# New palaeontological assemblage, sedimentological and chronological data from the Pleistocene Ma U'Oi cave (northern Vietnam)

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## Abstract

This paper describes recent material gathered during the second fieldwork at Ma U'Oi in November 2002 by a Vietnamese–French–Japanese team. The Ma U'Oi cave, located in the province of Hoà Binh (60 km SW from Hanoi), northern Vietnam, belongs to a karstic network developed in Triassic dark-grey limestones.

The cave is filled with coarse-grained breccias containing numerous fossil remains, partially preserved at several loci inside the cave (wall, vault and ground). We describe new teeth which confirm the occurrence of mammal taxa already mentioned at Ma U'Oi (Bacon et al., 2004)[Bacon, A-M., Demeter, F., Schuster, M., Long, V.T., Thuy, N.K., Antoine, P-O., Sen, S., Nga,

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## 1. Introduction

The work presented here is based on recent material gathered in November 2002 during the second field session of Ma U'Oi cave in northern Vietnam (Fig. 1). The cave is situated at the foot of a karst peak, about several 10 m above the present alluvial plain (Fig. 2). The previous year, we had found an in situ mammalian fauna of modern composition (Bacon et al., 2004; Demeter et al., 2004). The age of the fauna is estimated between late Middle Pleistocene (the age of Thum Wiman Nakin deposits is estimated at 169 kyr by the U/Th method (Esposito et al., 1998)) and Late Pleistocene (the biochronolo-
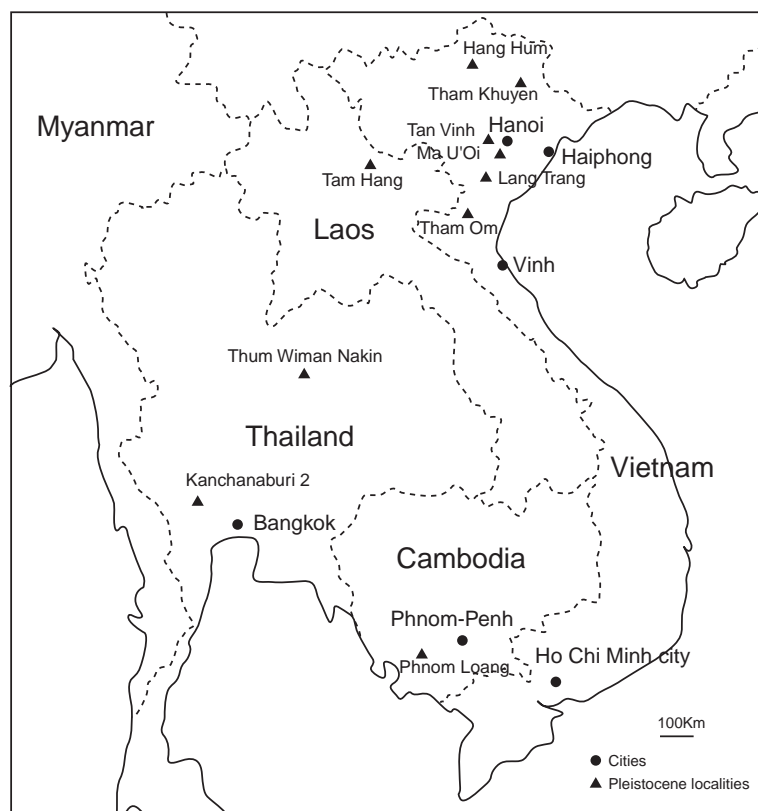


Fig. 1. Location of principal Pleistocene sites in Vietnam, Laos and Thailand.
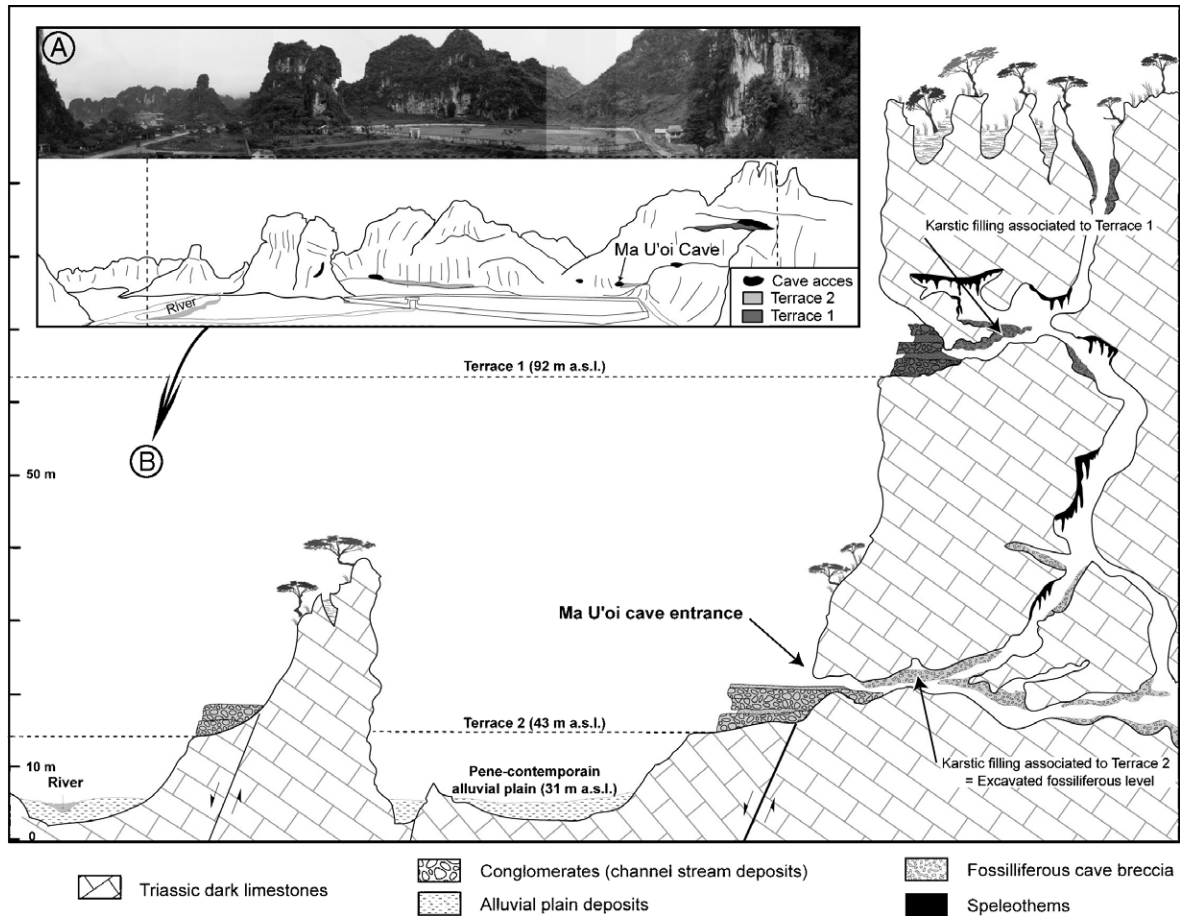
Fig. 2. A—Photomosaic of the characteristic "tower karst" landscape and general setting of Man Duc site, showing location of caves and alluvial terraces. B—Synthetic sketch showing the two alluvial terraces Terrace 1 (Unit 1) and Terrace 2 (Unit 2, Ma U'Oi cave) lying, respectively, at 92 and 43 m above sea level ("a.s.l."). The contemporaneous alluvial plain is situated at 31 m above sea level. Their sedimentological contents are also presented and consist of conglomeratic channel-stream facies associated with laminated sandy/silty clay material of alluvial plain facies. Both units of alluvial terraces are closely associated with endokarstic deposits (fossiliferous cave breccia and speleothems).

