



Contents lists available at ScienceDirect

Quaternary International

journal homepage: [www.elsevier.com/locate/quaint](http://www.elsevier.com/locate/quaint)

## The Middle Pleistocene mammalian fauna from Tam Hang karstic deposit, northern Laos: New data and evolutionary hypothesis

Anne-Marie Bacon<sup>a,\*</sup>, Philippe Duringer<sup>b</sup>, Pierre-Olivier Antoine<sup>c</sup>, Fabrice Demeter<sup>d</sup>, Laura Shackelford<sup>e</sup>, Thongsay Sayavongkhamdy<sup>f</sup>, Phonphan Sichanthongtip<sup>f</sup>, Phimmasaeng Khamdalavong<sup>f</sup>, Sengphet Nokhamaomphu<sup>f</sup>, Vong Sysuphanh<sup>f</sup>, Elise Patole-Edoumba<sup>g</sup>, François Chabaux<sup>b</sup>, Eric Pelt<sup>b</sup>

<sup>a</sup>UPR2147, CNRS, "Dynamique de l'évolution humaine: individus, populations, espèces". 44 rue de l'Amiral Mouchez, 75014 Paris, France

<sup>b</sup>Université de Strasbourg, EOST, "Institut de Physique du Globe de Strasbourg (IPGS)", CNRS/UDS UMR 7516. 1 rue Blessig, 67084 Strasbourg Cedex, France

<sup>c</sup>Institut des Sciences de l'Évolution de Montpellier, CC064, Université Montpellier 2, Place Eugène Bataillon, F-34095 Montpellier, France

<sup>d</sup>MR7206/USM704, Ecoanthropologie et Ethnobiologie, 57 rue Cuvier, 75005 Paris, France

<sup>e</sup>University of Illinois, Department of Anthropology, 109 Davenport Hall, MC-148. 607 S. Mathews Avenue, Urbana, IL 61801, USA

<sup>f</sup>Ministère de l'Information et de la Culture, Direction générale du Patrimoine, Vientiane, Laos

<sup>g</sup>Conservation du Patrimoine, Centre de recherche et de restauration des musées de France, Palais du Louvre, Porte des Lions, 14 quai François Mitterand, 75001 Paris, France

### ARTICLE INFO

Article history:

Available online xxx

### ABSTRACT

New fossil material was recovered at Tam Hang during the second fieldwork season conducted in 2007, by a Lao-French-American team. The Tam Hang site is located in northern Laos, in the Hua Pan province, about 260 km from Vientiane. The breccias of the Tam Hang South locality produced 404 new fossil specimens which complete the previous material recovered in 2003. The fossiliferous deposits are described geologically. In terms of palaeontology, the mammalian fauna is essentially composed of isolated teeth of middle- to large-sized mammals (Artiodactyla, Perissodactyla, Proboscidea, Carnivora, Rodentia, Primates). The overall fauna is compared to the six well-documented Middle to Late Pleistocene faunas from the Indochinese province (Yenchingkuo, Phnom Loang, Thum Wiman Nakin, Lang Trang, Duoi U'Oi, Ma U'Oi). On the basis of the faunal composition and evolutionary stages of the species, a biochronological framework at the transition between the Middle Pleistocene and the Late Pleistocene is proposed.

© 2010 Elsevier Ltd and INQUA. All rights reserved.

### 1. Introduction

In 1934, Jacques Fromaget, a geologist with the Geological Service of Indochina in Hanoi, undertook surveys in the Annamitic Mountains chain in northern Laos (Fig. 1). There he discovered the Tam Hang site, located on the southeast side of the P'ou Loi Mountain, in the Hua Pan province. Tam Hang is a "group of rock shelters" 100 m along the wall of a limestone tower karst, called Pà Hang. It is a reference site not only for its numerous archaeological and human remains, from the transition from the Palaeolithic to the Neolithic, but also for its two macromammalian assemblages,

whose composition suggests different dating in the Middle Pleistocene (Fromaget, 1936, 1937, 1940a, 1940b; Fromaget and Saurin, 1936; Arambourg and Fromaget, 1938; Saurin, 1950, 1951; Demeter, 2000; Shackelford, 2003).

Fromaget (1940b) subdivided the Tam Hang site into three localities (TH North, TH Central and TH South) (Fig. 2). On the walls of the rock shelters, Fromaget located two distinct fossiliferous breccias, also described in the literature as the "Hystrix tuf" or "tuf à Hystrix" (Arambourg and Fromaget, 1938). The "lower" breccia at TH Central and, in part, TH North, produced a mammal assemblage comprising 38 species. Fourteen are specific to the level: *Probocephalus* sp., *Cervus* aff. *grayi*, *Cervus* cf. *leptodus*, *Nemorhaedus* cf. *goral*, *Sus* cf. *brachygnathus*, *Ursus thibetanus kokeni*, *Ursus* sp., *Felis* sp.1 Choukoutien, *Felis* cf. *micotis*, *Crocota crocuta ultima*, *Canis* cf. *cynoides*, *Cuon* cf. *alpinus*, *Ailuropoda melanoleuca*, *Paradoxurus* sp. The "upper" breccia, only present at Tam Hang South is characterised by 27 species, including the presence of the bear *Ursus premalayanus*. Arambourg and Fromaget (1938) proposed that 23 species are

\* Corresponding author. Fax: +33 1 43 13 56 30.

E-mail addresses: [anne-marie.bacon@evolhum.cnrs.fr](mailto:anne-marie.bacon@evolhum.cnrs.fr) (A.-M. Bacon), [duringer@eost.u-strasbg.fr](mailto:duringer@eost.u-strasbg.fr) (P. Duringer), [pierre-olivier.antoine@univ-montp2.fr](mailto:pierre-olivier.antoine@univ-montp2.fr) (P.-O. Antoine), [demeter@mnhn.fr](mailto:demeter@mnhn.fr) (F. Demeter), [lshacke@illinois.edu](mailto:lshacke@illinois.edu) (L. Shackelford), [Thonsa999@hotmail.com](mailto:Thonsa999@hotmail.com) (T. Sayavongkhamdy), [elise.edoumba@culture.gouv.fr](mailto:elise.edoumba@culture.gouv.fr) (E. Patole-Edoumba), [chabaux@eost.u-strasbg.fr](mailto:chabaux@eost.u-strasbg.fr) (F. Chabaux).

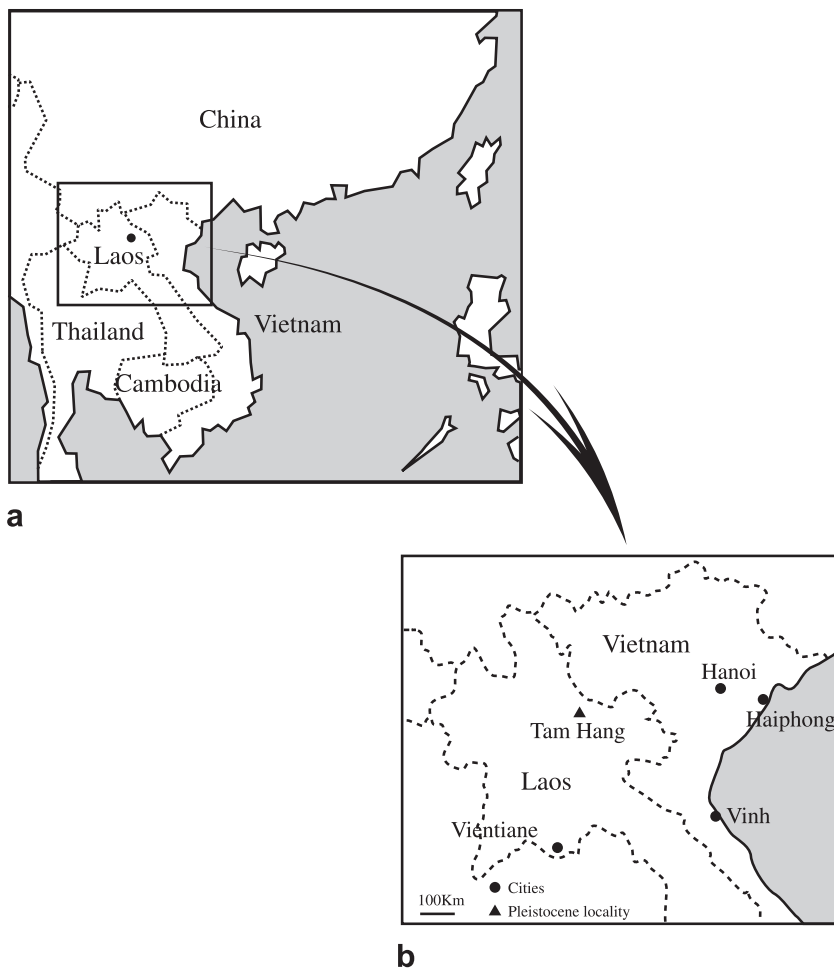


Fig. 1. (a) Map of the Indochinese province. (b) Location of the Tam Hang site in northern Laos.

common to the two levels: *Cervus orientalis*, *Muntiacus* aff. *muntjak*, *Muntiacus* cf. *muntjak*, *Spirocercus* sp., *Bos geron*, *Bubalus teilhardi*, *Sus lydekeri*, *Sus* sp., *Rhinoceros* cf. *sinensis*, *R. unicornis*, *Megatapirus augustus*, *Stegodon orientalis*, *Elephas namadicus*, *Ursus*

*angustidens*, *Panthera leo* cf. *indicus*, *Felis* aff. *issidiorensis*, *Arctonyx collaris rostratus*, *Macaca robusta*, *M. mulatta*, *M. cf. andersoni*, *Pongo pygmaeus*, *Hystrix* cf. *brachyura*, *Rhizomys troglodytes*. According to the authors, the two faunas belong to the Middle Pleistocene. After

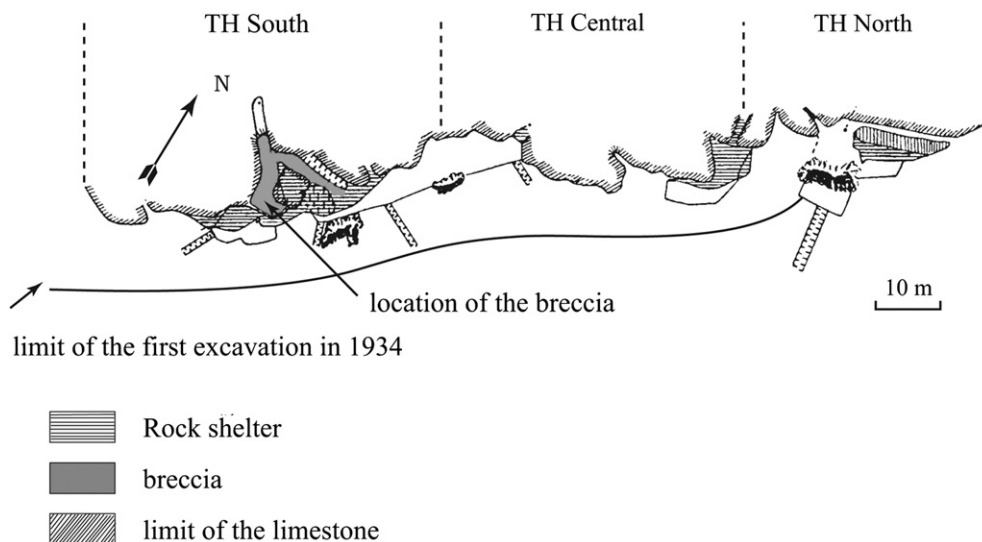


Fig. 2. Map of the Tam Hang site showing the three localities (modified from Fromaget, 1940b).

revision of a part of the material, *Beden et al.* (1972) added *Dicero-rhinus sumatrensis* to both faunal lists of the TH South and TH Central deposits. Tam Hang is thus an exceptional site in mainland Southeast Asia, as two localities, South and Central, produced two distinct diversified faunas (*Arambourg and Fromaget, 1938*) of middle- to large-sized mammals. These faunas are characteristic of the “*Stegodon-Ailuropoda* faunas”, which are known from the Early Pleistocene to the beginning of the Late Pleistocene in the Indo-chinese province.

After sixty years, the exact location of the site was lost, and several months of investigation were needed for one of the present authors, Thongsay Sayavongkhamdy, to re-locate it. In 2003, excavations at the site were re-opened by the authors. During the first fieldwork season, the Tam Hang South locality yielded 575 isolated mammalian teeth. Twenty-four taxa were listed, among which 14 species and 5 subspecies, the other 5 taxa being defined at the generic level (*Bacon et al., 2008a*). In comparison with the faunal list drawn up by *Arambourg and Fromaget (1938)*, excavation in 2003 recovered most of the taxa already identified, except *Stegodon orientalis*, *Megatapirus augustus* and *Elephas namadicus* (although *Elephas* is present), and the rat species *Rhizomys sinensis*. *Dicero-rhinus sumatrensis* was not identified in the material, and the authors do not recognize the three species of *Macaca*. New species added to the older list are *Prionailurus cf. bengalensis*, *Viverra zibetha*, the possible *Martes flavigula*, a gibbon and some colobines. In this preliminary report, five archaic subspecies were also listed. Some are attributed to the taxa already described in the literature: *Ursus thibetanus cf. kokeni*, *Arctonyx collaris cf. rostratus*, *Cuon*

*alpinus cf. antiquus* (*Matthew and Granger, 1923; Colbert and Hooijer, 1953*). Some others which have not been identified before were proposed, namely *Muntiacus muntiacus* ssp. and *Panthera tigris* ssp. (*Bacon et al., 2008a*).

This paper presents the original information collected during the fieldwork season in 2007 at Tam Hang South, the last one for this locality. First, the geological context lacking in the preliminary report (*Bacon et al., 2008a*) is presented. Study of the palaeontological record is completed with the description of the new fossil specimens. These consist of 404 isolated teeth, assigned to 30 taxa (18 species, 5 subspecies, 4 indeterminate species, and 3 taxa attributed only to family or subfamily level). In particular, certain archaic species were found that were not recovered in the earlier excavation (*Bacon et al., 2008a*), but were mentioned in the earlier faunal list by *Arambourg and Fromaget (1938)*. New taxa are also recorded for the first time from TH South: specifically five small carnivorans and one rodent species. Secondly, the overall Tam Hang South fauna is compared to the Middle to Late Pleistocene faunas from the Indochinese province, which are the only well-documented ones in the literature: Yenchingkuo in China (*Matthew and Granger, 1923; Colbert and Hooijer, 1953*), Phnom Loang in Cambodia (*Béden and Guérin, 1973*), Thum Wiman Nakin in Thailand (*Tougard, 1998*), Lang Trang (*de Vos and Long, 1993*), Duoi U’Oi and Ma U’Oi in Vietnam (*Bacon et al., 2004, 2006, 2008b*). The focus is on evolutionary aspect. A new biochronological framework is proposed, which is all the more important as well-dated faunas are rare, and the radiometric framework for the Indochinese province is still poorly-documented for this time period.

