	+	+	+		+	+
Rusa unicolor	Sambar	+		+		+	+
Family Bovidae							
Bovinae gen.et sp. indet.			+	+		+	
Capricornis sumatraensis	Serow	+	+			+	

Although some of these species are still living, their presence as fossils had not been recorded before from any cave in Peninsula Malaysia: *Hystrix brachyura, Atherurus macrourus, Viverra tangalunga, Panthera tigris, Dicerorhinus sumatrensis,* other taxa recently extinct in Peninsular Malaysia such as Orangutan (more discussion in next pages). Most of the teeth recovered could be attributed to the species level, and some of them could only be assigned to the genus level due to the difficulty in identifying the species. These include: *Pongo, Rhinoceros,* and *Sus.*

The dimensions and morphological features of the newly discovered fossilized Orangutan teeth from Peninsular Malaysian do not show a consistent and clear pattern compared with other Pleistocene taxa, however, there are no known morphological features to distinguish isolated teeth of two extant species, the Sumatran and Bornean species *Pongo abelii* and *P. pygmaeus*, respectively (Uchida, 1998; Smith *et al*., 2011; Hu *et al*., 2012; Smith *et al*., 2012). The overlap in sizes between the two species is an additional impediment to assigning these fossils to any either of them.

The isolated tooth from Badak Cave C in Lenggong Valley identified as from a rhinoceros, with large dimension and morphological characters close to *Rhinoceros sondaicus* showing that the species might have been present in this area during the Pleistocene, but the specific identification cannot be confidently ascertained due to its incomplete preservation. Other *Rhinoceros* teeth are attributed to indeterminate species as they are too fragmented and incomplete.

The problem is the same for some specimens of the *Sus* group either because they are too broken or have high morphological similarity to both *S. scrofa* and *S. barbatus*. Present dental similarities in their morphology and the difficulty in recognizing species lead to attribution of the large bovine teeth generally to indeterminate genus and species. It is the same with the *ex situ* Canidae specimens.

Four orders of mammals (Primates, Carnivora, Perissodactyla, Artiodactyla) are recorded from both sites (Figure 6.3), but the number of species for each one of them is different.

In Batu Caves (Figure 6.3, Top), 3 taxa of Primates (15.8% of the total number of large mammals), 5 taxa of Carnivora (26.3%), 3 taxa of Perissodactyla (15.8%), and 8 taxa of Artiodactyla (42.1%), were documented.

The same orders were found in Lenggong Valley (Figure 6.3 Bottom), but in different percentages, 2 taxa from each of the Primates, Carnivora, and Perissodactyla formed equal percentage of each group (16.7%), and 6 taxa of Artiodactyla (50.0%).