gical age of Lang Trang dated to 80–60 kyr (Long et al., 1996)).

We collected fossils in three distinct loci inside the cave (Fig. 3): (1) the breccia from walls and roof in room A2 of the corridor A and in the corridor B (in situ fauna); (2) the breccia from the floor in rooms A2 and A3 in corridor A ("mixed" fauna); and (3) the breccia from the roof in room A1 of the corridor A (in situ microvertebrate fauna).

During this second fieldwork, we found many additional isolated teeth. Those found in rooms A2 and A3 (Fig. 3) confirm the occurrence of mammals

already mentioned at Ma U'Oi (Bacon et al., 2004), while others found in room A1 emphasize the occurrence of new species, especially microvertebrates (primates, rodents, insectivores, small reptiles and amphibians). Concerning the rodents, the new data from Ma U'Oi enhance biostratigraphical correlations with Pleistocene Thai sites, the best documented ones so far (Chaimanee, 1998). Concerning insectivores and small reptiles, these new data are important because they are unique for the Pleistocene period of Southeast Asia. Indeed, except sporadic data from Tham Kuyen and Tham Hai, no microvertebrate
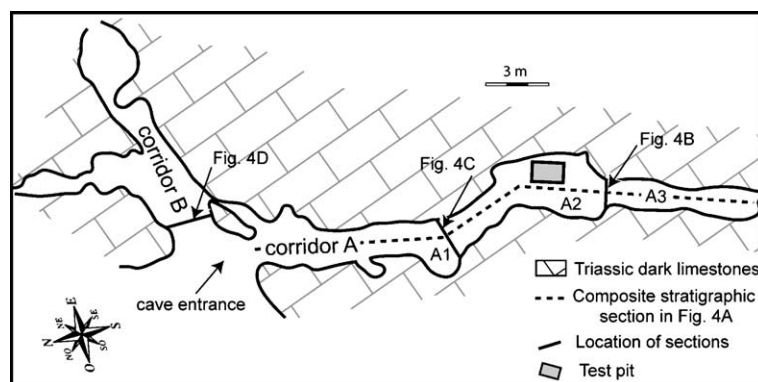
Fig. 3. Plan of Ma U'Oi cave. The cave consists of two corridors A and B. Corridor A is composed of three rooms A1, A2 and A3. The locations of the 3 sections drawn in Fig. 4(B–D) are noted on the plan.

assemblage is listed in Vietnamese Pleistocene sites (Cuong, 1985; Olsen and Ciochon, 1990).

First, we present the geological and sedimentological context of the cave and, secondly, we describe among the new findings the first microvertebrate assemblage from the Pleistocene of northern Vietnam. We also present U/Th dating of the cave deposits (data of C. Falguères, IPH, Paris) that are consistent with biochronological estimates.

The aim of this fieldwork is also to find human remains on the Pleistocene Asian mainland. The discovery of a new human molar and a skull fragment is important (Demeter et al., 2005) and confirms the occurrence of archaic *Homo* at Ma U'Oi (Demeter et al., 2004). In Vietnam, the chronology of Pleistocene sites ranges from $475 \pm 125$ kyr at Tham Kuyen (Ciochon et al., 1996) to 30–20 kyr at Keo Leng (Kha, 1976; Long and Du, 1981; Cuong, 1985; Olsen and Ciochon, 1990). The former site yielded a well-documented archaic fauna with *Homo erectus* while the latter yielded a modern fauna with *Homo sapiens*. Between these two "landmarks", the knowledge of the transition from *H. erectus* to *H. sapiens* and their respective environmental context is limited to a small number of sites: Tham Hai (300–200 kyr), Tham Om (250–140 kyr), Hang Hum (140–80 kyr) and Lang Trang (80–60 kyr) (Ciochon and Olsen, 1986; Olsen and Ciochon, 1990; de Vos and Long, 1993; Long et al., 1996; Ciochon et al., 1996). Thus, we briefly mention here these new data, as they have been already described in two previous papers (Demeter et al., 2004; 2005). Nevertheless, we replace them in the faunal and biochronological context.

## 2. Description of the Ma U'Oi cave and geological context

### 2.1. Location and geological setting of the cave

The Ma U'Oi cave is located in Man Duc village (Tan Lac District, Hoà Binh Province), 25 km SSW of Hoà Binh city in northern Vietnam (coordinates: N $20°37'22''$, E $105°16'40''$) (Fig. 1). This area belongs to the north-eastern extremity of the Annamitic Mountains chain and to the western border of the Red River fault zone (Deprat et al., 1963; Luong, 1978a,b; Ky et al., 2001).

The landscape of Tan Lac District is characterized by a typical and spectacular morphology of karst peaks hundred metres high above alluvial plain level. The so-called "tower karst" formed in monotonous limestone beds dated to the Carboniferous and the Triassic (Fig. 2A). Around the Ma U'Oi site, the bedrock consists of grey-dark micritic marine limestone attributed to the Early and to the Middle Triassic (Luong, 1978a,b; Martini et al., 1998). On the whole, this Triassic basement is weakly folded but shows severe fracturing due to tectonic deformation. The dense network of caves and galleries, which was developed through the time in this framework, is partially driven by faults and fractures as it is the case for other similar karst systems in Vietnam (e.g. Fenart et al., 1999).