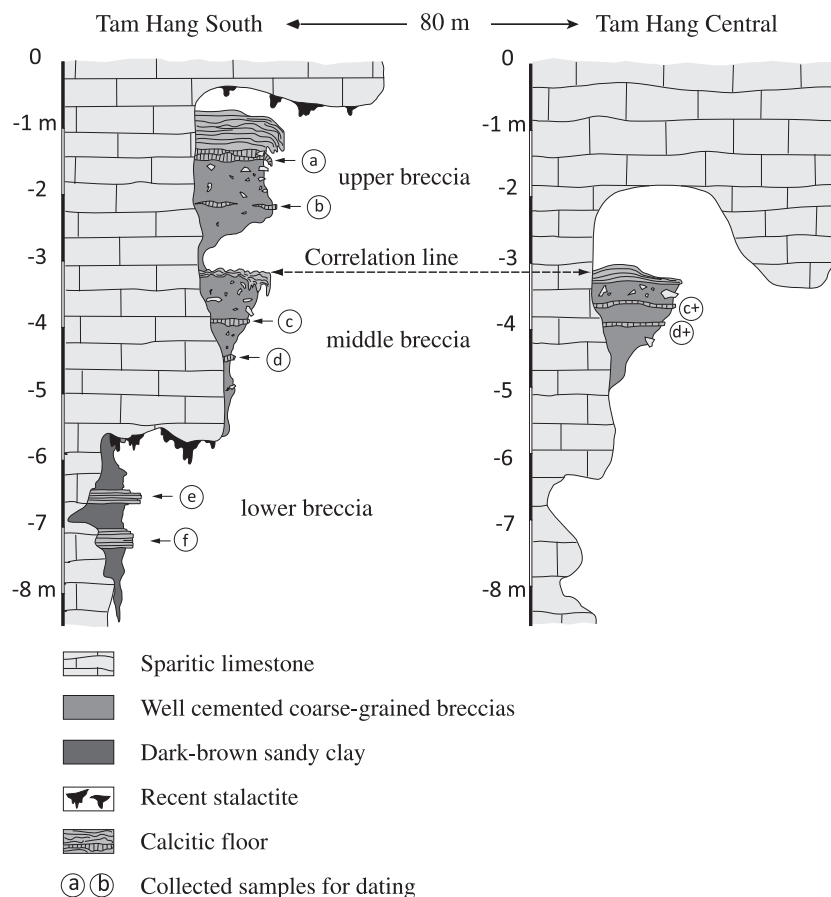


Fig. 3. Stratigraphy of the Tam Hang South and Tam Hang Central localities.

**Table 1**  
U/Th concentrations and activity ratios for the two carbonate samples “a” and “d”.

Carbonate sample	a	d1	d2
[U] ppb	40.1	19.8	20.5
[Th] ppb	43.4	17.3	15.8
$(^{230}\text{Th}/^{232}\text{Th})$	1.80	3.5	3.10
$(^{234}\text{U}/^{238}\text{U})$	1.208	1.232	1.236

## 2. New data from Tam Hang South

### 2.1. Geology

#### 2.1.1. Location and geological context

The Tam Hang site is located in the northeastern part of Laos about 260 km NNE from Vientiane, and 135 km ENE from Luang Prabang, the main town in the area. The mountains belong to the northern Annamitic Chain, oriented broadly from NNW to SSE. The oldest rocks of the area consist of Palaeozoic granite and diorite. These rocks are covered with a widespread sedimentary formation characterised by a grey to yellow argillaceous poorly cemented arkosic sandstone dated to the Silurian. Both granite and sandstone from the Palaeozoic basement are covered by a thick limestone unit deposited during the uppermost Triassic (Middle Indosinias). The stratigraphic column is dislocated by numerous vertical faults that often laterally bring the three major formations into contact on a same level (especially Silurian sandstones and Triassic limestones).

The limestone unit consists of structureless sparitic dark-grey carbonate without marl intercalation. It crops out in the form of large to small tower karsts on a scale of hectometres to kilometres, separated by the strongly-weathered Palaeozoic basement rocks (granite or arkosic sandstone) over a large surface area. Because of the strong erosion, especially dissolution by vertically-moving water processes during the last million years, the limestone unit displays numerous sinkholes, cavities and caves, showing a large variety of karstic fills. The Pleistocene and Holocene residual breccias which occur on the ground, wall and roof of the caves, indicate a succession of sedimentary infills and erosion phases depending on the climate variations and general uplift of the

region. The occurrence of palaeocurrents in the adjacent caves suggests that water streams flowed, both inside and outside, in the same cavity during the time. Many caves, situated at the highest level of the tower karsts, up to around 40 m above the Tam Hang site, are filled with typical fluvial well-rounded conglomerates, partly composed of Palaeozoic basement material.

#### 2.1.2. Analysis of the sedimentary fill and dating

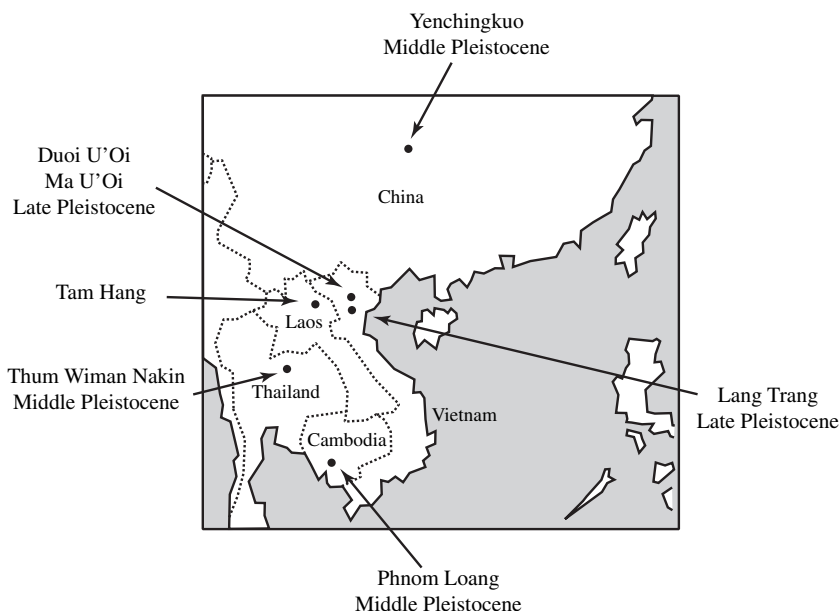
The Tam Hang site is located at the basal part of a vertical cliff about 100 m long, 60 m high. It is situated on the eastern side of the large tower karst of Pà Hang. Along the cliff are discontinuous cavities forming the rock shelters, some continuing towards the inside of the mountain in small caves.

The majority of the fossiliferous layers were partially excavated in the 1930s by Fromaget, who distinguished two breccias, Tam Hang South and Tam Hang Central, of different palaeontological contents. The two localities located at the same level are separated by a distance of about 80 m (Fig. 3). The remaining breccia from Tam Hang Central was very poor in vertebrate remains, and therefore only the breccia from Tam Hang South was excavated.

The TH South middle and upper breccias display a large range of facies including coarse to fine angular to rounded limestone clasts (up to 20 cm), iron-rich pisolites and a dense network of secondary calcitic veins. Both breccias are well-cemented by calcite and red brown clay. The sedimentary levels contain particle concentrations as limestone clasts from the Indosinias substratum, as well as pisolite-rich laminae, bones and teeth fragments, and quartz grains. Because of their high calcite content and their hard cemented nature, these breccias were difficult to excavate.

The lower breccia is very different, as it is dark brown with sandy clay content. Due to the lack of secondary calcite cementation, as is the case for middle and upper breccias, its excavation was very easy. The most complete and well-preserved teeth and fragmentary jaws come from this lower breccia.

For the Uranium–Thorium (U/Th) dating of the calcitic floors in the three breccias, six carbonate levels were sampled (Fig. 3), following the approach pioneered by Kaufman and Broecker (1965) for marine carbonate and biogenic formations. Two of the six carbonate samples (“a” and “d” composed of sub-samples “d1 and d2”) were selected for a first age determination on the basis of



**Fig. 4.** Location of the reference sites from the Middle and Late Pleistocene Southeast Asia.

mineralogical and petrological criteria, and analysed using the technique described in Granet et al. (2007), and Pelt et al. (2008). For these two carbonates, the low U/Th ratios and the high  $^{230}\text{Th}/^{232}\text{Th}$  activity ratios imply that both samples contain a large amount of initial detrital Th, which avoids any age determination of the carbonate sample from a single  $^{238}\text{U}/^{234}\text{U}/^{230}\text{Th}$  disequilibrium measurement Table 1. This scenario is very common for many continental carbonates (e.g., Chabaux et al., 2003, 2008). Additionally, the U/Th concentrations analysed for the four other carbonates by ICP-MS techniques confirm this (Fig. 3). The U/Th dating of all the carbonate units sampled for this work will therefore require the use of more complex approaches, such as the so-called “dirty carbonate” dating methods (Chabaux et al., 2008), which is beyond the scope of this present study.

### 2.1.3. Interpretation of the sedimentary processes

The deposits of the breccias are objectively linked to the cave fill processes, although they are now only preserved on the walls of the rock shelter. The presence of large limestone blocks in front of the rock shelter, and at the periphery of the tower karsts, indicates a succession of large rock collapses. Thus, the rock shelters are the result of the natural evolution of the relief, which exposed the walls of the caves.

The sedimentary succession shows at least two fill phases. The deposit of the lower breccia seems to be linked to the fill of a cave intermittently submerged, beneath the fluvial base level. It consists principally of sandy clays transported by moderate water flows, and deposited during calm periods (dry seasons). The two clearly distinguished calcitic floors could represent the intermittent fall of these water flows, or the water level of small pools in the cave (potential air exposure with slow water running downwards that allows calcite precipitation).

The two upper breccias with their coarse-grained pisolites and large limestone clasts up to 20 cm, mostly angular, are typical of deposits formed under strong water flows in caves which are situated above the alluvial plain level. Because of the absence of continuous outcrops in the rock shelters, it is not possible to determine the water direction during the process of sedimentation. However, the presence in the deposits of angular and unsorted limestone clasts, and the complete absence of rounded pebbles, suggest water flows from the inside to the outside of the caves by typical karstic processes during floods. Most of the vertebrate remains were concentrated at the bases of the small sedimentary sequences.

## 2.2. Palaeontology

### 2.2.1. Methodology

The TH South breccia was excavated using a hammer and chisel. In certain areas, the breccia was hard and highly encrusted, and so the removed sediment was crushed into small fragments. Then, the sediment was sieved in order to collect small mammals and microvertebrates, in addition to middle- and large-sized mammals. That is probably why many isolated teeth of small-sized mammals (mustelids, viverrids, felids and one rodent) were found, absent from the species list of Arambourg and Fromaget (1938). Indeed, taking into account the conditions of excavation of archaeological sites in the 1930s, it is very unlikely that Fromaget would have systematically used sieves in order to recover smaller elements. During the second fieldwork season, the lower breccia, which consists of a less calcified deposit, also was excavated.

### 2.2.2. Description and comparison

This section first describes the morphology of the new TH South specimens, and their systematic affinity. These specimens consist of

404 isolated teeth of middle- to large-sized mammals: Artiodactyla (cervid, bovid and suid), Perissodactyla (rhinocerotid and tapirid), Proboscidea (elephantid and stegodontid), Carnivora (mustelid, canid, viverrid, felid and ursid), Rodentia (hystricid and murid), and Primates (cercopithecoid, colobid, hylobatid and pongid).

Secondly, for each species, the overall material from the Tam Hang South site recovered during the two fieldwork seasons (that of the 2003 fieldwork season is published in Bacon et al. (2008a), and the new material is presented here) is compared with specimens of the well-documented faunas, whose morphological description and dimensions are available in the literature. The five Indochinese faunal assemblages in question are that of the Phnom Loang site in Cambodia dated to the late Middle Pleistocene (Carbonel and Guth, 1968; Beden et al., 1972; Beden and Guérin, 1973) and Holocene (Thein, 1974); Thum Wiman Nakin site in Thailand (Ginsburg et al., 1982; Chaimanee and Jaeger, 1993; Chaimanee, 1998; Tougaard, 1998, 2001), estimated by both the composition of the fauna and the radiometric dating ( $169 \pm 11$  ka,

**Table 2**

Dimensions of the Tam Hang South well-preserved teeth attributed to Artiodactyla: *Cervus unicolor*, *Muntiacus muntjak*, *Naemorhedus sumatraensis*, *Bubalus cf. bubalis*, *Bos cf. sauveli* (N: effectives, ranges of length and width).

Teeth	N	Length	Width
<i>Cervus unicolor</i>			
D3	1	23.8	18
D4	1	21.5	18.9
P3	3	14.7–16.9	17.3–18.6
P4	1	16.8	18.1
M1/M2/M3	3	18.6–25.9	24.7–25.8
d2	1	17.8	9
d3	6	17.1–23	8.5–11.8
d4	3	28.3–35.3	14.1–15.8
p2	14	12.3–15.1	7.1–10.6
p3	2	13.4–16.9	8.9–10.8
p4	4	17.3–20.9	10.8–11.7
m1	5	19.4–20.9	13.7–15.1
m2	4	23.5–25.6	16–16.8
m3	1	35.9	18.1
<i>Muntiacus muntjak</i>			
D4	8	10.3–12.5	12.6–13.9
P2/P3	7	8.7–10.5	8.4–11.3
P4	7	7.7–10	10.4–13
M1/M2/M3	11	12.4–14.4	13.9–16.3
d4	2	14.7–16.3	6.7–7.8
p2	1	8.2	4.9
p3/p4	3	9.8–10.8	5.7–6.2
m1/m2	9	12.6–15.4	8.1–10.6
m3	8	17.8–20.7	8.5–9.3
<i>Naemorhedus sumatraensis</i>			
P4	1	11.7	13.3
M1/M2	2	15.2–20.4	16.3–19.2
M3	1	22.7	15.2
m1/m2	1	15.7	12.6
m3	1	24.3	11.3
<i>Bubalus cf. bubalis</i>			
M1/M2/M3	3	21.3–31.6	23.5–24.7
p2	1	16.8	12.3
p3	1	22.2	14.4
p4	1	17.3	11.8
m1/m2	3	24.4–30.6	18.3–19.1
m3	1	44.4	19.4
<i>Bos cf. sauveli</i>			
D3	1	29.1	21.5
P2	1	16.3	11.9
P3	2	20.4–20.8	11.4–12.4
P4	1	17.2	22.6
M2/M3	1	22.1	23.9
p2	2	12.8–15.4	9.6–10.5
p3/p4	5	22–26.2	13.1–14.1
m1/m2	3	25.5–29.7	14.9–20.3
m3	2	37.8–44.9	16.5–20.1



U/Th) to the late Middle Pleistocene (Esposito et al., 1998, 2002); and the Middle Pleistocene Yenchingkuo site in southern China (Matthew and Granger, 1923; Colbert and Hooijer, 1953) (Fig. 4). The three Late Pleistocene sites are that of Lang Trang which yielded a mammalian fauna dated to between 100 ka and 80 ka old (de Vos and Long, 1993; Long et al., 1996), that of Duoi U'Oi from northern Vietnam which yielded a modern fauna whose bio-chronological age is consistent with the Uranium series dating of  $66 \pm 3$  ka (Bacon et al., 2008b), and that of Ma U'Oi, older than  $47 \pm 4$  ka (Bacon et al., 2004, 2006).