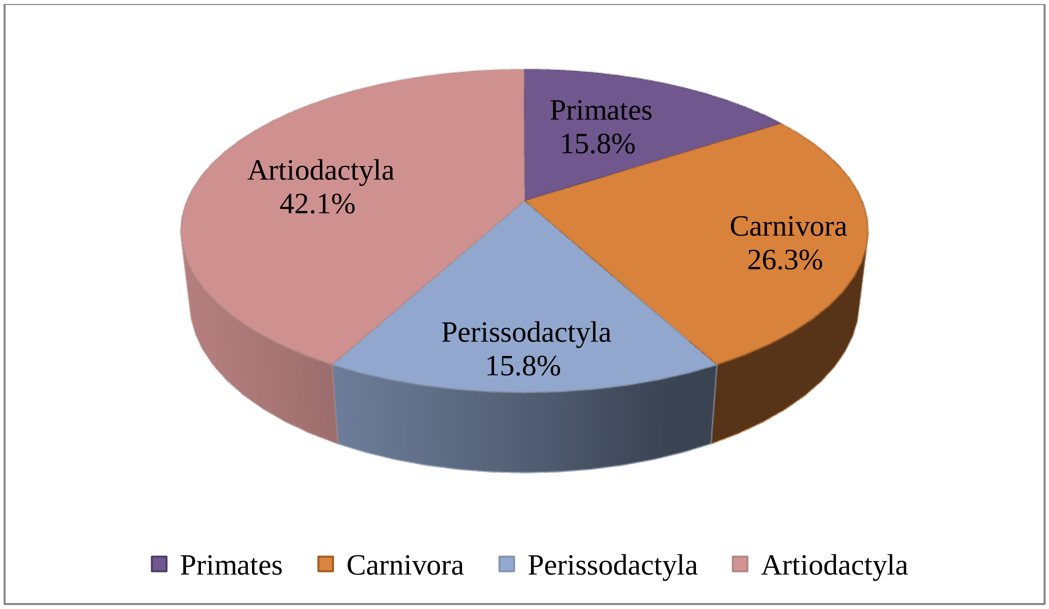
In terms of the families (Figure 6.4), the fauna fossils from Batu Caves appear more diversified than those in Lenggong Valley and is represented by 12 families (Cercopithecidae, Hominidae, Hystricidae, Canidae, Ursidae, Viverridae, Felidae, Tapiridae, Rhinocerotidae, Suidae, Cervidae, Bovidae) (Figure 6.4 Top), while only 8 of the families were found in Lenggong Valley with no record for Canidae, Viverridae, Felidae, and Tapiridae (Figure 6.4, Bottom).

Suidae formed the most abundant taxa in Batu Caves with 4 taxa (20.0%) against only 2 taxa (14.3%) in Lenggong Valley while the others families share the same amounts; 2 taxa (10.0%) each for Cercopithecidae, Bovidae, Cervidae, Rhinocerotidae, Ursidae, and 1 taxa (5.0%) each for Hominidae, Hystricidae, Canidae, Viverridae, Felidae, and Tapiridae.

Hystricidae formed the largest family among the total species number in Lenggong Valley with 3 taxa (21.4%) against 1 species (5.0%) in Batu Caves. The rest of the families have equal amounts, 2 taxa (14.3%) in Bovidae, Cervidae, Suidae, Rhinocerotidae, and 1 taxon (7.1%) for Cercopithecidae, Hominidae , and Ursidae.

No species of Viverridae, Felidae, Canidae, Tapiridae were discovered in the fauna of Lenggong Valley but only in Batu Caves represented by 1 species (5.0%) each.

The amount of material from both sites could be increased with more detailed collection especially through bulk sampling instead of just surface collecting in the future.