In the neighbourhood of Man Duc locality, several caves expose sections of great interest for understanding the development of the karstic network and the deposit of fossiliferous filling (Fig. 2). The caves are

partly filled with brown to red–brown argillaceous and breccia material with numerous iron pisoliths. Karstic fillings can reach several metres thick (until 4 m), preserved as relicts on walls, floor and roof of caves.

## 2.2. Sedimentology

General aspects of the fossiliferous breccia are described in Bacon et al. (2004). During the second fieldwork, new sedimentological investigations provided a better understanding of the mechanisms of deposit. The relations between endokarstic (activity inside the cave) and exokarstic (alluvial sedimentation) environments are also examined in order to reconstruct the complete geological setting of the Ma U'Oi cave and consequently to better know the Middle to Late Pleistocene environment of hominids in northern Vietnam.

### 2.2.1. Exokarstic environment

Along the cliffs, in the neighbourhood of Ma U'Oi site, several networks of caves appear at different levels above the present fluvial plain (Fig. 2A). Two distinct levels of alluvial terraces could be emphasized, respectively at 10 and 62 m above the level of the present alluvial plain (31 m a.s.l.) in a stair-like disposition (Terraces 1 and 2, Fig. 2).

One important observation is that each terrace is systematically at the same elevation than the access of cave networks. Terrace levels and alluvial deposits are associated with endokarstic sediments. These alluvial deposits consist mostly of conglomeratic channel-stream deposits, interstratified with sandy to silty alluvial plain or temporary pond deposits. In some places, they are interstratified with horizontal calcite layers, corresponding to exokarstic crystallizations (flowstone). Fossil remains found in both deposits confirm the relative correlation between karstic breccia and alluvial terrace deposits at the entrance of the cave.

Therefore, two depositional units, both consisting of synchronous alluvial and karst deposits, have been emphasized: Unit 1 (Terrace 1 deposits and associated karstic breccia) and Unit 2 (Terrace 2 deposits and Ma U'Oi excavated fossiliferous level) (Fig. 2B).

### 2.2.2. Endokarstic environment

Only the karst filling of the Unit 2, inside the Ma U'Oi cave, has been excavated. The breccia of the Unit 1 (Fig. 2) produced a poor fossiliferous content.

During fieldworks, we excavated parts of both corridors of the cave (A and B; Fig. 3), each being composed of several rooms. The fossiliferous facies show a quite constant composition in all excavated rooms (A1, A2, A3, and B, Figs. 3 and 4). It is characterized by breccia (mainly calcareous) of relative monotony, with a short-scale lateral and vertical extension (Bacon et al., 2004). In all excavated rooms, the fossiliferous level forms a thick layer (ranges from 0.5 to 1.5 m) covering the vault, the upper part of the walls and the floor (Fig. 4A).

In rooms A2 and A3, only few small relicts of the fossiliferous level remain on walls and vault of the karstic network, but it is well preserved on the floor where it forms an irregular pluridecimetric layer (0.5 to 1 m) (Fig. 4A). This ground level appears more as a relict, strongly weathered, suspended in a "rack-shaped" disposition, and strongly cemented on walls of the cave, rather than as a deposit generated by the collapse of breccia from the roof, as previously suggested in Bacon et al. (2004).

This breccia level is overlaid by the present-day soil of the cave which consists of 10–15 cm clay layer. Although most of the teeth have been recovered in the breccia, we realized that some teeth (particularly small ones of *Macaca*) may come from the overlying clays (on the basis of conservation of teeth, etc.). So, we described in Bacon et al. (2004) that all remains extracted from the ground were a heterogeneous assemblage of mammals (we designed it as the "mixed fauna") (Tables 1 and 2). We keep here the term "mixed fauna" as in the previous paper, even if we made sure that all elements found during the second fieldwork come exclusively from the ground breccia.

Moreover, this ground fossiliferous facies appear intercalated between two clay levels: in rooms A2 and A3 (Fig. 4A and B). It is covered by a level of modern human occupation containing both remains of charcoals and baked clays and it also overlies brown plastic clays with some recent pottery fragments. These clay deposits seem to be the latest deposits in the cave and to have filled the space between relicts of the fossiliferous breccia during last centuries (Bacon et al., 2004). In breccia of room A2 (Fig. 4), we found two human teeth and a skull fragment assigned to