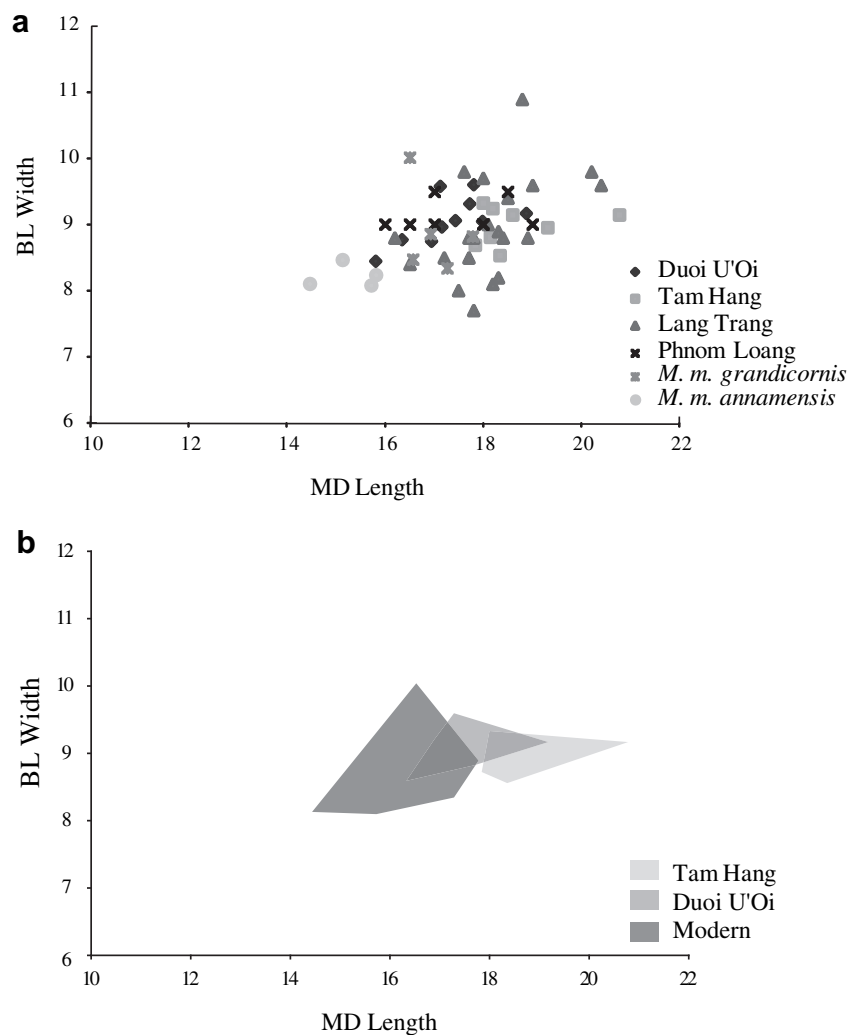
### 2.2.2.1. Artiodactyla

2.2.2.1.1. *Cervus unicolor*. The new specimens of *Cervus unicolor* Kerr, 1792, are represented by both elements of lower and upper dentition with 12 deciduous teeth, and 36 permanent premolars and molars (Table 2). All these elements resemble modern cervids, as already noted in Bacon et al. (2008a): the upper and lower molars have well-developed bilobate, even trilobate, entostyles, and bilobate ectostylids, well-developed styles and pillars, an anterior well-marked goat fold, and rugose enamel. The p3 are not molariform. The p4 presents a partial molarisation. The six new deciduous d4s have salient stylids, and very large columns are commonly present on the buccal side.

Considering all the teeth, there is a large overlap between populations from the different sites.

2.2.2.1.2. *Muntiacus muntjak*. Forty-three new teeth (8 deciduous and 35 permanent), some of which are fragmentary, are attributed to *Muntiacus muntjak* (Zimmerman, 1780). As noted previously (Bacon et al., 2008a), there are some differences between the teeth of Tam Hang South and those of Phnom Loang (Thein, 1974), and Duoi U'Oi (Bacon et al., 2008b) in the frequency of some features. However, this observation needs to be confirmed by additional material.

The dimensions of the Tam Hang teeth overlap largely with those of the Phnom Loang sample (Thein, 1974), Thum Wiman Nakin (Tougaard, 1998) and Lang Trang (de Vos and Long, 1993). However, the muntjac sample from Yenchingkuo (*Muntiacus muntjak margae*) cannot be included in this comparison, as the published measurements concern the rows of teeth rather than isolated teeth (Colbert and Hooijer, 1953). The dimensions of the Tam Hang teeth exceed those of Duoi U'Oi (Bacon et al., 2008b), and also those of two samples of modern populations (*Muntiacus muntjak grandicornis* from Myanmar, and *Muntiacus muntjak annamensis* from Vietnam), as shown in the Fig. 5a for the m3. The greatest difference is observed in the length of the crown (Fig. 5b). The comparison between the D4s dimensions from Tam Hang, Duoi U'Oi and the two modern samples, further emphasises these size



**Fig. 5.** (a) m3 length and width of *Muntiacus muntjak* from Duoi U'Oi (*M. muntjak* ssp.2) ( $n = 11$ ) (Bacon et al., 2008b), Tam Hang (*M. muntjak* ssp.1) ( $n = 8$ ), Lang Trang (*M. muntjak*) ( $n = 21$ ) (de Vos and Long, 1993), Phnom Loang (*M. muntjak*) ( $n = 8$ ) (Thein, 1974), and two modern populations, *M. m. grandicornis* from Myanmar ( $n = 5$ ), and *M. m. annamensis* from Vietnam ( $n = 4$ ). (b) Comparison between the m3 ranges of variation of Tam Hang and modern populations.

differences (Fig. 6). This suggests the presence at Tam Hang of a subspecies different from that which is present at Duoi U'Oi. These are referred to here as *Muntiacus muntjak* ssp.1 and *Muntiacus muntjak* ssp.2, respectively.

2.2.2.1.3. *Naemorhedus sumatraensis*. Four new teeth are attributed to the small bovid species *Naemorhedus sumatraensis* (Bechstein, 1799), on the basis of characteristic morphological traits, namely simple dental pattern with smooth enamel, styles and stylids more prominent than the pillars of the cuspids.

Overall, the dimensions of the teeth are comparable to those from Phnom Loang (Thein, 1974), and Lang Trang (de Vos and Long, 1993). The data do not justify an assignment to the extinct subspecies *Naemorhedus sumatraensis kanjereus* however, which is known from Yenchingkuo (Colbert and Hooijer, 1953), and probably also from Thum Wiman Nakin (Tougaard, 1998) (*N. s. cf. kanjereus*).

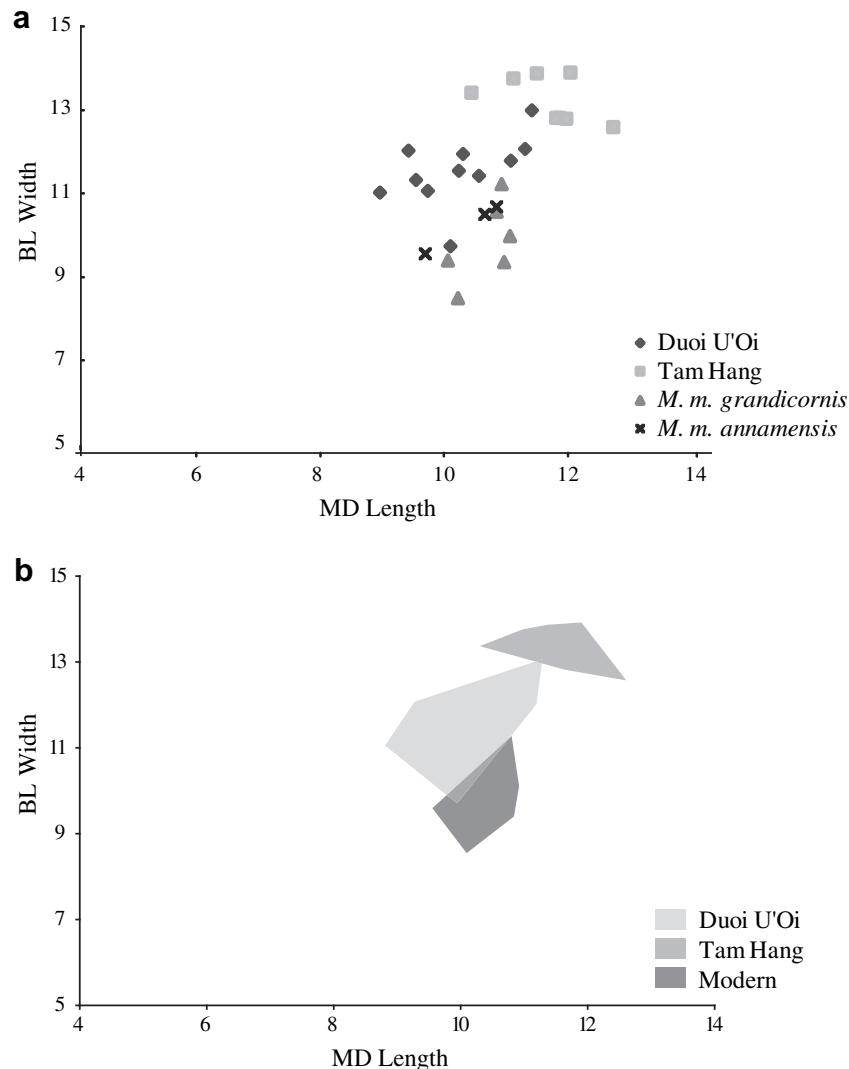
2.2.2.1.4. *Bubalus bubalis*. Among the bovids, sixteen new teeth can be attributed to the large species *Bubalus bubalis* (Linnaeus, 1758). Some worn and fragmentary teeth could only be attributed to *B. cf. bubalis*. Overall, the cones, conids, and pillars of the cuspids are more massive and voluminous in *Bubalus* than they are in *Bos*. The teeth present a complex dental pattern, notably with

a relatively folded infundibulum on the upper molars, and the U shape of the protoconid and hypoconid on the lower molars. The columns (entostyle and ectostylid) between the cuspids are not bilobed. On one molar, the entostyle appears fused to the lobes. The second column on the m3 is absent.

The dimensions of all the *B. bubalis* teeth are comparable to the other fossil data from Phnom Loang (Thein, 1974), Lang Trang (de Vos and Long, 1993), Yenchingkuo (Colbert and Hooijer, 1953) and Thum Wiman Nakin (Tougaard, 1998).

#### 2.2.2.1.5. *Bos cf. sauveli*

It is difficult to differentiate between the four species of *Bos* (*B. sauveli*, *B. javanicus*, *B. frontalis*, *B. gaurus*) on the basis of the morphology of the molars, this latter being homogeneous within the genus (Thein, 1974). Some of the premolars are more useful for the species assignment than others. Thus, nine new elements are assigned to *Bos cf. sauveli* Urbain, 1937, particularly on the basis of two complete and unworn p4s which conform to the known morphology of this species. The rounded valley between the metaconid and the entoconid is specific to *Bos sauveli*, the other species possess a valley with a more angular outline (Thein, 1974).



**Fig. 6.** (a) D4 length and width of *Muntiacus muntjak* from Duoi U'Oi (*M. muntjak* ssp.2) ( $n = 11$ ) (Bacon et al., 2008b), Tam Hang (*M. muntjak* ssp.1) ( $n = 8$ ), and two modern populations, *M. m. grandicornis* from Myanmar ( $n = 5$ ), and *M. m. annamensis* from Vietnam ( $n = 4$ ). (b) Comparison between the D4 ranges of variation of *Muntiacus muntjak* from Tam Hang, Duoi U'Oi, and from modern populations.

The dimensions of the teeth of *B. sauveli* are comparable to those from Thum Wiman Nakin (Tougaard, 1998). Metric data are scarce, and thus provide little further information.

Finally, in the previous record (Bacon et al., 2008a), *Bos sauveli* was considered as overrepresented (17 teeth) in comparison with *Bubalus bubalis* (6 teeth). The new record illustrates that both species are equally well-represented, with 29 and 23 isolated teeth respectively.

#### 2.2.2.1.6. *Sus scrofa*

Numerous teeth are assigned to the suid *Sus scrofa* Linnaeus, 1758, (7 deciduous and 57 permanent), and only to *S. cf. scrofa* when dental remains are fragmentary. One incomplete lower jaw with highly worn teeth is also recorded. In general, the teeth of *S. scrofa* have smooth enamel and the molars present numerous accessory tubercles with characteristic star-like folds. The cingulum presents also numerous styles and stylids.

The tooth dimensions of *Sus scrofa* from the Duoi U'Oi, Tam Hang, and Lang Trang samples (de Vos and Long, 1993; Bacon et al., 2008b) are comparable in size (Table 3). However, some differences between them were observed, with distinctions between the size

**Table 3**

Dimensions of the Tam Hang South well-preserved teeth attributed to Artiodactyla, *Sus scrofa*, *Sus cf. barbatus*; Perissodactyla, *Rhinoceros unicornis*, *Rhinoceros sondaicus*, *Rhinoceros sp.*, *Tapirus indicus intermedius*, *Megatapirus augustus*; Proboscidea, *Elephas sp.* and *Stegodon orientalis* (N: effectives, ranges of length and width, H: height, P: number of lamellae).

Teeth	N	Length	Width
<i>Sus cf. scrofa</i>			
D3	2	14.2–14.4	9.5–10
D4	4	14.4–16.3	11.9–13.1
P1	5	8.1–10.6	3.4–5.1
P2	5	12.4–13.6	6.6–8.2
P3	4	11.4–14.2	10.1–11.1
P4	9	11.8–14.3	13.6–16.6
M1	3	18.1–18.8	13.9–14.6
M2	6	18.7–23.4	15.7–19.4
M3	2	37.4–42	20.8–22.7
p1	3	8.8	3.4–4.1
p2	7	11.5–12.9	5.6–9.1
p3	13	10.1–14.1	6.9–10.8
p4	7	13.9–16.6	10.2–11.9
m1	10	15.9–19.9	11.7–14.4
m2	3	20.3–23.4	15.6–17
m3	4	39.1–41.9	16.2–17.4
<i>Sus cf. barbatus</i>			
D2	2	10.8–11	5.4–6.2
D3	1	14.5	8.8
M2	1	24.8	20.6
M3	2	33.6–44.3	18.6–22.5
p2	5	11.3–12.5	5.1–5.7
p4	4	14.1–16.5	8.5–10.8
m2	1	22	14.6
<i>Rhinoceros unicornis</i>			
d1	3	21–22.5	11–11.5
d2	1	(32)	17
<i>Rhinoceros sondaicus</i>			
d1	3	18–19.5	9.5–10
d2	3	28–30	15.5–17
m2	1	49	30
<i>Rhinoceros sp.</i>			
d4	2	42.5–43	21.5–23.5
<i>Tapirus indicus cf. intermedius</i>			
p2	2	27.4–27.5	16.5–16.7
m2	1	26	20.8
<i>Megatapirus augustus</i>			
m2	1	34.1	25.8
<i>Elephas sp.</i>			
M	1	103.9	62.4 (H = 161.4, P = 8)
<i>Stegodon orientalis</i>			
D4	1	>100	58 (H = 40, P = 5+)

ranges of the Duoi U'Oi and Lang Trang teeth, and the size range of the Tam Hang Teeth. These differences are slight for the m3, but particularly notable for the M2 (Fig. 7). The dimensions of the Tam Hang molars are smaller than those of Duoi U'Oi, possibly suggesting the presence of two distinct subspecies: ?*Sus scrofa* ssp.1 at Tam Hang, and ?*Sus scrofa* ssp.2 at Duoi U'Oi. The M2 data indicate that the subspecies present at Lang Trang could be the same than that at Duoi U'Oi (Fig. 7).

#### 2.2.2.1.7. *Sus cf. barbatus*

*Sus barbatus* Müller, 1838, and *Sus scrofa* Linnaeus, 1758, are morphologically similar to each other, and so distinguishing between these species is sometimes difficult. However, *Sus barbatus* with 3 deciduous and 15 permanent identified teeth presents a more dental complex pattern with accessory tubercles. The other feature which distinguishes *S. barbatus* from *S. scrofa* is the rugose enamel on the molars.

No size differences can be noted between *S. barbatus* from Tam Hang, Thum Wiman Nakin (Tougaard, 1998) and Duoi U'Oi (Bacon et al., 2008b), which are the the only three continental sites where this species is identified at present.

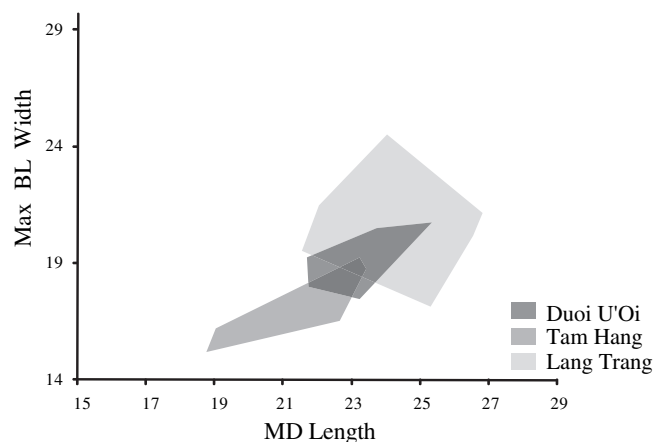
2.2.2.2. *Perissodactyla*. Two d4s are referred to *Rhinoceros sp.* and seven tooth fragments are identified at the subtribe level only (*Rhinocerotina* indet.).

#### 2.2.2.2.1. *Rhinoceros unicornis*

In the new collections, only two d1s of *Rhinoceros unicornis* Linnaeus, 1758, have been recovered at Tam Hang. These teeth are large, possessing a wide talonid, a simple lophid pattern, and a shallow posterior valley, that is open on the lingual side (Fig. 8).

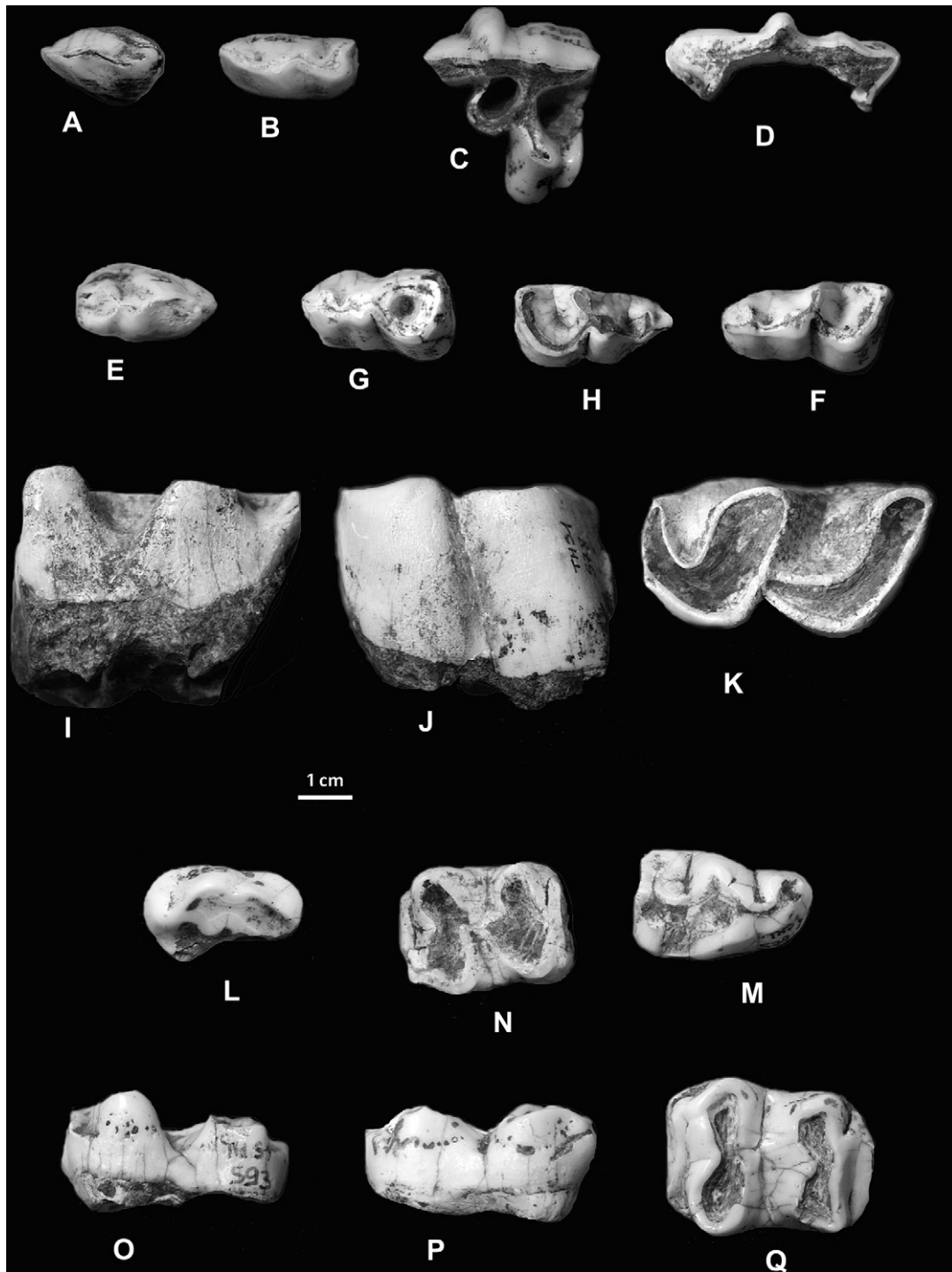
#### 2.2.2.2.2. *Rhinoceros sondaicus*

The previous material only consisted of one d2 (Bacon et al., 2008a). *Rhinoceros sondaicus* Desmarest, 1822, is now represented by nine additional deciduous teeth (3 d1, 3 d2, 2 D2, and 1 D3) and one m2 (Fig. 8). In comparison with the d1s of *R. unicornis*, the d1s of *R. sondaicus* are smaller. They have a posterior valley that is open posteriorly, a complicated lophid pattern, and a narrower talonid. The three d2s display the same pattern as the d2 referred to as *R. unicornis* by Bacon et al. (2008b), but they are much smaller and narrower, i.e. falling within the size range of *R. sondaicus* but exceeding that of known specimens representing *Dicerorhinus sumatrensis* (Guérin, 1980). The paralophid is forked, and the paracoid forms a huge bulk. The posterior valley is open lingually in two specimens, but closed in the third one. The upper milk teeth (D2 and D3) belong to a single taxon: in occlusal view, the ectoloph is plicated, with a huge protocone fold, or a salient mesostyle. Such



**Fig. 7.** M2 length and width of *Sus scrofa* from Duoi U'Oi (*S. scrofa* ssp.1) ( $n = 12$ ) (Bacon et al., 2008b), Tam Hang (*S. scrofa* ssp.2) ( $n = 6$ ), and Lang Trang (*S. scrofa*) ( $n = 46$ ) (de Vos and Long, 1993).





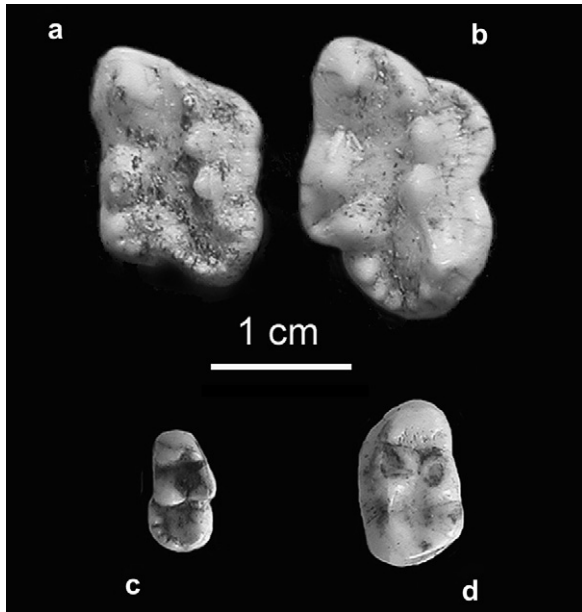
**Fig. 8.** Perissodactyl remains from Tam Hang South (fieldwork 2007). *Rhinoceros unicornis*. A. Left d1 (TH588), occlusal view. B. Left d1 (TH599), occlusal view. *Rhinoceros sondaicus*. C. Left fragmentary D2 (TH596), occlusal view. D. Right fragmentary D3 (TH585a), occlusal view. E. Left d1 (TH586), occlusal view. F. Left d2 (TH581), occlusal view. G. Left d2 (TH590), occlusal view. H. Right d2 (TH592), occlusal view. Left m2 (TH578), in lingual (I), buccal (J), and occlusal views (K). *Tapirus indicus* cf. *intermedius*. L. Left fragmentary P2 (TH598), occlusal view. M. Right p2 (TH579), occlusal view. N. Left m2 (TH597), occlusal view. *Megatapirus augustus*. Right m2 (TH593) in lingual (O), buccal (P), and occlusal views (Q).

profiles only match *R. sondaicus* (Guérin, 1980: 61, Fig. 6). The m2 without constriction or cingulid is undistinguishable from Southeast Asian fossil or recent specimens referred to *R. sondaicus* by Guérin (1980) and Bacon et al. (2004, 2006).

#### 2.2.2.2.3. *Tapirus indicus* cf. *intermedius*

Not recovered previously, the Malayan tapir, *Tapirus indicus* Desmarest, 1819, is documented by four permanent upper and

lower cheek teeth (2 p2, 1 P2, 1 m2), among which one of the p2, eroded, was previously misidentified and referred to *Rhinoceros sondaicus* (Bacon et al., 2008b). Both p2s have elongated triangular occlusal outlines, with thick enamel, which allows us to identify them as lower permanent p2 rather than lower deciduous d2. Their dimensions fall well within the size range provided by Hooijer (1947) for *Tapirus indicus intermedius*, i.e. much smaller than the



**Fig. 9.** Some carnivores remains from Tam Hang South. (a) Right M1 of *Arctonyx colaris* cf. *rostratus* (TH120), (b) Right M1 of *Meles meles* (TH120), (c) Right m1 of *Melogale personata* (TH883), (d) Left m1 of *Paradoxurus hermaphroditus* (TH884).

p2 of *Megatapirus augustus*, the teeth of both taxa being almost indistinguishable on a morphological grounds (Colbert and Hooijer, 1953; Tong, 2005). The fourth tooth, a lower bilophodont m2, is described below in comparison with the other m2 (Fig. 8).

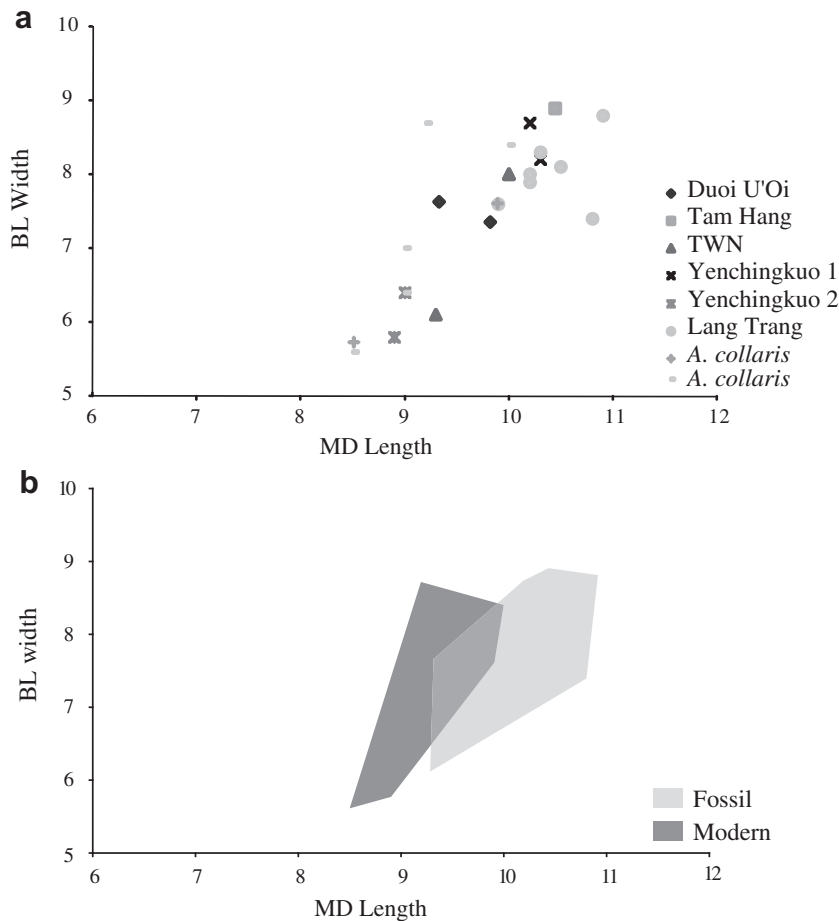
#### 2.2.2.4. *Megatapirus augustus*

The extinct giant tapir, *Megatapirus augustus* Matthew and Granger, 1923, is identified in the new record by a single right bilophodont m2 (Fig. 8). Although the proportions and morphological features of the two available tapir lower molars are quite similar (hypolophid narrower than the metalophid; wide talonid; no prominent hypoconulid; Tong et al., 2002), the size contrast is striking: one m2 (34.1 × 25.8 mm) is 25% larger than the second m2 (26.0 × 20.8 mm) and both teeth fall within size ranges provided by Colbert and Hooijer (1953) for *M. augustus* and *T. indicus*, respectively. They are identified as m2s due to a contact-facet in their posterior side (precluding m3), and the hypolophid being much narrower than the metalophid (precluding m1 and further indicating that these specimens are m2s).

#### 2.2.2.3. Proboscidea

##### 2.2.2.3.1. *Elephas* sp.

Three isolated lamellae of *Elephas*, one belonging to a permanent molar and the two others to milk teeth, have been found during the second excavation season at Tam Hang South. The incomplete lamella, straight and high, with thin enamel (2.6 mm), suggests a permanent upper molar of *Elephas* (Maglio, 1973; van den Bergh, 1999). The two other small elements are slightly curved lamellae of deciduous teeth. The specific attribution to



**Fig. 10.** (a) P4 length and width of *Arctonyx collaris* from Duoi U'Oi (*A. collaris*) ( $n = 2$ ) (Bacon et al., 2008b), Tam Hang (*A. c. cf. rostratus*) ( $n = 1$ ), Thum Wiman Nakin (TWN) (*A. c. rostratus*) ( $n = 3$ ) (Tougaard, 1998), Yenchingkuo 1 (*A. c. rostratus*) ( $n = 2$ ) (Colbert and Hooijer, 1953), Lang Trang (*A. collaris*) ( $n = 7$ ) (de Vos and Long, 1993), and three modern populations from Thailand ( $n = 2$ ), China ( $n = 5$ ), and Yenchingkuo 2 from China ( $n = 2$ ) (Colbert and Hooijer, 1953). (b) Comparison between the P4 ranges of variation of fossil and modern samples.

**Table 4**

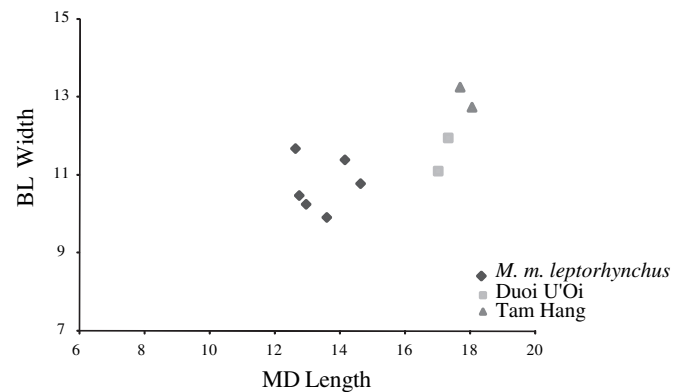
Dimensions of the Tam Hang South well-preserved teeth attributed to Carnivora, *Arctonyx collaris* cf. *rostratus*, *Meles meles*, *Melogale personata*, *Cuon alpinus* cf. *antiquus*, *Viverra zibetha*, *Paradoxurus hermaphroditus*, *Prionailurus* cf. *bengalensis*, *Panthera tigris*, *Ursus thibetanus* cf. *kokeni*, *Helarctos malayanus*, and Primates, *Macaca* sp., colobid, *Hylobates* sp. and *Pongo pygmaeus* (N: effectives, ranges of length and width).

Teeth	N	Length	Width
<i>Arctonyx collaris</i> cf. <i>rostratus</i>			
P4	1	10.4	8.9
M1	1	15.8	10.8
p4	1	10.8	6.3
m1	1	–	8
<i>Meles meles</i>			
M1	2	17.6–18	12.7–13.2
m1	1	–	7.2
<i>Melogale personata</i>			
m1	2	8.5–9.3	4.4–4.9
<i>Cuon alpinus</i> cf. <i>antiquus</i>			
P1	1	6	4.5
P3	1	10.8	5.4
M1	2	11.7–14.1	16–16.6
p4	2	10.9–12.2	5.3–6.3
m2	1	8.1	6.4
<i>Viverra zibetha</i>			
M1	1	7	10.8
<i>Paradoxurus hermaphroditus</i>			
m1	1	10.8	6.5
<i>Prionailurus</i> cf. <i>bengalensis</i>			
m1	1	10.4	4
<i>Panthera tigris</i>			
P3	1	21.8	10.9
P4	1	24.9	–
p4	2	26.4–26.6	12.5–14.9
<i>Ursus thibetanus</i> cf. <i>kokeni</i>			
P4	5	11.7–13.9	8.8–9.6
M2	1	27.6	15.6
m1	1	22.1	10
m2	2	19.9–20.4	11.9–12.4
m3	1	15.1	12
<i>Helarctos malayanus</i>			
m1	1	16.4	9
m2	1	16.1	10.5
m3	1	12.2	11.2
<i>Macaca</i> sp.			
D2	3	7.5–8.2	7.1–7.2
P3	11	5.4–7	5.6–8
P4	7	5.6–6.6	6–8
M1/M2/M3	41	8–10.2	7.1–9.8
p3	5	9–11.6	5–6.4
p4	5	6.8–7.7	5.6–6
m1/m2	12	7.6–10	5.8–8.9
m3	7	10.1–13.7	7–9
Colobid			
M1/M2	2	5.9–7.6	6.2–6.8
<i>Hylobates</i> sp.			
P4	1	4.6	6.2
M2	1	6.3	6.2
p4	2	6.3–6.5	4.8
m2	1	8.2	6.8
<i>Pongo pygmaeus</i>			
M1	1	13.9	14.7
M1/M2	1	15.5	15

either *E. namadicus* or *E. maximus* is impossible, as noted previously for the two first recovered upper molars (Bacon et al., 2008a).

#### 2.2.2.3.2. *Stegodon orientalis*

Not recovered previously, the second set of proboscidean teeth consists of three elements with the characteristics of the genus *Stegodon* Owen, 1887. Two fragmentary and isolated lophs are ridge-shaped. The width of the enamel varies from 3.3 mm to 5.2 mm. The third specimen is a deciduous molar with the following characteristics: the crown is low and the occlusal surface slightly convex; the tooth presents five lophs, but it is incomplete



**Fig. 11.** M1 length and width of *Meles meles* from Tam Hang ( $n = 2$ ), Duoi U'Oi ( $n = 2$ ) (Bacon et al., 2008b), and one modern population of *M. meles leptorhynchus* (China, Tibet, North Vietnam) ( $n = 6$ ).

(the number of lophs is probably 6); the width of enamel is 3.7 mm; between two lophs, the valley has a “Y” shape (Osborn, 1942; Sondaar, 1984; van den Bergh et al., 1992). The morphology and the dental parameters (number of lamellae, lamellar frequency, height, length and width of the crown) suggest a D4 of *S. orientalis* (Hopwood, 1935; Colbert and Hooijer, 1953; van den Bergh, 1999).

#### 2.2.2.4. Carnivora

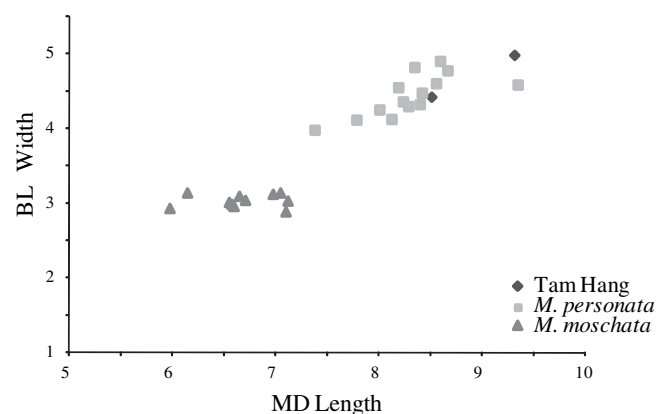
##### 2.2.2.4.1. *Arctonyx collaris* cf. *rostratus*

Three new teeth are attributed to the badger species *Arctonyx collaris* Cuvier, 1825, one large complete p4, and the fragmentary distal halves of two m1s, which display the same characteristics as those previously recovered (Bacon et al., 2008b), namely with small hypoconulid and hypoconid (Fig. 9).

Considering the overall teeth dimensions (Bacon et al., 2008b), only the size of the P4s suggests a cautious assignment to the extinct subspecies *Arctonyx collaris* cf. *rostratus* first described at Yenchingkuo (Colbert and Hooijer, 1953), and also known from Thum Wiman Nakin (Tougaard, 1998) (Fig. 10a). The main difference between the P4 of modern and fossil samples is on the mesiodistal length of the crown Table 4. The dimensions of the two M1 teeth are less convincing between modern and fossil samples (Fig. 10).

##### 2.2.2.4.2. *Meles meles*

A previous paper by Bacon et al. (2008b) questioned the great variability in dimensions and morphology (especially upper and lower first molars) among the 8 teeth of the melines. After a revision, it is proposed that this variability can be explained by the presence of two different species of the badger at Tam Hang:



**Fig. 12.** m1 length and width of *Melogale personata* from Tam Hang ( $n = 2$ ), and two samples of modern species, *M. personata* (Nepal, Myanmar, Thailand, Vietnam) ( $n = 15$ ), and *M. moschata* (South China, Myanmar, Vietnam, Hainan, Taiwan) ( $n = 11$ ).

*Arctonyx collaris* cf. *rostratus* and *Meles meles* (Linnaeus, 1758). In comparison with the upper M1 of *A. collaris*, those of *M. meles* have the two main buccal cusps (metacone and paracone) not aligned with the posterobuccal cone, this cusp being shifted towards the inner side of the crown (Fig. 9). The hypocone is developed. The crown is long mesiodistally. On the lower m1 of *M. meles*, the cusps are well-developed, especially the protoconid.

Compared with the modern subspecies *Meles meles leptorhynchus*, the badgers *M. meles* present at Tam Hang and Duoi U'Oi have larger tooth dimensions, as shown in Fig. 11.

#### 2.2.2.4.3. *Melogale personata*

*Melogale personata* Geoffroy Saint-Hilaire, 1831, the ferret-badger, is represented by two m1 teeth. The morphology of these lower molars is relatively simple and conforms to that of the modern species (trigonid composed of three well-developed cusps, talonid low, rounded and large). The dimensions of the molars fall into the range of variability of the modern *Melogale personata*, while the other species present on the Asian continent, *Melogale moschata*, is smaller (Figs. 10 and 12).

#### 2.2.2.4.4. *Paradoxurus hermaphroditus*

Only one tooth of a viverrid, an m1 of *Paradoxurus hermaphroditus* (Pallas, 1777), is identified. The cusps are low and have

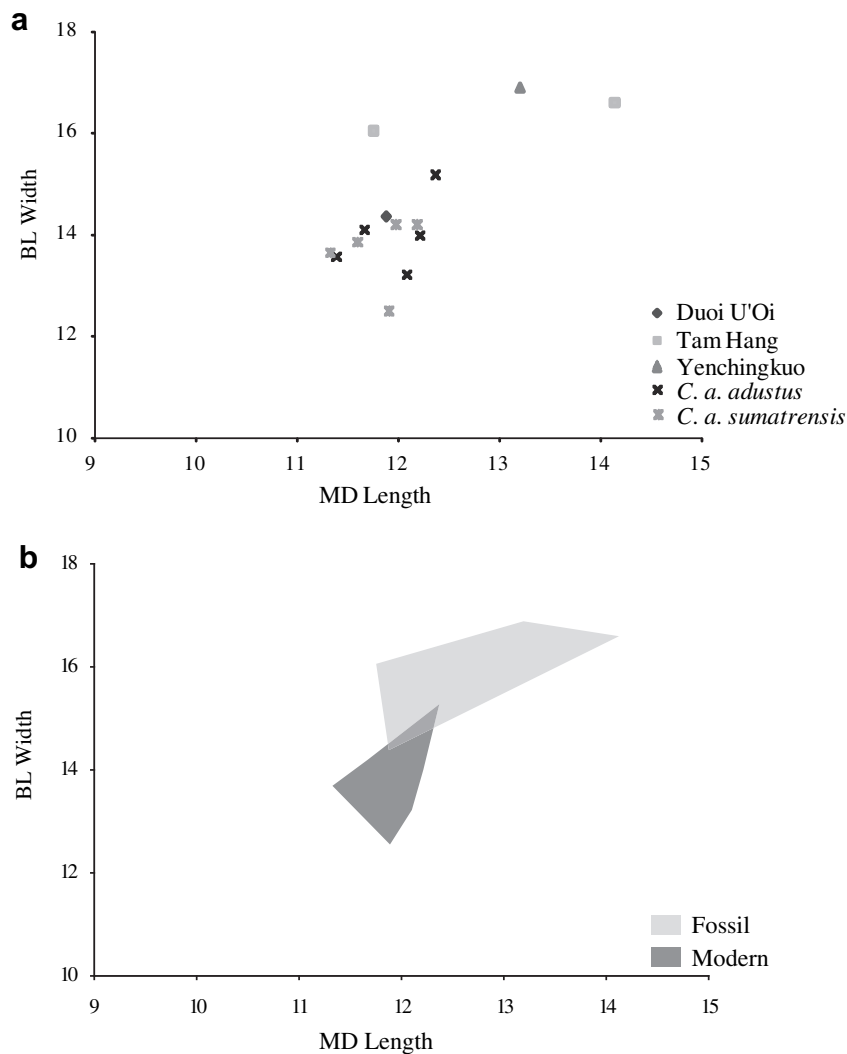
globular shape, and the talonid is rather flat with few developed cusps (Fig. 9).

#### 2.2.2.4.5. *Cuon alpinus* cf. *antiquus*

Four teeth (1C, 1M1, 1p4, 1m2) conform to the dental pattern of *Cuon alpinus* Pallas, 1811. The dimensions of these newly discovered teeth are not particularly large, except the M1. Indeed, this upper molar, along with the other one recovered in 2003, are close in size to the extinct subspecies described at Yenchingkuo *Cuon alpinus antiquus* (Colbert and Hooijer, 1953) (Fig. 13a). This comparable size and also the morphology (a large and well-developed paracone, a smaller metacone, parastyle and metastyle much less marked), allow cautious attribution to *C. alpinus* cf. *antiquus* (Bacon et al., 2008a). Comparatively, the size of the M1 from Duoi U'Oi is closer to those of the two modern samples represented by one subspecies from Myanmar *Cuon alpinus adustus*, and the other one from Malaysia *Cuon alpinus sumatrensis*. The fossil specimens are larger, both in length and width, than the modern ones (Fig. 13b).

#### 2.2.2.4.6. *Panthera tigris*

The felids are represented by two new canines, two upper incisors (I3) and two fragmentary premolars (one P4 and one p4), all of them conforming to the morphology of the modern tiger *Panthera tigris* (Linnaeus, 1758).



**Fig. 13.** (a) M1 length and width of *Cuon alpinus* from Duoi U'Oi (*C. alpinus*) ( $n = 1$ ) (Bacon et al., 2008b), Tam Hang (*C. a. cf. antiquus*) ( $n = 2$ ), Yenchingkuo (*C. a. antiquus*) ( $n = 1$ ) (Colbert and Hooijer, 1953), and two modern populations, *C. a. adustus* from Myanmar ( $n = 5$ ) and *C. a. sumatrensis* from Malaysia ( $n = 5$ ). (b) Comparison between the M1 ranges of variation of fossil and modern samples.

Overall, these two lower p4s are massive teeth, whose dimensions are close to the p4s from Yenchingkuo (Matthew and Granger, 1923; Colbert and Hooijer, 1953) (Fig. 14a). Both samples of teeth (Yenchingkuo and Tam Hang) have greater dimensions than those of the two modern populations of *Panthera tigris tigris* present in the Indochinese area (Myanmar and India). Additional material would be necessary to propose a fossil subspecies.

#### 2.2.2.4.7. *Ursus thibetanus cf. kokeni*

Among the ursids, five teeth have the characteristics of *Ursus thibetanus* Cuvier, 1823. Two canines and one incisor at present cannot be differentiated between *Ursus* and *Helarctos*. The teeth attributed to *U. thibetanus* consist of two P4s characterised by a voluminous lingual cuspid, a salient paracone, and also a salient metastyle forming a mesiodistal blade. One M2 is fragmentary but the fragment which consists of an elongated talonid, and so is recognisable as *U. thibetanus*. The two lower molars are represented by one m2 and one m3, both of large size.

In the earlier excavated sample of 2003 (Bacon et al., 2008a), one m1 has dimensions that suggested the presence of *Ursus thibetanus kokeni* at Tam Hang (Matthew and Granger, 1923; Colbert and Hooijer, 1953). The new elements are also close to this subspecies. However, one may question the validity of this taxon as the teeth of

*U. thibetanus* from Yenchingkuo (Matthew and Granger, 1923; Colbert and Hooijer, 1953), Lang Trang (de Vos and Long, 1993), Thum Wiman Nakin (Tougard, 1998), and Duoi U'Oi (Bacon et al., 2008b) have all comparable dimensions. At present, this material is cautiously assigned to *Ursus thibetanus cf. kokeni*.

#### 2.2.2.4.8. *Helarctos malayanus*

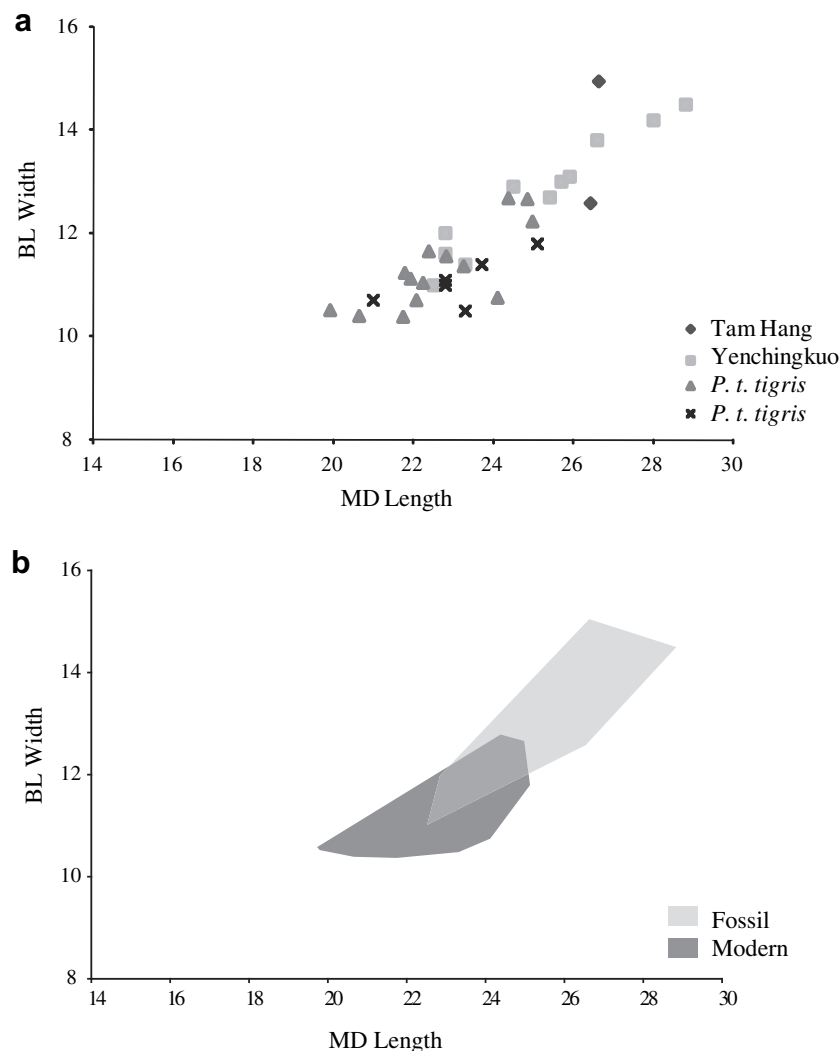
Only two new lower molars, m2 and m3, conform to those of the modern *Helarctos malayanus* (Raffles, 1821). They are smaller than the comparable elements of *U. thibetanus*. The metric data from this species of the reference sites are too sparse to facilitate comparisons.

2.2.2.5. *Rodentia*. The hystricid common porcupine *Hystrix brachyura* Linnaeus, 1758, is represented by numerous incisors and cheek teeth. To these elements may be added a small rodent hemimandible assigned to the murid *Leopoldamys sabanus* (Thomas, 1887).

#### 2.2.2.6. *Primates*

##### 2.2.2.6.1. *Macaca sp.*

Among the new Tam Hang specimens, forty-three cercopithecoid teeth (26 upper and 17 lower) are attributed to an undetermined macaque (*Macaca sp.*), as the distinction between species is problematic, based on isolated teeth only.



**Fig. 14.** (a) p4 length and width of *Panthera tigris* from Tam Hang (*P. tigris*) ( $n = 2$ ), Yenchingkuo (*P. tigris*) ( $n = 11$ ) (Colbert and Hooijer, 1953), and two modern populations of *P. t. tigris* from Myanmar ( $n = 11$ ) and India ( $n = 6$ ) (Colbert and Hooijer, 1953). (b) Comparison between the p4 ranges of variation of fossil and modern samples.



Comparing the lower m3 between the samples from Pleistocene sites indicates that those of Tam Hang and Lang Trang (de Vos and Long, 1993) have the same ranges of variation, with the largest teeth (Fig. 15a). Comparatively, the Duoi U'Oi sample (Bacon et al., 2008b) has smaller molars in length and width, and it is intermediate between these two fossil samples and the modern sample composed of two subspecies of *Macaca fascicularis bintangensis* (Thailand and Malaysia), and *Macaca mulatta mulatta* from Myanmar. It is, however, impossible to deduce if these differences between the samples are at the subspecies or species level. The m3 range of variation of all the fossil macaques does not show overlap with that of the modern macaques (Fig. 15b).

#### 2.2.2.6.2. Colobid (*Trachypithecus/Presbytis*)

At least three teeth suggest that one colobid is present at Tam Hang. However, since the taxonomic attribution is limited to the family level, the size comparison with the taxa from the other Indochinese Pleistocene sites is not informative.

#### 2.2.2.6.3. *Hylobates* sp.

The gibbon is a rare species in the sample with only one worn new p4 specimen recorded, which remains undetermined at the species level.

#### 2.2.2.6.4. *Pongo pygmaeus*

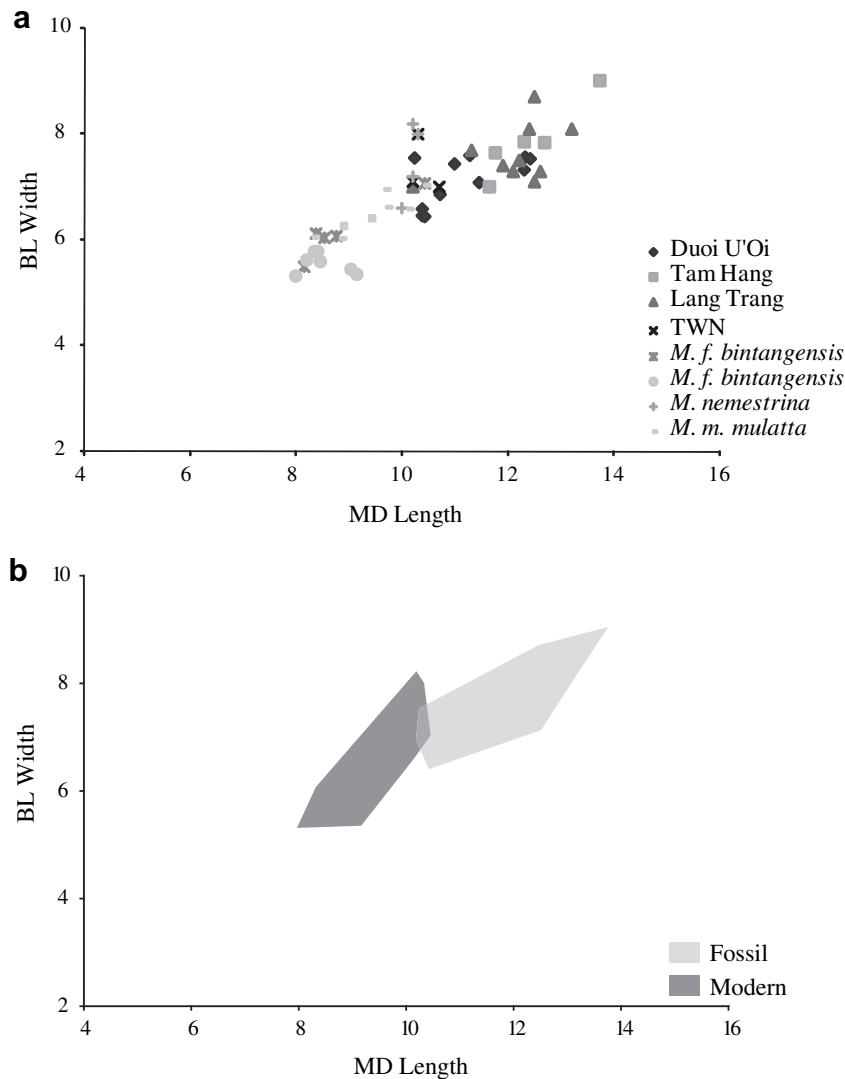
Two molar (M1/M2) teeth with highly worn occlusal surfaces are assigned to *Pongo pygmaeus*.

### 3. Discussion

#### 3.1. New faunal list

The new data presented in Table 5 establish the Tam Hang South faunal list (Bacon et al., 2008a). The presence of *Cervus eldii* is not confirmed, nor the presence of *Axis porcinus*, which was previously questioned. The second field season did not yield additional elements of *Martes flavigula*, *Viverra zibetha* and *Prionailurus cf. bengalensis*, which remain represented in the faunal record by only one tooth for each taxon. Some new faunal taxa can be added to the list: *Tapirus indicus*, *Melogale personata*, *Meles meles* (already discovered in 2003 but not recognized), *Paradoxurus hermaphroditus*, *Pongo pygmaeus* and *Leopoldamys sabanus*. The list is also expanded with the addition of two archaic species, *Stegodon orientalis* and *Megatapirus augustus*.

Overall, the faunal inventory, resulting from both excavations of 2003 and 2007, is composed of 35 taxa, among which 22 are



**Fig. 15.** (a) m3 length and width of *Macaca* from Duoi U'Oi (*Macaca* sp.) ( $n = 11$ ) (Bacon et al., 2008b), Tam Hang (*Macaca* sp.) ( $n = 5$ ), Lang Trang (*Macaca* sp.) ( $n = 10$ ) (de Vos and Long, 1993), Thum Wiman Nakin (*Macaca* cf. *nemestrina*) ( $n = 3$ ) (Tougaard, 1998), and two modern populations, *M. fascicularis bintangensis* from Thailand ( $n = 7$ ) and Malaysia ( $n = 5$ ), *M. nemestrina* from Thailand ( $n = 4$ ), and *M. mulatta mulatta* from Myanmar ( $n = 13$ ).

**Table 5**

List of new permanent and deciduous teeth from the Tam Hang South locality.

Species	Permanent teeth	Deciduous teeth
<i>Cervus unicolor</i>	2i1, 3P3, 1P4, 5M, 8p2, 3p3, 3p4, 4m1/m2, 4m2, 3m3	2D3, 1D4, 1d2, 2d3, 6d4
<i>Muntiacus muntjak</i> ssp.1	2I, 3P2/P3, 5P4, 12M, 4p3/p4, 6m1/m2, 3m3	5D4, 3d4
<i>Naemorhedus sumatraensis</i>	1P4, 1M1/M2, 1M3, 1m1/m2	–
<i>Bubalus cf. bubalis/B. bubalis</i>	1 P3, 5M, 1 p2, 3p3, 1p4, 4m1/m2, 1m3	–
<i>Bos cf. sauveli/B. sauveli</i>	1P2, 1P3, 1p2, 3p3/p4, 1m1/m2, 1m3	1D3
? <i>Sus cf. scrofa</i> ssp.1/ ? <i>Sus scrofa</i> ssp.1	2P1, 1P2, 2P3, 3P4, 7M1, 7M2, 1M3, 2p1, 4p2, 9p3, 6p4, 6m1, 1m2, 6m3	1D3, 5D4, 1d4
<i>Sus cf. barbatus</i>	2P3, 1M1, 3M2, 2M3, 2p2, 2p4, 1m2, 2m3	2D2, 1D3
<i>Rhinoceros unicornis</i>	–	2 d1
<i>Rhinoceros sondaicus</i>	1 m2	3 d1, 3 d2, 2 D2, 1 D3
<i>Rhinoceros</i> sp.	–	2 d4
Rhinocerotina indet.	1 P/M, 2 M	2 D2, 1 d2/3, 1d
<i>Tapirus indicus cf. intermedius</i>	1P2, 2p2, 1m2	–
<i>Megatapirus augustus</i>	1m2	–
<i>Elephas</i> sp.	1 M	2d
<i>Stegodon orientalis</i>	1M/m	1D/d, 1D4
<i>Arctonyx collaris cf. rostratus</i>	1p4, 2m1	–
<i>Meles meles</i>	2M1, 1m1	–
<i>Melogale personata</i>	2m1	–
<i>Cuon alpinus cf. antiquus</i>	1C, 1M1, 1p4, 1m2	–
<i>Paradoxurus hermaphroditus</i>	1m1	–
<i>Panthera tigris</i>	1C, 2I3, 1P4, 1c, 1p4	–
<i>Ursus thibetanus cf. kokeni</i>	2P4, 1M2, 1m2, 1m3	–
<i>Helarctos malayanus</i>	1m2, 1m3	–
Ursid undet. ( <i>Ursus</i> / <i>Helarctos</i> )	1I3, 2C	–
<i>Macaca</i> sp.	2I2, 3C, 5P3, 3P4, 13M, 4c, 3p3, 1p4, 7m1/m2, 2m3	–
? <i>Trachypithecus/Presbytis</i>	1I2, 1M1/M2, 1p4	–
<i>Hylobates</i> sp.	1p4	–
<i>Pongo pygmaeus</i>	2M1/M2	–
<i>Hystrix brachyura</i>	38I, i, 5P4, 17M, 17m	–
<i>Leopoldamys sabanus</i>	1 hemimandible	–

identified at the species level, 6 at the subspecies level, and 5 at the genus, subfamily or family level (Table 6).

In comparison with the faunal list drawn up by Arambourg and Fromaget (1938), most of the original taxa were reidentified using updated systematics. However, as the authors could not examine the originally excavated material (except for the teeth of the orangutans housed at the National Museum of Natural History in Paris), it is likely that certain species identified in the new fossil sample correspond to some species previously identified by Arambourg and Fromaget (1938). Indeed, it is possible that, for example, *Cervus orientalis* is synonymous with *Cervus unicolor*, the only abundant great-sized cervid present in the new record at Tam Hang South. This may equally apply to *Bos geron*, *Bubalus teilhardi*, *Naemorhedus caudatus*, *Sus lydekkeri*, *Rhinoceros sinensis*, *Felis* aff. *issidiorensis*, *Ursus angustidens*, and *Ursus premalayanus*, which were all identified by Arambourg and Fromaget (1938) (Table 6). For the Indian lion (*Panthera leo cf. indicus*) cited in the species list of 1938, on the basis of the new data, it is suggested that Arambourg and Fromaget originally misidentified the teeth because of their great size. This is probable, as the tiger (*Panthera tigris*) represented at Tam Hang South possess very massive premolars (Bacon et al., 2008a). Despite the two field-work seasons, the material was not sufficient to recognize *Elephas namadicus*, and the three distinct species of *Macaca*.

The new collection provided additional material of *Rhinoceros unicornis* and *R. sondaicus*, two rhinocerotids already mentioned in the cave by Bacon et al. (2008a), but not of material attributable to the Sumatran rhino, *Dicerorhinus sumatrensis*, although listed by Beden et al. (1972). Two tapirs are now recognized at Tam Hang

South (*Tapirus indicus* and *Megatapirus augustus*), while only the latter was mentioned by Arambourg and Fromaget (1938).

The preliminary report (Bacon et al., 2008a) listed five archaic subspecies, some attributed to taxa already described in the literature, namely *Ursus thibetanus cf. kokeni*, *Arctonyx collaris cf. rostratus*, *Cuon alpinus cf. antiquus* (Colbert and Hooijer, 1953), and some others not named, *Muntiacus muntjak* ssp., or only suggested, *Panthera tigris* ssp. The new overall data confirms the presence of the three first subspecies, and suggests that of *Tapirus indicus cf. intermedius*, but the material still remains limited to a few teeth. The supplementary data of *Muntiacus muntjak* allow a deeper analysis of size variability that illustrates three size gradients, *M. muntjak* ssp.1 at Tam Hang South, *M. muntjak* ssp.2 at Duoi U'Oi, and the modern populations of *M. Muntjak*. The case of *Sus scrofa* also suggests two size gradients, that of Tam Hang South *Sus scrofa* ssp.1 being distinct from that of Lang Trang and Duoi U'Oi *Sus scrofa* ssp.2.

Finally, the data confirm the relative rarity of the orangutan (*Pongo pygmaeus*), which is only represented by two teeth among the 979, in comparison with its abundance at Tam Hang Central.

**Table 6**

Species of the Tam Hang South faunal list after Arambourg and Fromaget (1938) compared with the updated faunal list from the same locality (2003 and 2007 field seasons).

Tam Hang South Arambourg and Fromaget (1938)	Tam Hang South Bacon et al. (2008a) and this paper
Artiodactyla	Artiodactyla
<i>Cervus orientalis</i>	<i>Cervus unicolor</i>
<i>Muntiacus</i> aff. <i>muntjak</i>	? <i>Cervus cf. eldii</i>
<i>Muntiacus cf. muntjak</i>	? <i>Axis porcinus</i>
<i>Bos geron</i>	<i>Muntiacus muntjak</i> ssp.1
<i>Bubalus teilhardi</i>	<i>Bos sauveli/B. cf. sauveli</i>
"Bovidé de petite taille"	<i>Bubalus bubalis/B. cf. bubalis</i>
<i>Nemorhaedus cf. caudatus</i>	<i>N. sumatraensis/Naemorhedus cf. caudatus</i>
<i>Sus lydekkeri</i>	<i>Sus scrofa</i> ssp.1/S. cf. <i>scrofa</i> ssp.1
<i>Sus</i> sp.	<i>Sus cf. barbatus</i>
Perissodactyla	Perissodactyla
<i>Rhinoceros cf. sinensis</i>	<i>Rhinoceros unicornis</i>
<i>Dicerorhinus sumatrensis</i> *	<i>Rhinoceros sondaicus</i>
<i>Megatapirus augustus</i>	( <i>Rhinoceros</i> sp.)
	(Rhinocerotina indet.)
	<i>Megatapirus augustus</i>
	<i>Tapirus indicus cf. intermedius</i>
Proboscidea	Proboscidea
<i>Elephas namadicus</i>	<i>Elephas</i> sp.
<i>Stegodon orientalis</i>	<i>Stegodon orientalis</i>
Carnivora	Carnivora
<i>Arctonyx collaris rostratus</i>	<i>Arctonyx collaris cf. rostratus</i>
<i>Panthera leo cf. indicus</i>	<i>Meles meles</i>
<i>Felis</i> aff. <i>issidiorensis</i>	<i>Melogale personata</i>
<i>Ursus angustidens</i>	? <i>Martes cf. flavigula</i>
<i>Ursus premalayanus</i>	<i>Cuon alpinus cf. antiquus</i>
	<i>Viverra zybetha</i>
	<i>Paradoxurus hermaphroditus</i>
	<i>Prionailurus cf. bengalensis</i>
	<i>Panthera tigris</i>
	<i>Ursus thibetanus cf. kokeni</i>
	<i>Helarctos malayanus</i>
Primates	Primates
<i>Macaca robusta</i>	<i>Macaca</i> sp.
<i>Macaca mulatta</i>	? <i>Trachypithecus/Presbytis</i>
<i>Macaca cf. andersoni</i>	<i>Hylobates</i> sp.
<i>Pongo pygmaeus</i>	<i>Pongo pygmaeus</i>
Rodentia	Rodentia
<i>Hystrix brachyura</i>	<i>Hystrix brachyura</i>
<i>Rhizomys troglodytes</i>	<i>Leopoldamys sabanus</i>

\*Beden et al. (1972).

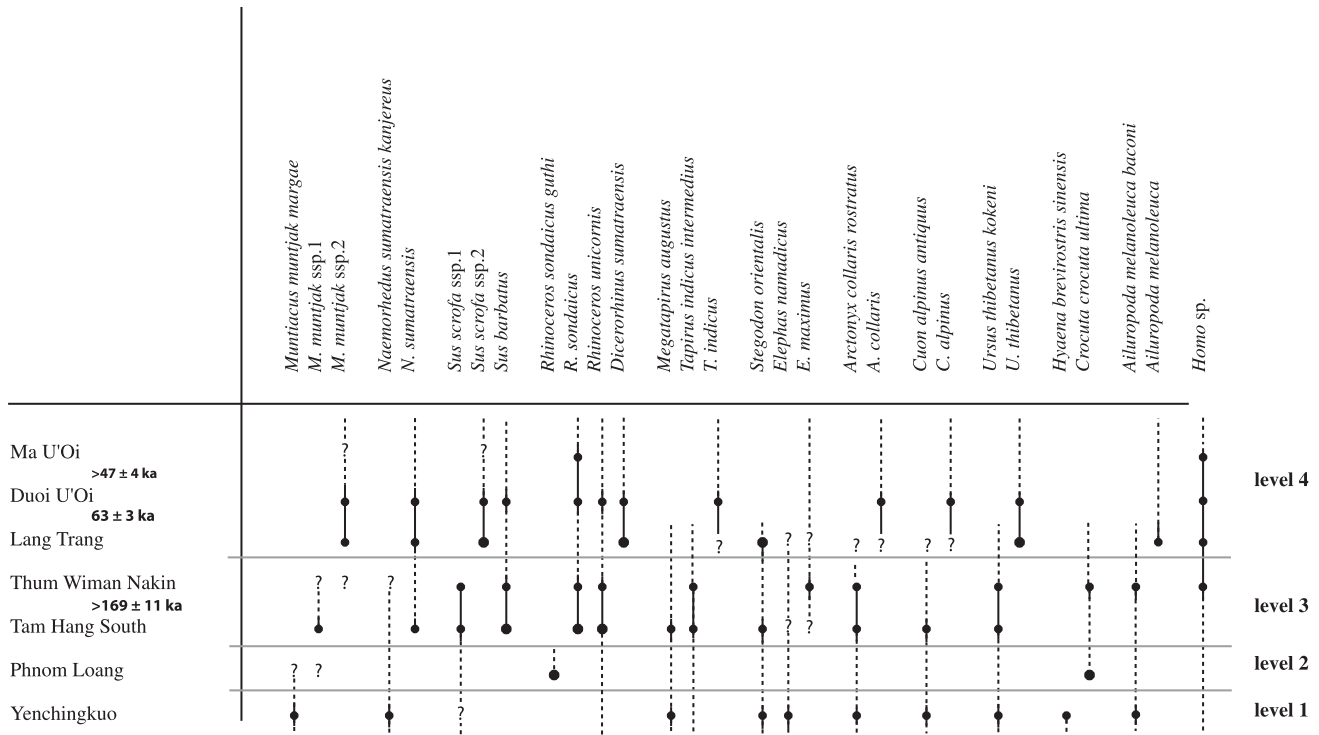


Fig. 16. Biochronological framework designed with the seven well-documented faunas from the Indochinese province: Ma U'Oi (Bacon et al., 2004, 2006), Duoi U'Oi (Bacon et al., 2008b) and Tam Hang South (Bacon et al., 2008a, and this paper) studied by the authors; Lang Trang (de Vos and Long, 1993), Thum Wiman Nakin (Tougaard, 1998), Phnom Loang (Beden and Guérin, 1973), and Yenchingkuo (Matthew and Granger, 1923; Colbert and Hooijer, 1953). The evolutionary stages *Sus scrofa* ssp.1 (Thum Wiman Nakin) and *Sus scrofa* ssp.2 (Lang Trang) have been deduced from the original data of M2 (de Vos and Long, 1993; Tougaard, 1998).

Three taxa which were previously assumed to be specific to the “lower” level of Tam Hang Central and, in part, Tam Hang North, *Ursus thibetanus kokeni*, *Cuon cf. alpinus* and *Paradoxurus sp.*, have been also recovered in the new record of Tam Hang South.

3.2. Proposal of a biochronological framework

The newly recovered Tam Hang South mammalian assemblage has the characteristics of the Middle Pleistocene faunas. It is composed of both extinct species (*Megatapirus augustus*, *Stegodon orientalis*), and modern species showing few advanced evolutionary stages (*Arctonyx collaris cf. rostratus*, *Cuon alpinus cf. antiquus*, *Ursus thibetanus cf. kokeni*, *Tapirus indicus cf. intermedius*). Concerning some other lineages, new evolutionary stages are proposed, *Muntiacus muntjak ssp.1*, *Sus scrofa ssp.1*. In this respect, the Tam Hang South fauna resembles faunas of approximately the same age, those of the Phnom Loang site in Cambodia (Carbonel and Guth, 1968; Beden et al., 1972; Beden and Guérin, 1973) and Thum Wiman Nakin in Thailand (Ginsburg et al., 1982; Chaimanee and Jaeger, 1993; Chaimanee, 1998; Tougaard, 1998, 2001) with an estimated

age older than 169 ± 11 ka (U-series), the late Middle Pleistocene (Esposito et al., 1998, 2002). The Late Pleistocene fauna from the Lang Trang site (100 ka–80 ka) is distinguished by its relative modernity (de Vos and Long, 1993; Long et al., 1996), whereas those of Duoi U'Oi and Ma U'Oi in northern Vietnam (respectively 66 ± 3 ka and >47 ± 4 ka) (Bacon et al., 2004, 2006, 2008b; Demeter et al., 2004, 2005) are totally modern in their composition.

On the basis of the evolutionary stages of the species and the occurrence of new taxa (Mein, 1975; Guérin, 1982, 1987, 1988), Fig. 16 is a simplified diagram showing the distribution in the time of the six reference faunas, from a part of the Middle to the Late Pleistocene. The diagram emphasises four evolutionary levels.

“Level 1”, the oldest one, presents a fauna of archaic content with all of the taxa extinct, as is the case for the Yenchingkuo assemblage. *Hyaena brevirostris sinensis* is present. The fauna corresponds to a part of the Middle Pleistocene.

Level 2 is characterised by the appearance of *Rhinoceros sondaicus guthi*, and *Crocota crocuta ultima*, another hyaena. The reference site is Phnom Loang. According to Beden and Guérin (1973, p.45), the fossil

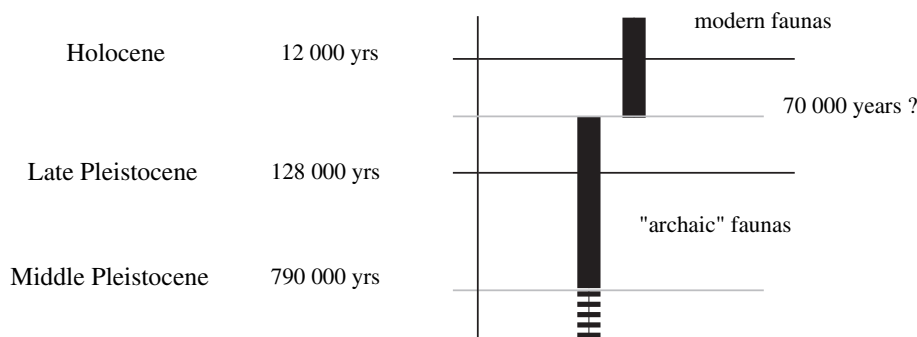


Fig. 17. Hypothesis of a biochronological framework suggesting the replacement of faunas with some archaic taxa by modern faunas during the Late Pleistocene, around 70 000 years.

subspecies *Rhinoceros sondaicus guthi* from Phnom Loang is distinguished in part by the large dimensions of its teeth, in comparison with the Indochinese modern form (Groves and Guérin, 1980).

Level 3 contains diversified faunas, as those of Tam Hang South and Thum Wiman Nakin, with an association of extinct species (*Stegodon orientalis*, *Megatapirus augustus*) and subspecies (*A. colaris rostratus*, *C. alpinus antiquus*, *U. thibetanus kokeni*, *T. indicus intermedius*, *A. melanoleuca baconi*, *M. muntjak ssp.1*, *S. scrofa ssp.1*). The Tam Hang South fauna illustrates this association, with the possible appearance of new taxa, *Sus barbatus* and *Rhinoceros unicornis*. The appearances of *Muntiacus muntjak ssp.1* and *Elephas maximus* are also questioned. Both levels (2 and 3) represent the late Middle Pleistocene.

Level 4 corresponds to the Late Pleistocene. The oldest faunas from this level retain some archaic species. It is the case of the Lang Trang fauna with *Stegodon orientalis*, possible *Elephas namadicus*, and the probable extinct forms of *Tapirus indicus*, *Cuon alpinus*, *Rhinoceros sondaicus* (Long et al., 1996) showing that some archaic taxa could have persisted during the beginning of the Late Pleistocene, between around 130 ka and 70 ka. Numerous other Chinese sites also have these faunal compositions with a mixture of modern and archaic species (Wu and Poirier, 1995; Chen et al., 2002; Wang et al., 2007; Jin et al., 2009). The appearance of *Dicerorhinus sumatraensis* is questioned in this level, but it is mentioned by some authors in Early Pleistocene deposits (Tong and Guérin, 2009). The Duoi U'Oï assemblage is devoid of any archaic component marking the end of the "Stegodon-Ailuropoda era" around 70,000 years in the region. On the basis of this evolutionary hypothesis, the replacement of faunas with still some archaic elements by modern faunas at the middle of the Late Pleistocene can be suggested (Fig. 17). However, the mammalian fossil record, at the transition between the Middle Pleistocene and the Late Pleistocene, is not sufficiently documented for the Indochinese province. New data are needed to describe the evolutionary changes that occurred in the mammalian lineages, and to propose a precise biochronological framework.

#### 4. Conclusion

Similarly to the Thum Wiman Nakin fauna in Thailand, that of Tam Hang South can be considered as a reference for the late Middle Pleistocene. In comparison with the historical work first done by Arambourg and Fromaget (1938), new taxa are recorded for the first time at Tam Hang South, in particular for the Perissodactyla and Carnivora, which appear to be much more diversified. On the basis of dental size gradients, new evolutionary stages are proposed in some mammalian lineages (suids, cervids). The results allow the proposal of a new biochronological framework, which needs to be completed and tested by new data for this time period.

#### Acknowledgements

This study has been funded by the Foreign Ministry in France (attributed to Anne-Marie Bacon), the CNRS (UPR2147 and UMR7206), and the University of Illinois (attributed to Laura Shackelford), under the patronage of the Ministry of Information and Culture of the Lao P.D.R. (Thongsa Sayavongkhamdy). The authors would like to thank the authorities of Vieng Thong District and Hua Pan province (Phengsi Sonsuckpat, Vong Sysuphanh), as well as those of Long Nguapha village in the Lao P.D.R. We extend our thanks to all the villagers who participated in the excavation. The authors would also like to thank D. Fouchier (UPR2147) and A. Bouzheghaia (Université Louis Pasteur) who produced the drawings.

#### References

- Arambourg, C., Fromaget, J., 1938. Le gisement quaternaire de Tam Nang (Chaîne Annamitique septentrionale). Sa stratigraphie et ses faunes. Comptes Rendus de l'Académie des Sciences 203, 793–795.
- Bacon, A.-M., Demeter, F., Schuster, M., Vu The Long, Nguyen Thi Kim Thuy, Antoine, P.-O., Sen, S., Ha Hu Nga, Nguyen Thi Mai Huong, 2004. The Pleistocene Ma U'Oï cave, northern Vietnam: palaeontology, sedimentology and palaeoenvironments. Geobios 37 (3), 305–314.
- Bacon, A.-M., Demeter, F., Roussé, S., Vu The Long, Düringer, P., Antoine, P.-O., Nguyen Thi Kim Thuy, Nguyen Thi Mai Huong, Dodo, Y., Matsumura, H., Schuster, M., Anezaki, T., 2006. New palaeontological assemblage, sedimentological and chronological data from the Pleistocene Ma U'Oï cave (Northern Vietnam). Palaeogeography, Palaeoclimatology, Palaeoecology 23, 280–298.
- Bacon, A.-M., Demeter, F., Tougaard, C., de Vos, J., Sayavongkhamdy, T., Antoine, P.-O., Bouasisengpaseuth, B., Sichanthongtip, P., 2008a. Redécouverte d'une faune pléistocène dans les remplissages karstiques de Tam Hang au Laos: premiers résultats. Comptes Rendus Palevol 7, 277–288.
- Bacon, A.-M., Demeter, F., Düringer, P., Helm, C., Bano, M., Vu The Long, Nguyen Thi Kim Thuy, Antoine, P.-O., Bui Thi Mai, Nguyen Thi Mai Huong, Dodo, Y., Chabaux, F., Rihs, S., 2008b. The Late Pleistocene Duoi U'Oï cave in northern Vietnam: palaeontology, sedimentology, taphonomy and palaeoenvironments. Quaternary Science Reviews 27, 1627–1654.
- Beden, M., Carbonel, J.P., Guérin, C., 1972. La faune du Phnom Loang (Cambodge). Comparaison avec les faunes pléistocènes du nord de l'Indochine. Archives Géologiques du Viêt-Nam 15, 113–122.
- Beden, M., Guérin, C., 1973. Le gisement de vertébrés de Phnom Loang (Province de Kampt, Cambodge). Travaux et Documents de l'O.R.S.T.O.M., 97 pp.
- Carbonel, J.P., Guth, C., 1968. Le gisement pléistocène inférieur du Phnom Loang (Cambodge), stratigraphie, et faune. Comptes Rendus de l'Académie des Sciences 67, 2077–2080.
- Chabaux, F., Bourdon, B., Riotte, J., 2008. U-series Geochemistry in weathering profiles, river waters and lakes. In: Krishnaswami, S., Cochran, J.K. (Eds.), U/Th Series Radionuclides in Aquatic Systems. Radioactivity in the Environment, vol. 13. Elsevier, pp. 49–104.
- Chabaux, F., Riotte, J., Dequincey, O., 2003. U-Th-Ra fractionation during weathering and river transport. Reviews in Mineralogy and Geochemistry 52, 533–576.
- Chaimanee, Y., 1998. Plio-Pleistocene rodents of Thailand. Thai Studies in Biodiversity 3, 1–103.
- Chaimanee, Y., Jaeger, J.-J., 1993. Pleistocene mammals of Thailand and their use in the reconstruction of the paleoenvironments of Southeast Asia. SPAFA Journal 3 (2), 4–10.
- Chen, G., Wang, W., Mo, J., Huang, Z., Tian, F., Huang, W., 2002. Pleistocene vertebrate fauna from Wuyun cave of Tiandong country, Guangxi. Vertebrata Palasiatica 40, 42–51.
- Colbert, E.H., Hooijer, D.A., 1953. Pleistocene mammals of the limestone fissures of Szechwan, China. Bulletin of the American Museum of Natural History 102, 1–134.
- Demeter, F., 2000. Histoire du peuplement humain de l'Asie extrême-orientale depuis le Pléistocène supérieur récent. Thèse de doctorat d'Anthropologie, Université de Paris 1 Panthéon-Sorbonne, vol. 2, Paris.
- Demeter, F., Bacon, A.-M., Nguyen Kim Thuy, Vu The Long, Düringer, P., Roussé, S., Coppens, Y., Matsumura, H., Dodo, Y., Nguyen Mai Huong, Anezaki, T., 2005. Discovery of a second human molar and cranium fragment in the late Middle to Late Pleistocene cave of Ma U'Oï (Northern Vietnam). Journal of Human Evolution 48, 393–402.
- Demeter, F., Bacon, A.-M., Nguyen Kim Thuy, Vu The Long, Matsumura, H., Ha Huu Nga, Schuster, M., Nguyen Mai Huong, Coppens, Y., 2004. An archaic *Homo* molar from northern Vietnam. Current Anthropology 45 (4), 535–541.
- de Vos, J., Vu The Long, 1993. Systematic discussion of the Lang Trang fauna, unpublished report.
- Esposito, M., Reyss, J.L., Chaimanee, Y., Jaeger, J.-J., 2002. U-series dating of fossil teeth and carbonates from snake cave, Thailand. Journal of Archaeological Science 29, 341–349.
- Esposito, M., Chaimanee, Y., Jaeger, J.-J., Reyss, J.L., 1998. Datation des concrétions carbonatées de la "Grotte du serpent" (Thaïlande) par la méthode Th/U. Comptes Rendus de l'Académie des Sciences 326, 603–608.
- Fromaget, J., 1936. Sur la stratigraphie des formations récentes de la Chaîne annamitique septentrionale et sur l'existence de l'Homme dans le Quaternaire inférieur de cette partie de l'Indochine. Comptes Rendus de l'Académie des Sciences 203, 738–741.
- Fromaget, J., 1937. Aperçu sur la Stratigraphie et l'Anthropologie préhistorique des formations récentes dans la Chaîne Annamitique et le Haut-Laos. Compte rendu de la douzième session du Congrès préhistorique de France, Toulouse-Foix, 785–798.
- Fromaget, J., 1940a. Les récentes découvertes anthropologiques dans les formations préhistoriques de la chaîne annamitique. Proceedings of the Third Congress of Prehistorians of the Far East, Singapore 1938, 51–59.
- Fromaget, J., 1940b. La stratigraphie des dépôts préhistoriques de Tam Hang (Chaîne Annamitique septentrionale) et ses difficultés. Proceedings of the Third Congress of Prehistorians of the Far East, Singapore 1938, 60–70.
- Fromaget, J., Saurin, E., 1936. Note préliminaire sur les formations cénozoïques et plus récentes de la Chaîne Annamitique septentrionale et du Haut-Laos. Bulletin du service géologique de l'Indochine XXII (3), 48.
- Ginsburg, L., Ingavat, R., Sen, S., 1982. A Middle Pleistocene (Loangian) cave fauna in northern Thailand. Comptes Rendus de l'Académie des Sciences 294, 295–297.



- Granet, M., Chabaux, F., France-Lanord, C., Stille, P., Pelt, E., 2007. Time-scales of sedimentary transfer and weathering processes from U-series nuclides: clues from the Himalayan rivers. *Earth and Planetary Science Letters* 261, 389–406.
- Groves, C.P., Guérin, C., 1980. Le *Rhinoceros sondaicus annamiticus* (Mammalia, Perissodactyla) d'Indochine: distinction taxinomique et anatomique; relations phylétiques. *Géobios* 13 (2), 199–208.
- Guérin, C., 1980. Les rhinocéros (Mammalia, Perissodactyla) du Miocène terminal au Pléistocène supérieur en Europe occidentale. Comparaison avec les espèces actuelles. Documents du Laboratoire de Géologie de Lyon. Sciences de la Terre 79 (3 fasc.), 1185.
- Guérin, C., 1982. Première biozonation du Pléistocène européen, principal résultat biostratigraphique de l'étude des Rhinocerotidae (Mammalia, Perissodactyla) du Miocène terminal au Pléistocène supérieur d'Europe occidentale. *Geobios* 15 (4), 593–598.
- Guérin, C., 1987. Biochronologie. In: Miskovsky, J.-C., et al. (Eds.), *Géologie de la préhistoire: méthodes, techniques, applications*, GéoPré édit. Maison de la géologie, Paris, pp. 801–830.
- Guérin, C., 1988. Biozones or mammal units? Methods and limits in Biochronology. In: Lindsay, E.H., Fahlbusch, V., Mein, P. (Eds.), *European Neogene Mammal Chronology*. Plenum Press, New York, pp. 119–130.
- Hooijer, D.A., 1947. On fossil and prehistoric remains of Tapirus from Java, Sumatra and China. *Zoologische Mededeeling Leiden* 26, 1–38.
- Hopwood, A.T., 1935. Fossil Proboscidea from China. *Palaeontologica Sinica, Series. C* 9 (3), 1–108.
- Jin, C.Z., Pan, W.S., Zhang, Y.Q., Cai, Y.J., Xu, Q.Q., Tang, Z.L., Wang, W., Wang, Y., Liu, J.Y., Qin, D.G., Edwards, R.L., Cheng, H., 2009. The Homo sapiens cave hominin site of Mulan Mountain, Jiangzhou District, Chongzuo, Guangxi with emphasis on its age. *Chinese Science Bulletin* 54, 3848–3856.
- Kaufman, A., Broecker, W.S., 1965. Comparison of  $^{230}\text{Th}$  and  $^{14}\text{C}$  ages for carbonate materials from lakes Lahontan and Bonneville. *Journal of Geophysical Research* 70, 4039–4054.
- Long, V.T., de Vos, J., Ciochon, R.S., 1996. The fossil mammal fauna of the Lang Trang caves, Vietnam, compared with Southeast Asian fossil and recent mammal faunas: the geographical implications. *Bulletin of the Indo-Pacific Prehistory Association* 14, 101–109.
- Maglio, V.J., 1973. Origin and evolution of Elephantidae. *Transactions of the American Philosophical Society* 63 (3), 1–149.
- Matthew, W.D., Granger, W., 1923. New fossil mammals from the Pliocene of Szechuan, China. *Bulletin of the American Museum of Natural History* 48, 563–598.
- Mein, P., 1975. Résultats du groupe de travail des Vertébrés. Report on activity on the RCMNS working group (1971–1975). IUGS, regional committee on Mediterranean Neogene Stratigraphy, Bratislava. 78–81.
- Osborn, H.F., 1942. *Proboscidea*, vol. II. Amer. Mus. Press, New York.
- Pelt, E., Chabaux, F., Innocent, C., Navarre-Sitchler, A.K., Sak, P.B., Brantley, S.L., 2008. Uranium-Thorium Chronometry of weathering rinds: rock alteration rate and paleo-isotopic record of weathering fluids. *Earth and Planetary Science Letters* 276, 98–105.
- Saurin, E., 1950. *Tapirus indicus intermedius* Hooijer dans le Quaternaire Indo-Chinois. *Compte Rendu de la Société géologique de France* 14, 257–259.
- Saurin, E., 1951. Etudes géologiques et Préhistoriques. *Bulletin de la société géologique des Etudes Indochinoises* 26, 439–525.
- Shackelford, L.L., 2003. Late Pleistocene Postcranial Skeletal remains from Tam Hang (Laos). *American Journal of Physical Anthropology* 120 (S36), 189 [abstract].
- Sondaar, P.Y., 1984. Faunal evolution and the mammalian biostratigraphy of Java. *Courier Forschungs Institut Senckenberg* 69, 219–235.
- Thein T., 1974. La faune néolithique du Phnom Loang (Cambodge) (Ruminants). Doctorat de 3ème cycle de l'Université Paris VI, 159 p.
- Tong, H., 2005. Dental characters of the Quaternary tapirs in China, their significance in classification and phylogenetic assessment. *Geobios* 38, 139–150.
- Tong, H.W., Liu, J.Y., Han, L.G., 2002. On fossil remains of Ealey Pleistocene tapir (Perissodactyla, mammalia) from Fanchang, Anhui. *Chinese Science Bulletin* 47, 586–590.
- Tong, H.W., Guérin, C., 2009. Early Pleistocene *Dicerorhinus sumatrensis* remains from the Liucheng *Gigantopithecus* cave, Guangxi, China. *Geobios* 42, 525–539.
- Tougaard C., 1998. Les faunes de grands mammifères du Pléistocène moyen terminal de Thaïlande dans leur cadre phylogénétique, paléoécologique et biochronologique. Thèse de Doctorat, Université de Montpellier II, 175 p.
- Tougaard, C., 2001. Biogeography and migration routes of large mammal faunas in South-East Asia during the Late Middle Pleistocene: focus on the fossil and extant faunas from Thailand. *Palaeogeography, Palaeoclimatology, Palaeoecology* 168, 337–358.
- van den Bergh, G.D., Aziz, F., Sondaar, P.Y., Hussain, S.T., 1992. Taxonomy, stratigraphy and paleozoogeography of Plio-Pleistocene Proboscideans from the Indonesian islands. *Bull. Geol. Res. Developm. Center Bandung, Palaeontology* 7, 28–58.
- van den Bergh, G.D., 1999. The Late Neogene elephantoid-bearing faunas of Indonesia and their palaeozoogeographic implications. A study of the terrestrial faunal succession of Sulawesi, Flores, and Java, including evidence for early hominid dispersal east of Wallace's Line. *Scripta Geologica* 117, 419.
- Wang, W., Potts, R., Baoyin, Y., Huang, W., Cheng, H., Lawrence Edwards, R., Ditchfield, P., 2007. Sequence of mammalian fossils, including hominoid teeth, from the Buling Basin caves, South China. *Journal of Human Evolution* 52, 370–379.
- Wu, X.Z., Poirier, F.E., 1995. *Human Evolution in China. A Metric Description of the Fossils and a Review of the Sites*. Oxford University Press, New York. 317 pp.