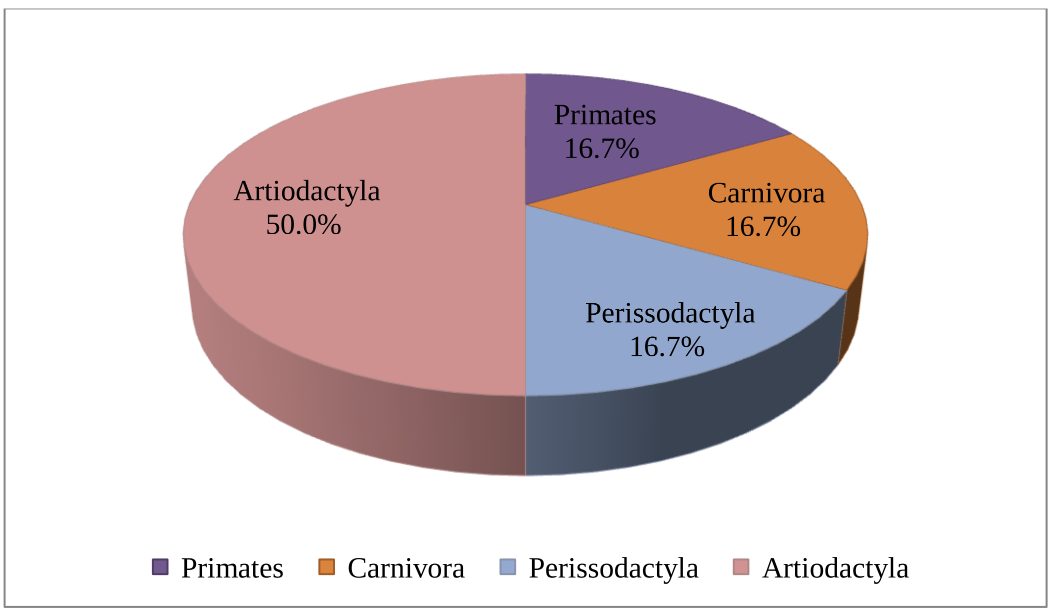
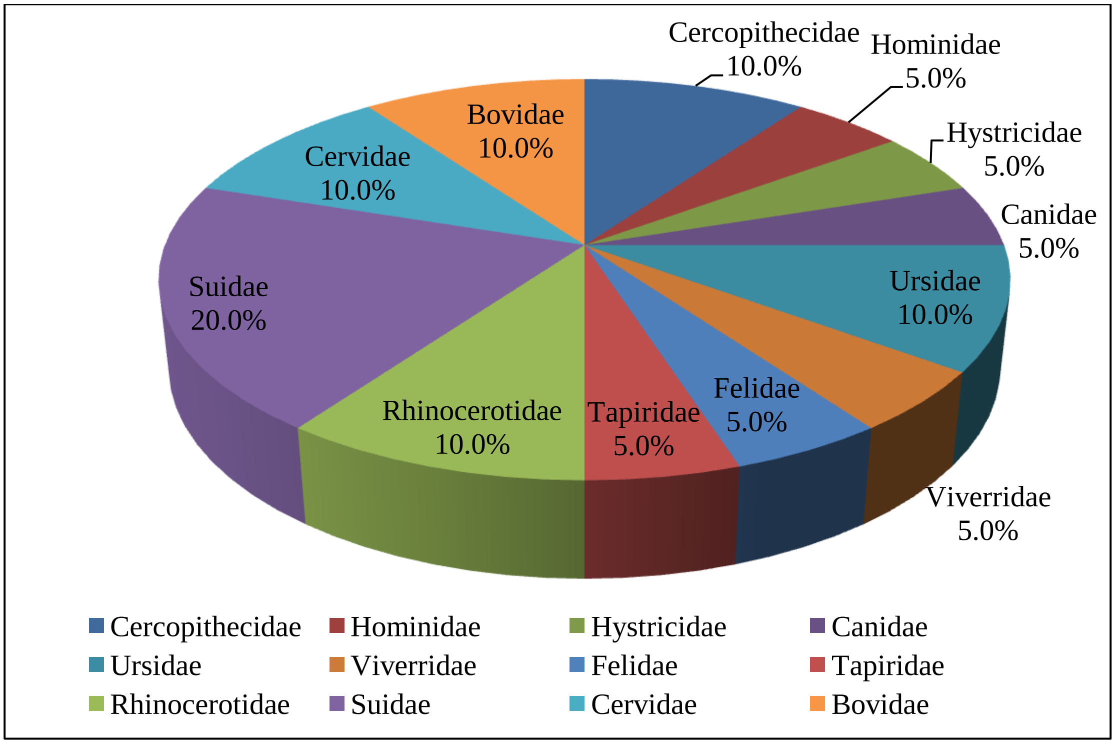


Figure 6.3 Relative abundance of orders of macrovertebrate teeth fossil at Batu Caves (top) and Lenggong Valley (bottom) in Peninsular Malaysia.