Fig. 4. A—Composite stratigraphic section of Ma U'Oi cave (corridor A, see Fig. 3 for location) showing the particular disposition of breccia relicts. Ages and locations of breccia samples (MU1 and MU2) dated by U/Th radiometric methods (data of Falguères) are also listed. B–D—Schematic sedimentary logs of rooms A3, A1 (corridor A) and B1 (corridor B), respectively, showing the particular outcrop conditions of the breccia, its composition and its internal organization (i.e. repetitive fining-up units) (see also Fig. 3 for location).
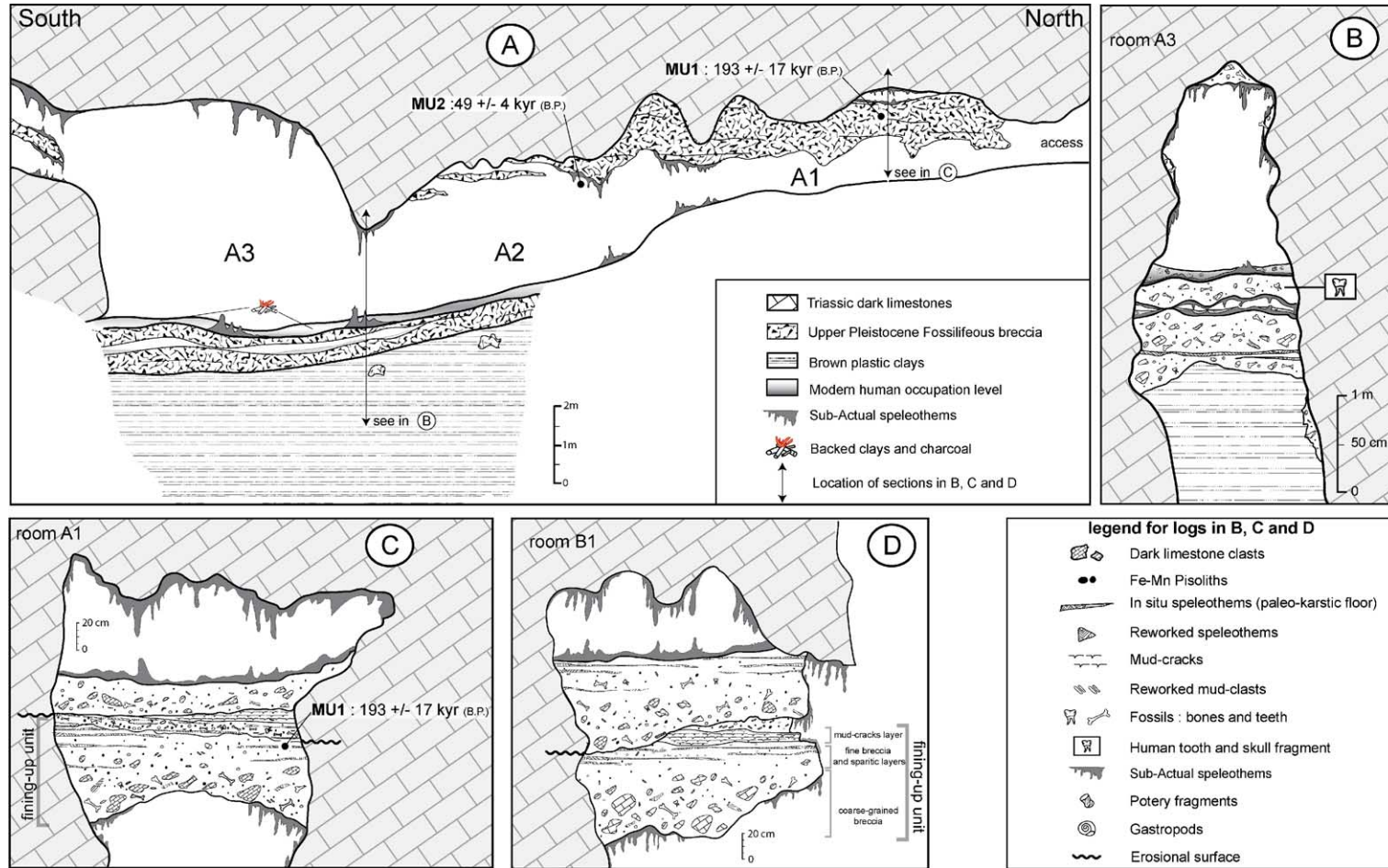
Table 1

Record and measurements in millimetre of the well-preserved teeth of mammals recovered at Ma U'Oi during the second fieldwork

| Taxa | Numero | Element | Length | Width |
|---|---|---|---|---|
| **Artiodactyla** | | | | |
| Artiodactyla indet. | MU67 | I4 right | 5.5 | 3.5 |
| Artiodactyla indet. | MU74 | I2/I3 left | 5.5 | 4.1 |
| *Sus scrofa* | MU89 | M3 right | 35.7 | 21.7 |
| **Perissodactyla** | | | | |
| *Rhinoceros* cf. *unicornis* | MU53 | M3 right | 53 | 62 (ant)–68 (diag. L) |
| **Primate** | | | | |
| *Macaca* sp. | MU56 | M right | 8.8 | 8.7 |
| Archaic *Homo* | MU57 | M2 left | 10.8 | 12.6 |
| *Homo* sp. | MU88 | skull fragment | – | – |
| **Proboscidea** | | | | |
| *Elephas* aff. *namadicus* | MU168 | fragmentary molar | – | – |

All specimens have been extracted from the ground breccia in room A2 (corridor A), except one specimen *Rhinoceros* cf. *unicornis* originating from corridor B. The other teeth recovered during the first fieldwork in the same loci are listed in Bacon et al. (2004; Table 3).

archaic *Homo* (Demeter et al., 2004, 2005), together with isolated teeth of mammals (Bacon et al., 2004). Consequently, human remains and traces of human activities in the cave have two different origins: (1) from a modern human occupation with traces of charcoals and baked clays at the surface of the soil and (2) from an accumulation of mammal fauna during the Pleistocene with isolated teeth in a typical breccia cave. In both levels, no tools were found.

Despite the apparent monotony of karstic sediments, it is possible to distinguish in some outcrops of the breccia (rooms A1 and B1, Fig. 4C and D), especially in the upper part of deposits, a complex vertical structure. The general scheme of this structure is the repetition of small-scaled sedimentary units, in fining-upward sequences (Fig. 4C and D). This reveals short-term variations in the filling dynamics. Generally, the basal part of units consists of an eroded surface, which is overlaid by a coarse-grained breccia (with large angular clasts of dark limestones (5 to 20 cm in average), reworked speleothems, Fe–Mn pisoliths, pieces of bones and teeth). From bottom to top, clasts size decreases while proportion of argillaceous material increases. Progressively, the facies changed

into a rich argillaceous level, layered with sparse, centimetric and horizontal calcite layers (sparite) representing karstic calcitic floor (Fig. 4D). Above, when most of the upper part of outcrops is preserved, decimetric horizontal mud layers showing polygonal mud cracks appear in some places (rooms A1 and B1 in Fig. 4C and D). In other places of the cave, such

Table 2

Record (and for some measurements) in millimetre of the well-preserved teeth of rodents, insectivores, chiropters, primates and artiodactyls recovered at Ma U'Oi in room A1 (corridor A)

| Taxa | Numero | Element | L | W |
|---|---|---|---|---|
| **Artiodactyla** | | | | |
| Artiodactyla indet. | MU106 | P3/P4 | – | – |
| *Muntiacus muntjak* | MU93 | DP3/DP4 | 9.94 | 11.6 |
| *M. muntjak* | MU94 | DP3/DP4 | 8.99 | 11.44 |
| *M. muntjak* | MU95 | DP3/DP4 | 8.86 | 11.35 |
| *M. muntjak* | MU96 | DP3/DP4 | 9.66 | 11.95 |
| **Primate** | | | | |
| *Macaca* sp. | MU100 | p4 right | 6.36 | 4.42 |
| *Macaca* sp. | MU101 | m1/m2 left | 8.50 | 6.33 |
| *Macaca* sp. | MU102 | m3 left | 10.95 | – |
| *Macaca* sp. | MU103 | canine | – | – |
| **Carnivora** indet. | MU104 | premolar | – | – |
| **Rodentia** | | | | |
| *Hystrix brachyura* | MU97 | p4 left | 8.25 | 5.15 |
| *Hystrix brachyura* | MU98 | m1/m2 left | 8.07 | 5.86 |
| *Hystrix brachyura* | MU99 | m1/m2 right | 8.10 | 5.96 |
| *Leopoldamys sabanus* | MU108–MU125 | 8M; 6m; 2 mandibles (m1–m2; m1) | cf. Table 4 | |
| *Niviventer fulvescens* | MU126–MU140 | 12 molars; 2 mandibles (m1–m2) | cf. Table 4 | |
| *Hapalomys delacouri* | MU151 | m2 | cf. Table 4 | |
| *Hylopetes phairei* | MU152–MU153 | p4; m3 | cf. Table 4 | |
| *Hylopetes* sp. | MU154 | one mandible (p4–m1–m2) | cf. Table 4 | |
| Petauristinae indet. | MU155 | one mandible (p4–m1–m2–m3) | cf. Table 4 | |
| **Insectivora** | | | | |
| *Crocidura* sp. | MU156–MU165 | 9 mandibles; 1 maxillar | – | |
| **Chiroptera** | | | | |
| Pteropodinae indet. | MU167 | lower molar | – | |

All these new specimens, constituting the microvertebrate fauna were found during the second fieldwork. L: length and W: width.

internal structure of the breccia is repetitive and shows superposed units (rarely complete), 0.2 to 0.7 m thick (Fig. 4C and D) (Roussé et al., 2003).

## 3. Interpretation and discussion

The present disposition of the breccia up to the vault of the cave results from distinct processes. First, the limestone karstic network is completely filled with sediments. Then, the reactivation of the karstic system conducts to a partial erosion of this sedimentary filling, leaving scarce relicts of breccia in protected areas (i.e. vault, floor and walls of the karstic network).

The filling of the cave shows sequential deposits. First, limestone clasts, mud pebbles, Fe–Mn-rich pisoliths, as well as bones and teeth were all transported by water flows inside the karst. Secondly, a phase of intense speleothems precipitation (development of horizontal karstic calcite layers) developed under vadose circulations, associated with a decrease of clastic supply. Finally, the presence of well-defined decimetric muddy layers and mud cracks strongly suggests a phase of desiccation and complete drying of the karst. The repetition of such elementary sequences results from a complete or partial reworking of sequences. This multi-episodes filling is initiated by small fluctuations in the base level, in relation to high frequency variations of climatic conditions (Musgrove et al., 2001). The current timing and kinematics of such features are difficult to emphasize without precise radiometric dating framework based on a regional setting. However, the kinematics could be very fast in regard to the complex internal organization of the fossiliferous breccia and may be linked to short-term variations related to East Asia monsoon climate over the past 2 million years (Liu et al., 2003).

The close relation between karstic deposits inside the caves and alluvial terraces proves that the endokarstic and exokarstic environments are controlled by the same factors and share a common evolution. The stair-like geometry of the terrace and related karstic deposits (Unit 2 and above the older Unit 1) reflect a continuous fall of the quaternary alluvial plain with several phases conducting to terrace and karstic deposits (Fig. 2).

During rise of the base level, there is simultaneously filling of the cave and accumulation of deposits in the alluvial plain. Later, when the base level drops abruptly, due to regional tectonic movements and/or eustatic oscillations, the filling of the cave is partly eroded and appears as relicts on walls of the karstic network. The stair-like profile of paleoterraces appears progressively with lowering of the valley. Variations recorded by sedimentary units (Unit 1 and 2) may be linked to variations in rising and erosion rates or to global climatic oscillations during the Pleistocene.

U/Th dating has been performed on 2 samples. MU 1 from the upper part of the fossiliferous breccia (coarse-grained sparite from stalagmitic floor, see Fig. 4 for location) reveals an age of 193 kyr ± 17 kyr, i.e. late Middle Pleistocene (C. Falguères, pers. com., 2004). Sampled speleothems (MU 2, sparite), partially covering the fossiliferous breccia (see Fig. 4 for location), gives for filling alteration an age of 49 ± 4 kyr (i.e. late Late Pleistocene) (C. Falguères, pers. com., 2004). The latter could correspond to the latest base level drop that led to the present configuration of the site (definitive drying-up of the cave).

Recently, in surrounding areas (Dien Bien Phu basin, 150 km W/NW from the studied area), a recent tectonic activity was emphasized by Zuchiewicz et al. (2004) who described perched alluvial deposits dated from Late Pleistocene to Holocene. The combination of sea level oscillations with an active tectonic background is considered as the most relevant factor to explain the architecture of deposits (stair geometry). Moreover, the vicinity of Man Duc site with the Red River delta plain (less than 30 km) suggests that the Pleistocene sea level oscillations may have controlled the base level and subsequently karstic and alluvial dynamics.

The sea level pattern proposed by Molodkos and Bolikhovskaya (2002) for the last 600 kyr, in northern Eurasia, allows to establish a good correlation between the Middle Pleistocene rise and the high stand of sea level (240/180 kyr) and the development of Unit 2 (dated to 193 kyr) (Fig. 2). The erosion of Unit 2 is supposed to have started soon after 180 kyr and continued until at least 49 kyr and it may be still active today. For the Unit 1 development, due to lack of radiometric dating and biostratigraphical data, we hypothesize with regard to the age of Unit 2, a correlation with the Middle Pleistocene rise and the high

stagnation of sea level (around 400 and/or 330 kyr). Thus, erosion of Unit 1 may have been effective between 330 and 250 kyr.

In conclusion, genesis and preservation of the fossiliferous karstic breccia are controlled in a short time scale by hydrology inside the karsts (Roussé et al., 2003; Bacon et al., 2004). In longer term, deposit and preservation of cave breccia or other fillings are directly linked to the combined variations of tectonic uplift and sea level oscillations (Molodkos and Bolikhovskaya, 2002; Roussé et al., 2003; Zuchiewicz et al., 2004).

## 4. Palynological data

Twenty palynological samples composed of hard clays have been taken every 10 cm in the test pit in room A2 (Fig. 3). Inside the test pit, the first sample is 10 cm deep and the twentieth sample is 200 cm deep. Despite the use of techniques adapted to preparation of poor mineral sediments (Girard and Renault-Miskovsky, 1969; Goeury and de Beaulieu, 1979), no pollens were found. Conditions of sedimentation, the physico-chemical nature of the soil, the alternation of dryness and wet, the content of phosphates, etc., are factors probably responsible for the non-conservation of spores and pollens. We should take in the future new samples in other places in the cave, where the karstic setting is more stable and not dependent on outside influences.

## 5. New palaeontological data

We only describe here the new material recovered during the second fieldwork in November 2002 (Tables 1 and 2). All remains consist of rootless isolated teeth gnawed by porcupines (with roots "bevelled" worn until crowns characteristic of the activity of these rodents) and probably by some carnivores, which suggests that the carcasses were probably exposed outside the cave before being carried away by water in the karstic network. This is a well-known phenomenon in Pleistocene and Holocene caves of Southeast Asia (Roze, 1989; Hooijer, 1946a; Tougard, 1998; Zeitoun et al., 2005). We did not find traces of human activity on teeth.

### 5.1. The in situ fauna

The second field season confirms the presence of a large one-horned rhino at Ma U'Oi, with one upper molar MU53 extracted from the in situ breccia of the wall of corridor B (Table 1 and Fig. 4D). This tooth has a subtriangular occlusal outline and does not present trace of a posterior tooth, which allows to identify it as a right M3, even though it displays a very unique shape: the metaloph is fully developed and distinct from the ectoloph, determining a small postfossette. In other words, there is no fusion between the ectoloph and the metaloph (a feature named "ectometaloph") as it is observed in most rhinocerotids. This morphology is a symplesiomorphic trait of rhinocerotoids (Rhinocerotidae + Hyracodontidae + Amynodontidae; e.g., Antoine, 2002, 2003). To our knowledge, such a feature had never been observed in any post-Palaeogene rhinocerotid species except in pathologic specimens; thus, this "atavism" may not be considered as diagnostic. Other morphological features of MU53 (sigmoid protoloph lacking any antecrochet, long sagittal crochet, and corrugated enamel) point out Rhinoceros rather than Dicerorhinus among Pleistocene rhinocerotids from Southeast Asia. Additional characters such as a shallow parastyle groove, a smooth paracone fold, an anteriorly constricted protocone, and large dimensions closely match Rhinoceros unicornis (recent and fossil; Hooijer, 1946b; Guérin, 1980). Yet, the unusual shape of its metaloph does not allow us to formally assign MU53 to this species. As a matter of fact, we prefer to assign this pathological tooth to R. cf. unicornis (Table 1).

### 5.2. The "mixed" fauna

The breccia produced two artiodactyl incisors (MU67 and MU74), a fragmentary molar of Elephas aff. namadicus (MU168) (on the basis of section of lamels), one M3 of Sus scrofa (MU89), one upper molar of Macaca sp. (MU56), one M2 (MU57) and a skull fragment (MU88) of archaic Homo (Table 1). These teeth were extracted from ground deposits (located in rooms A2 and A3, corridor A) (Fig. 4A).

The M3 (MU89) presents the same characteristics as modern S. scrofa. It is slightly smaller than the corresponding M3 from Thai sites (Tougard, 1998) but resembles those from Lang Trang (de Vos and

Long, 1993). Size and morphology of the upper molar of *Macaca* do not provide diagnostic arguments to identify the concerned species.

The human tooth (MU57) presents a well-preserved crown. It shows an irregular distribution in enamel thickness, absence of a doubled *crista transversa* and two interproximal contact facets that support the identification of this tooth as a human maxillary molar, probably an M2 (Demeter et al., 2005). Its morphology shows a closer affinity with early Asian *H. sapiens* rather than *H. erectus*, by the absence of occlusal wrinkles, peripheral placement of cusp apices, and taurodontism (CT scan). However, its crown diameter cannot be distinguished from those of some *H. erectus* (especially from Zhoukoudian). For these reasons, MU57 is attributed to an archaic form of *Homo* (Demeter et al., 2005). MU88 is a skull fragment cautiously identified as coming from the upper left squamous of the occipital part, also referred to archaic *Homo*.

### 5.3. The "roof" fauna or microvertebrate fauna

Most of the fauna, mainly microvertebrates, from the roof of room A1 (corridor A) (Figs. 3 and 4C), were recovered during the second fieldwork. These remains were concentrated in a small area with numerous small bones and teeth visible at the surface of the roof (Fig. 4C). The abundance of small mammals suggests areas of feeding of small carnivores, which could have been trapped by muddy water flows in the karstic network.

The fauna consists of microvertebrates (primates, rodents, insectivores, chiropters, small reptiles and amphibians), but we also found two cervids (one premolar of a great-sized undetermined artiodactyl (MU106) and four teeth of a small-sized cervid (MU93-96). The four small cervids (Table 2) display characteristics of decidual jugal teeth (DP3 and DP4) of *Muntiacus muntjak*. Their dimensions (mesiodistal length and buccolingual width) match those of decidual teeth (DP3 and DP4) of modern *M. muntjak* (Table 3). In comparison with permanent molars of this species, the enamel is also finer.

The "roof" fauna also yielded a rodent assemblage including at least two sciurids (flying squirrels), four murines and one hystricine. Among the 36 isolated murid molars, 17 belong to the long-tailed giant rat *Leopoldamys sabanus* (MU108–MU125), 16 to the

smaller chestnut rat *Niviventer fulvescens* (MU126–MU140), one to the lesser marmoset mouse *Hapalomys delacouri* (MU151) and two to the Phayre's flying squirrel *Hylopetes phayrei* (MU152 and MU153) (Table 2). Concerning molars of *L. sabanus* recovered at Ma U'Oi (Table 4), dimensions slightly exceed those of molars found in fossil Thai sites (Chaimanee, 1998; pages 114–115). *N. fulvescens* from Ma U'Oi presents the same morphological features as *N. fulvescens* from Thai sites (Chaimanee, 1998), except that the labial cusplet (cv5) is sometimes present in m1 and also in m2 [Chaimanee (1998) notes that in m2 "there is no anterolabial cusp or cv5"]. A size difference between Thai and Vietnamese fossils can also be observed in molars of *N. fulvescens*, the latter being slightly larger. A right m2 (MU151) attests the presence of a third murid genus *Hapalomys* at Ma U'Oi. Its dimensions (Table 4) are close to those of fossil *H. delacouri* from Snake Cave main layer and to those of living specimens (dimensions of the other species *H. longicaudatus* being larger (Musser, 1982), with however a slightly smaller width (Chaimanee, 1998; page 65).

Two lower teeth of sciurid (one left p4 (MU152) and one right m3 (MU153)) are assigned to *Hylopetes* on the basis of descriptions in Chaimanee (1998). Dimensions of the m3 fall within those of living and fossil *H. phayrei*. The p4 is however slightly larger than those of the latter species (but much larger than *H. spadiceus* listed in fossil Thai localities). Two fragmentary mandibles are also listed among new findings (Table 2). The larger one (MU155) has highly worn out teeth that only allow us to refer it to a petauristinae indet. The smaller one (MU154) is attributed to *Hylopetes* sp., due to tooth wear. The molar dimensions match those of *H. phayrei* and exceed those of *H. spadiceus* (Chaimanee, 1998, page 166).

Three new teeth, one p4 (MU97) and two molars (m1 or m2; MU98–99), and many incisors of a large rodent are referred to the common *Hystrix brachyura* (Table 2). Their dimensions exceed those of modern *Hystrix* (length of p4) and those of fossil *Hystrix* from Lang Trang (lengths of both m1/m2; Table 3). They are also larger than the fossil teeth of *H. brachyura* from other sites in Java (Punung) and Sumatra (de Vos and Long, 1993).

Several fragments of insectivore jaws were also found at Ma U'Oi (Table 2). They principally con-

Table 3
Ranges of variation in millimetre of some Ma U'Oi teeth compared with those of modern mammals

| Species | N | Tooth | MD length | BL width |
|---|---|---|---|---|
| *Muntiacus muntjak* (modern) | 10 | DP2 | 8.1–10.6 | 5.3–7.2 |
| *Muntiacus muntjak* (modern) | 10 | DP3 | 9.5–11.1 | 6.9–9.2 |
| *Muntiacus muntjak* (modern) | 10 | DP4 | 9.5–11.7 | 8.5–11.4 |
| MU93–MU96 | 4 | DP3/DP4 | 8.8–9.9 | 11.3–11.9 |
| *Muntiacus muntjak* (modern) | 24 | M1 | 9.5–13.7 | 9.4–13.8 |
| *Muntiacus muntjak* (modern) | 18 | M2 | 11.5–15.3 | 11.1–14.9 |
| *Muntiacus muntjak* (modern) | 11 | M3 | 11.9–14.1 | 10.7–13.9 |
| MU34 | 1 | M2/M3 | 14.4 | 15.1 |
| *Muntiacus muntjak* (Thai sites) | 1 | M1 | 13 | 13.3 |
| *Muntiacus muntjak* (Thai sites) | 5 | M2 | 9.9–15.2 | 13.6–16.1 |
| *Muntiacus muntjak* (Thai sites) | 11 | M3 | 10.5–17.1 | 10.6–16.5 |
| *Hystrix brachyura* (modern) | 5 | p4 | 6.2–7.5 | 5.2–6.8 |
| MU97 | 1 | p4 | 8.2 | 5.1 |
| *Hystrix brachyura* (Lang Trang) | 10 | p4 | 8–10.1 | 6–7.6 |
| *Hystrix brachyura* (modern) | 13 | m1 | 5.9–7.7 | 5.5–6.4 |
| *Hystrix brachyura* (modern) | 13 | m2 | 6–7.7 | 5–7.3 |
| MU98–MU99 | 2 | m1/m2 | 8–8.1 | 5.8–5.9 |
| *Hystrix brachyura* (Lang Trang) | 23 | m1/m2 | 7.5–9.2 | 6.2–8.3 |
| MU89 | 1 | M3 | 35.7 | 21.7 |
| *Sus scrofa* (Lang Trang) | 40 | M3 | 28–44.2 | 19.9–26 |
| *Sus scrofa* (Thai sites) | 3 | M3 | 39–42.1 | 22.1–22.4 |
| *Sus* cf. *barbatus* (Thai sites) | 2 | M3 | 35.9–42.7 | 24–24.4 |
| MU42–MU43-1 | 2 | p3 | 13.9–14 | 7.6–8.1 |
| *Sus scrofa* (Lang Trang) | 37 | p3 | 12–15.4 | 6.1–8.7 |
| *Sus scrofa* (Thai sites) | 2 | p3 | 13–14.3 | 6.1–6.9 |
| *Sus* cf. *barbatus* (Thai sites) | 3 | p3 | 14–14.8 | 8.2–8.3 |
| MU6 | 1 | p4 | 15.6 | 12.1 |
| *Sus scrofa* (Lang Trang) | 58 | p4 | 13.7–17.3 | 8.6–12.1 |
| *Sus scrofa* (Thai sites) | 3 | p4 | 14.1–16.1 | 9–11.9 |
| *Sus* cf. *barbatus* (Thai sites) | 1 | p4 | 14.1 | 16.9 |

Measurements of modern specimens (*Muntiacus* and *Hystrix*) were taken by the authors. The sample of Muntjacs for decidual teeth is composed of 1 *M. muntjak*, 6 *M. m. grandicornis* and 3 *M. m. anamensis* and that for permanent teeth, 4 *M. muntjak*, 10 *M. m. grandicornis*, 1 *M. m. peninsulae*, and 8 *M. m. anamensis*. Measurements of *M. muntjak* from Thai sites are from Tougard (1998). The modern sample of rodents is composed of 13 specimens of *H. brachyura*. Original measurements of *H. brachyura* from Lang Trang (Vietnam) are from de Vos and Long (1993). N: number of specimens; MD length: mesiodistal length; and BL width: buccolingual width.

sist of nine fragmentary mandibles and one maxillar of the middle-sized shrew *Crocidura* sp. (Soricidae, Crocidurinae). Ma U'Oi specimens are medium-sized and diagnostic of this genus, but the species level is difficult to determine (Repenning, 1967): the p4 has a triangular cusp, the dental formula is 1–2–3, the articular facets of mandibular condyles are united either along the lingual side of the condyle with a labial interarticular depression, the mental foramen is beneath the protoconid of m1, the cingulum-like groove along the medial side of the incisor continues below the notch in basal border of tooth and the talonid of m1 is moderately compressed.

Among microvertebrate remains, numerous vertebrae and cranial fragments of amphibians and reptiles have been discovered at Ma U'Oi and determined by J-C Rage (Table 5). Except the anguid *Ophisaurus* sp., the systematics is limited to the family level, or even to higher taxa. Nevertheless, one can note at Ma U'Oi the presence among Colubridae of an aquatic snake and that of an arboreal snake with elongated caudal vertebrae (Table 5).

### 5.4. The overall fauna of Ma U'Oi

All findings of the two fieldworks are gathered in Table 5. Despite the extraction of most of the breccia

Table 4

Measurements in millimetre of rodents teeth found among the microvertebrates ("roof" fauna) at Ma U'Oi

| Species | N | Length | $x$ | Width | $x$ |
|---------|---|--------|-----|-------|-----|
|  |  | Range |  | Range |  |
| *Leopoldamys sabanus* |  |  |  |  |  |
| M1 | 4 | 4.52–5.05 | 4.85 | 3.06–3.62 | 3.21 |
| M2 | 4 | 3.74–4.26 | 3.98 | 2.88–3.04 | 2.93 |
| m1 | 5 | 3.99–4.63 | 4.33 | 2.49–2.99 | 2.70 |
| m2 | 4 | 3.17–3.73 | 3.50 | 2.76–3.18 | 2.98 |
| *Niviventer fulvescens* |  |  |  |  |  |
| M1 | 2 | 3.31–3.62 | 3.46 | 2.03–2.08 | 2.05 |
| M2 | 2 | 2.19–2.75 | 2.47 | 1.69–2.29 | 1.95 |
| m1 | 5 | 2.63–2.96 | 2.81 | 1.57–1.85 | 1.72 |
| m2 | 7 | 1.75–2.44 | 2.05 | 1.59–1.99 | 1.74 |
| *Hapalomys delacouri* |  |  |  |  |  |
| m2 | 1 | – | 1.92 | – | 1.65 |
| Petauristinae indet. |  |  |  |  |  |
| p4 | 1 | – | 2.24 | – | 2.27 |
| m1 | 1 | – | 2.63 | – | 2.53 |
| m2 | 1 | – | 2.83 | – | 2.95 |
| m3 | 1 | – | 3.65 | – | 2.56 |
| *Hylopetes phayrei* |  |  |  |  |  |
| p4 | 1 | – | 1.78 | – | 1.58 |
| M3 | 1 | – | 2.73 | – | 2.27 |
| *Hylopetes* sp. |  |  |  |  |  |
| p4 | 1 | – | 1.77 | – | 1.70 |
| m1 | 1 | – | 1.79 | – | 2.15 |
| m2 | 1 | – | 2.15 | – | 2.56 |
| *Hystrix brachyura* |  |  |  |  |  |
| p4 | 1 | – | 8.25 | – | 5.15 |
| m1/m2 | 1 | – | 8.07 | – | 5.86 |
| m1/m2 | 1 | – | 8.10 | – | 5.96 |

Some highly worn out teeth were not measured. *N*: number of specimens and *x*: mean. All measurements were taken by the authors. The other teeth of rodents recovered during the first fieldwork are listed in Bacon et al. (2004; Table 3).

of walls in corridor A (Figs. 3 and 4A), the in situ faunal assemblage stays relatively poor. It is composed of 30 teeth referred to *S. scrofa*, *M. muntjak*, *Rusa* cf. *unicolor*, *Rhinoceros* cf. *sondaicus* and *R.* cf. *unicornis*. Due to the difficulty in recognizing some mammals at the species level, because of their fragmentary state or lack of distinctive features, the other taxa have been identified at the genus level, *Macaca* sp., *Cuon* sp. (a canine first erroneously described as

*Herpestes* sp.) and *Elephas* sp. (only one lamel) (Bacon et al., 2004). Concerning rodents, 10 teeth attributed to three species *N. fulvescens, N. andersoni* and *L. sabanus* are listed.

There are no differences between data from the in situ breccia of walls and those from the floor breccia (21 teeth of mammals, two molars and a cranial fragment of hominid), except the occurrence of *Bandicota* sp., *E.* aff. *namadicus*, and archaic *Homo* in the latter (Table 5). Indeed, the faunal assemblage from the floor (*R.* cf. *unicornis* and *E.* aff. *namadicus*) and the fauna from the walls (*R.* cf. *unicornis* and *Elephas* sp.) suggest they might be contemporary. Moreover, the second fieldwork allows us to specify that vault, floor and wall breccia are composed of the same deposits. After the complete filling of the cave, the erosion left relics of breccia in these fossiliferous areas (Fig. 4).

The microvertebrate fauna from the third locus (Fig. 4C) consists of an accumulation of small rodents, insectivores (32 isolated teeth and 16 jaws), reptiles and amphibians (numerous vertebrae and fragments of jaws) (Table 5). The only taxa common to the three loci are *M. muntjak* (4 teeth), an undetermined species of *Macaca* sp. (4 teeth), and the most common murids *N. fulvescens* and *L. sabanus* recorded in many Southeast Asian fossil sites.

## 6. Discussion

The second fieldwork confirms the first occurrence of one-horned rhino *R.* cf. *unicornis* in the Pleistocene of Vietnam (closely related to the recent Indian rhino, nowadays essentially restricted to India (Corbet and Hill, 1992; Nowak, 1999). The controversial *Rhinoceros sinensis* is the only rhino species reported so far in Middle Pleistocene Vietnamese localities (Olsen and Ciochon, 1990; Long et al., 1996; Tougard, 2001), while the lesser two-horned *Dicerorhinus sumatrensis* is only certified at Lang Trang (de Vos and Long, 1993; Long et al., 1996). The absence of *Rhinoceros* sensu stricto at Lang Trang (*D. sumatrensis* is the only reported rhinocerotid) could be due to local circumstances, as this species is still extant in small numbers in Vietnam (Corbet and Hill, 1992; Nowak, 1999).

Table 5
All taxa found in the Ma U'Oi cave

| Taxa | Roof fauna | In situ fauna | Mixed fauna | Common name |
|---|---|---|---|---|
| Artiodactyla | Artiodactyla indet. | – | Artiodactyla indet. | – |
| Suidae | – | *Sus scrofa* | *Sus scrofa* | Wild boar |
| Cervidae | – | *Rusa* cf. *unicolor* | *Rusa* cf. *unicolor* | Sambar |
| | *Muntiacus muntjak* | *Muntiacus muntjak* | – | Muntjac |
| Perissodactyla | | | | |
|   Rhinocerotidae | – | *Rhinoceros* cf. *sondaicus* | – | Javan rhinoceros |
| | – | *Rhinoceros* cf. *unicornis* | *Rhinoceros* cf. *unicornis* | Indian rhinoceros |
| Proboscidea | | | | |
|   Elephantidae | – | *Elephas* sp. | *Elephas* aff. *namadicus* | Elephant |
| Primate | | | | |
|   Cercopithecidae | *Macaca* sp. | *Macaca* sp. | *Macaca* sp. | