CHAPTER SEVEN

SUMMARY AND SUGGESTIONS

7.1 Summary

No serious detailed work on vertebrate fossils had previously been done in Peninsular Malaysia. The current study is on Middle to Upper Pleistocene mammalian teeth and bone fragments exposed on the surfaces of cemented calcite breccia and cave-wash deposits attached to the walls and ceiling and occasionally floors of mostly ground-level caves at Batu Caves in Selangor and Lenggong Valley in Perak. The smaller-sized teeth were extracted and identified while extraction of the bigger and more fragile bones was largely unsuccessful.

The Batu Caves site has many small accessible caves at the base of the limestone massif that contain macro and microfossils of mammals but no one has collected or studied them in the past. There are also some higher level caves such as the Dark Cave that also contains fossils but has not been worked on in this study due to lack of time. This would be an important follow-up as those fossils would be older than the Late Pleistocene fossils recovered from the base of Batu Caves.

The same applies to the Lenggong Valley site with its many unexplored caves as well as many other caves scattered all over Peninsular Malaysia and Sabah and Sarawak in north Borneo.

In this study, macrovertebrate fossils were successfully recovered, cleaned and identified and studied from a few selected caves (Cistern, Swamp, Villa, and Dark Caves) at Batu Caves Massif in Selangor, and (Badak Cave C and Ngaum Cave) at Lenggong Valley in Perak. Several new species were identified within the assemblages were successfully used

to determine the composition of vertebrate communities in the Middle and Late Pleistocene with the palaeoenvironment during these period. Cave deposits associated with these fossils were also collected for petrographic analysis and processed with acid to extract microvertebrate fossils. The fossils consist mainly of isolated teeth and fragmented bones. In addition to these two primary sites, two other sites (Naga Mas Cave and Datok Cave) in the Kinta Valley, Perak that had yielded vertebrate fossils were also reexamined. There has been no previous thesis done on this topic of macrovertebrate fossils in Peninsular Malaysia. Although a few faunal lists are available in the published literature, they were just small parts of archaeological studies focusing mostly on the artifacts and stone tools for Holocene sites with no fauna details. The scope of this PhD study was limited by the short time available for this project. Limitation of time meant that it was not possible to include some other studies like detailed microfossil studies and palynology that would have complimented and further added to the value of studying the macrovertebrate fossils.

Samples of the matrix from Cistern, Swamp and Villa Caves from the Batu Caves site and Badak Cave C in Lenggong Valley site were sent to Macquarie University, Australia, for dating by using luminescence and U-series methods. The results put the age of Batu Caves as Late Pleistocene and Badak Cave C as Middle Pleistocene. Since a Middle Pleistocene age has not previously been recorded in Peninsular Malaysia, samples from Badak Cave C were sent for confirmatory redating to Professor Jian-xin Zhao, Radiogenic Isotope Laboratory, University of Queensland, Australia, using Thermal Ionisation Mass Spectrometry (TIMS) and Multi-Collector Inductively Coupled Plasma Mass Spectrometry (MC-ICP-MS) techniques (details in Appendix A). The age has been confirmed that the deposits and associated fossils in Badak Cave C are older than 500 ka.

Peninsular Malaysia represents an important biogeographic chronological link to other continental Middle and Late Pleistocene sites for faunal comparisons with the other sites.

The new data from Peninsular Malaysia links and fills a gap in the biogeographical distribution of the macrofauna in the region during the Early Middle and Late Pleistocene times and allow for new fauna correlations between the two provinces: the Indochinese province in the north (southern China, Vietnam, Laos, Cambodia, Myanmar, and Thailand), and the Sundaic province in the south (Peninsular Malaysia, Sumatra, Java and Borneo).

Studies of the fauna in the current sites reveal that they contain species that are still living but their presence as fossils had not been not recorded before in any cave in Peninsula Malaysia like *Hystrix brachyura, Atherurus macrourus, Viverra tangalunga, Panthera tigris, Sus barbatus, Dicerorhinus sumatrensis* while other taxa like *Pongo* and *Ursus thibetanus* are absent today in Peninsular Malaysia.

These fossils trace the extinctions and migrations of these fauna in the Middle and Late Pleistocene in Southeast Asia. They support the idea of migration of northern fauna of Southeast Asia to the south, from south China to Indonesia and provide new data for the hypothetical continental migration route.

Other large mammals such as *Sus barbatus, Rhinoceros sondaicus,* and *Dicerorhinus sumatrensis* are more restricted in the two provinces of Southeast Asia. They are threatened with extinction due to habitat destruction and reduction in increasingly populated areas and are becoming scarce nowadays.

The presence of these mixed faunal assemblages combined with those such as *Pongo* gives key information on past climates and paleoenviroments suggesting partially open, probably evergreen forest biotopes with humid conditions. These interpretations need further support and confirmation from more collections of both macro and microfossils from other caves and palynological data from the Middle and Late Pleistocene in Malaysia and Southeast Asia.

7.2 Suggestions for further work

It is certain that more work would need to be done to confirm these new findings in Peninsular Malaysia by doing more work on the same samples as well as by collecting new material from other Quaternary sites to track the evolution of large mammals in this country in particular and to refine the biochronological scale at a regional level.

Here are some of my proposals for future work:

- The current new findings highlight the great potential for extending such studies to new localities in Peninsular Malaysia with long-term collaborations with researchers from other institutions as has been done in several other countries such as Thailand.

- In palaeoenvironmental analyses, palynological studies provide important clues to paleoenvironment changes. This is what is recommended for the future especially as no studies has been done for the cave deposits in Peninsular Malaysia. Such studies together with systematic fossil studies will give a comprehensive picture of the environmental variables that had occurred in the past.

- Microvertebrate fossils have also been collected in this research but not worked on in detail due to the limitation of time with the main focus on macrovertebrate fossils. Detailed specific identifications must be done in future work with additional collections from other localities.

At the end of the 20th century, witnessed a significant evolution in the use of the paleontological data in ecological and conservation studies, and has indicated some fruitful directions that paleoecology could go in the future like:

- In terms of taxonomy, ancient DNA analysis may hold the key to saving endangered species. "Conservation paleobiology" is the field of science that relies on animal fossils

and ancient pollen analysis together with carbon dating to explain the history of endangered species and where they had lived in the past to guide reintroduction to new areas. It offers clues on how to conserve their modern-day descendants and also tell us how species could possibly respond to climate change.

- Microscopic examination of enamel surfaces of the teeth of extinct species allows for identification of the possible plant remains eaten by an animal prior to its death. The key evidence is tiny silica crystals that grows inside plant cells and redeposit in the soil after plants decay in the form called phytoliths or "plant stones". This technique can be used to identify palaeoenvironments and also evolutionary history of many different types of plants (Carter, 1999) and provide useful information about the kind of diet of extinct animals

- Modern studies use carbon isotope ratios associated with C_3 or C_4 plant characteristics derived from fossil teeth enamel or animals that ate these food to reconstruct from their diet the organism's diet, ecology, body temperature and related paleoclimatic and paleoenvironmental changes (Wang *et al,* 1994; Sponheimer *et al*, 2003& 2005).

- Microstructure analysis of the mammalian enamel teeth which is highly variable in shape, size, thickness, and structure, within and between mammalian species provides the strongest clues to the evolutionary history of taxa. Fracture and deformation of solids can used to provide a quantitative account of how mammalian enamel may be adapted to diet and could be especially useful as a dietary indicator for extinct taxa (Lucas *et al*, 2008).