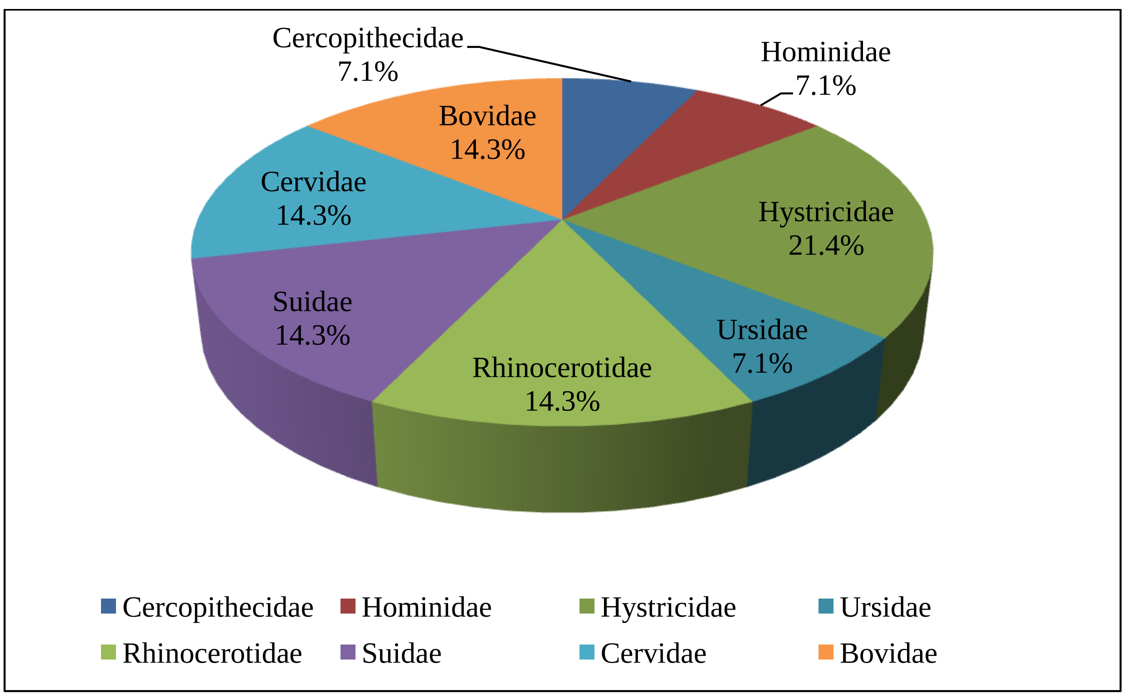


Figure 6.4 Relative abundance of families of macrovertebrate teeth fossil at Batu Caves (top) and Lenggong Valley (bottom) in Peninsular Malaysia.

6.4 Dating

Samples of the matrix hosting the teeth from: Cistern, Swamp, Villa Caves at the Batu Caves site and Badak Cave C in Lenggong Valley site, have been dated by luminescence and U-series methods. The optically-stimulated luminescence (OSL), red thermoluminescence (TL) and U-series results are all internally and stratigraphically consistent and are comparable within their minimum/maximum age confines. The stratigraphic integrity of the deposits provides confidence in the final luminescence age estimates as it indicates that the sediments have not been disturbed during the burial period. The OSL data has been processed using a minimum age, whereas the red TL results represent maximum ages (detail methods in Appendix A). In all instances the OSL and red TL ages are older than the ages estimated for the overlying flowstones according to the U-series techniques, demonstrating the agreement between the two independent dating methods. The combined chronological evidence from Batu Caves indicates that the fossiliferous breccia in the three sites were deposited in the Late Pleistocene no earlier than 57 ± 17 – 66 ± 16 ka (the maximum age for breccia deposition according to the red TL data) and later than 33 ± 3 – 48 ± 5 ka (the OSL ages estimates) and is supported by the corresponding U-series minimum ages. This represents a depositional age range of 66 - 33 ka.

The sediments in Badak Cave C are beyond the datable range of OSL, red TL and U-series. The final results of the techniques confidently assumed that the deposits are older than 500 ka, and therefore, only a minimum age chronology has been presented. An alternate dating technique is required to establish a reliable age for these deposits, however a minimum age of 500 ka clearly demonstrates that this fossil assemblage has a greater antiquity than those found in Batu Caves and can be assigned to the Middle Pleistocene epoch which is not recorded before in any caves in Peninsular Malaysia.

The results are interpreted in the light of other evidence of prevailing environments in the prehistory of the Sundaic biogeographic subregion

6.5 Contributions of this study to distribution of Late Middle and Late Pleistocene faunas in Southeast Asia

A) Biochronology

The chronological ages determined for the two different localities in this region belong to two different times: Middle Pleistocene before 500 ka for the older Badak Cave C, and Late Pleistocene between 66 and 33 ka for the younger Batu Caves. The Peninsular Malaysia fauna represents an important contribution for comparison with other continental Middle and Late Pleistocene sites in this region with similar fauna compositions such as Yenchingkuo in south China (Colbert and Hooijer, 1953), Tam Hang (South) in Laos (Bacon *et al.,* 2011), Phnom Loang in Cambodia (Beden & Guérin, 1973). In Southeast Asia, the known distribution between the fossils of Middle and Late Pleistocene age is unequally documented. Most of the Middle Pleistocene localities with significant diversity recorded are from the Indochinese province and only a few from the Sundaic province: the Sangiran Dome (Early to Middle Pleistocene 830–1000 ka) and Trinil (Middle Pleistocene 500 ka) (Widianto, 1991), and Punung III (Middle to Late Pleistocene 118 - 128 ka) (Westaway *et al*., 2007) in Java, thus making Badak Cave C with 500 ka as one of the oldest few dated sites known from the Sundaic province. As for the Late Pleistocene, the fossiliferous sites in the Sundaic province which may be useful for biostratigraphy are based on faunal similarity with single localities or from closely related localities eg. the Pandang Highland caves were correlated with Punung (de Vos, 1983), so Batu Caves with well its dated fauna of 66 - 33 ka can be interpreted in the light of other prehistoric sites in this region. Diverse paleontological sites are found in two distinct biogeographical areas: the Indochinese province in the north and Sundaic province in the south (Lekagul & McNeely, 1977) (Figure 6.5) with mammalian fauna of Middle and Late Pleistocene ages in fossil localities included in the present study as in (Figure 6.6) and Tables (6.2 & 6.3). The Philippine fauna is not included because it has endemic fauna related but different from those in the Indochinese and Sundaic provinces, except for the fauna of Palawan Island.

The fauna recovered from Batu Caves (between 66 and 33 ka) is of the same relative age with some Indochinese sites like: Duoi U'Oi (66 ± 3 ka) (Bacon *et al.*, 2008b), and Lang Trang (80 – 60 ka) (de Vos and Long, 1993; Long *et al.*, 1996) in Vietnam, and also with the Sundaic sites like Lida Ajer, (80 ka) (Skelton & de Vos in preparation, in Long *et al.*, 1996), and Sibrambang in Sumatra (the closest island to the Malay Peninsula). Even though the date for these sites is still debated they have the strongest faunal similarity to Batu Caves. Most elements present at Batu Caves also occur in these sites such as: *Helarctos malayanus, Tapirus indicus, Dicerorhinus sumatrensis, Capricornis sumatraensis,* while *Panthera tigris* does not occur in Lida Ajer, and *Sus barbatus* does not occur in Lang Trang.

Badak Cave C with Middle Pleistocene fauna has relatively the same age as some Indochinese sites: Yenchingkou (Colbert & Hooijer, 1953), Wuyun and Daxin (Rink *et al.*, 2008) in south China and Tham Khuyen (475 ka) in Vietnam.

Although the Trinil site in Java (Widianto, 1991) corresponds in age with the Badak Cave C (500 ka), it will not be included into the discussion because the site has endemic taxa with a low number of species (Long *et al.*, 1996). However, these sites mentioned above have extinct or missing Pleistocene fauna not found in our sites but found in other sites of either Indochinese or Sundaic Provinces. This is the case for the ancient Proboscidea fauna *Stegodon orientalis* and *Elephas maximus/ namadicus*, *Elephas* sp. The *Stegodon* species were more common in most of the Late Middle Pleistocene sites and their numbers began to decrease in the Late Pleistocene.

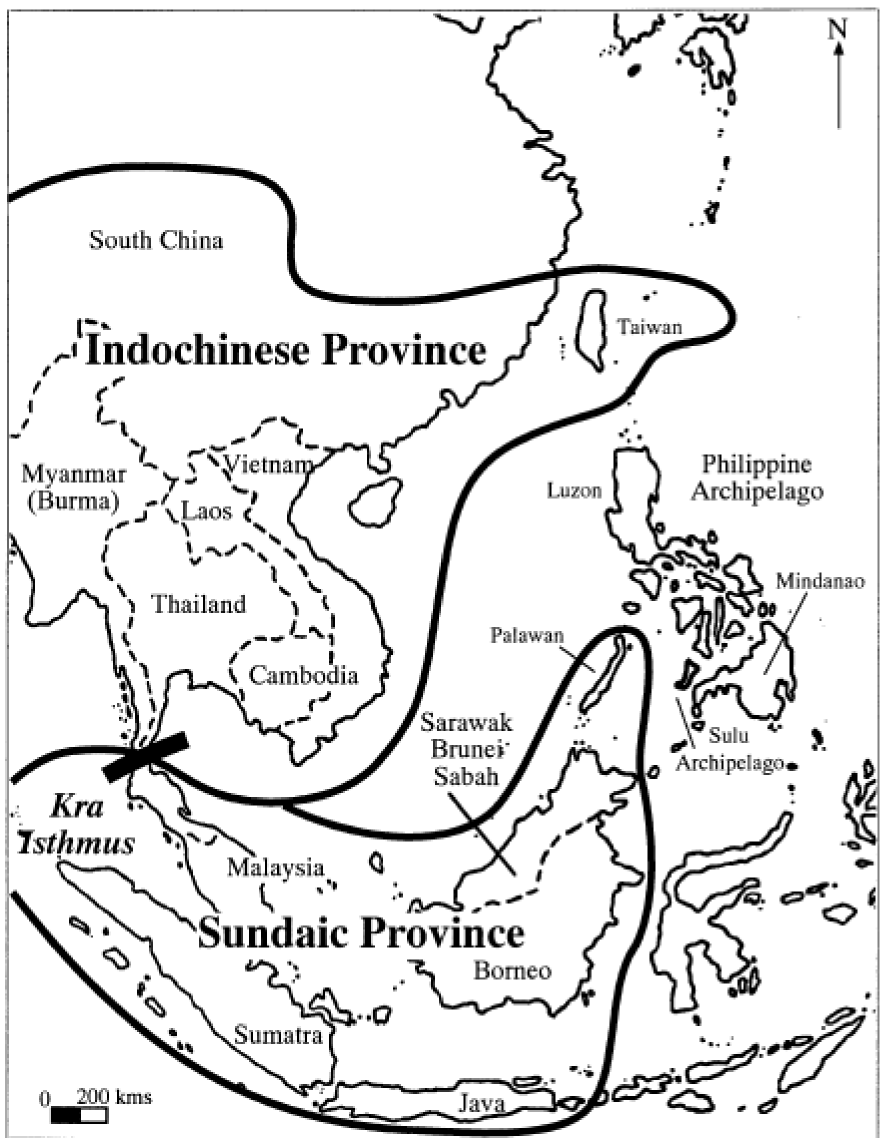


Figure 6.5 Map of the Southeast Asian biogeographic provinces (after Tougard, 2001).

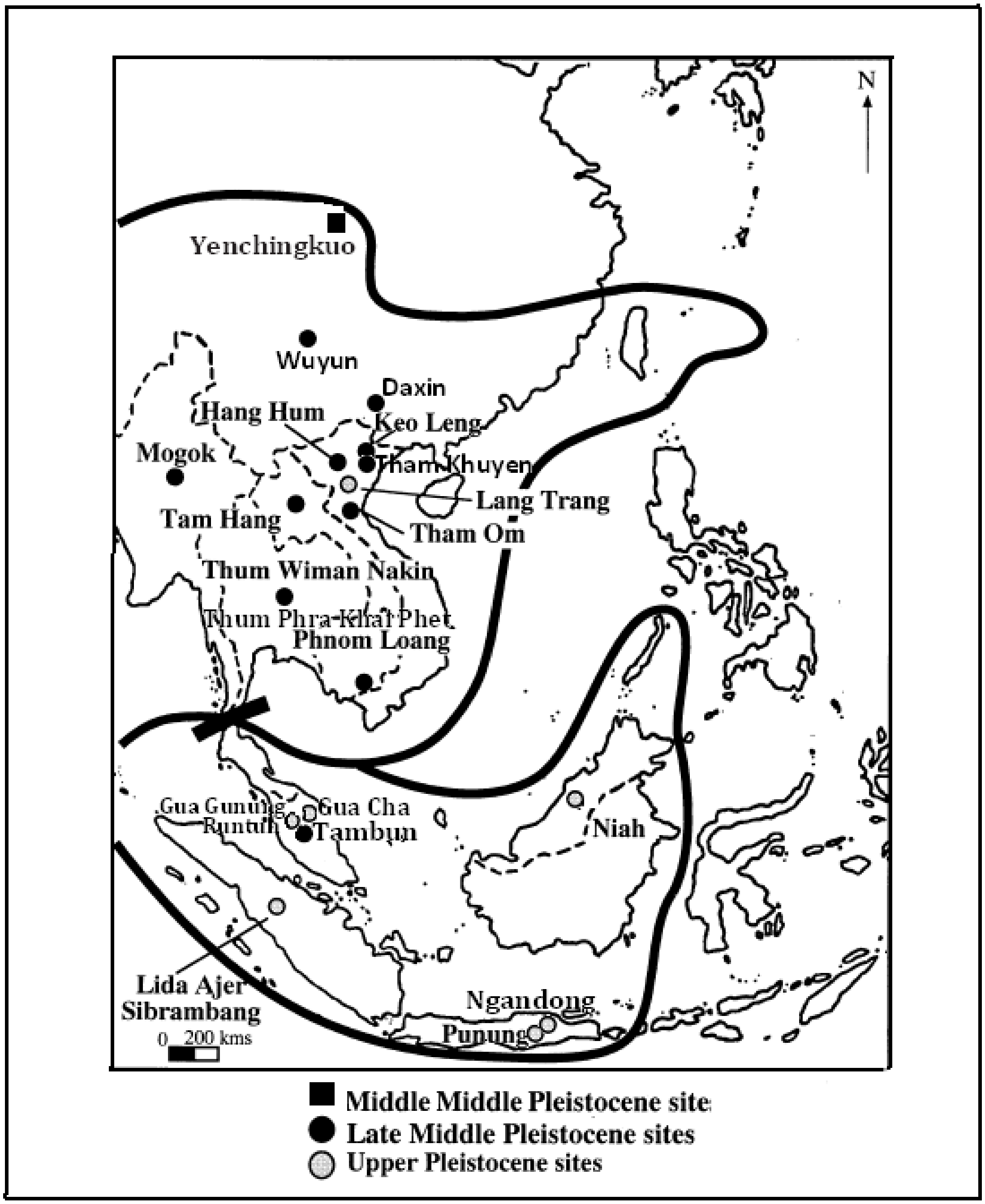


Figure 6.6 Map of the fossil localities included in the present study.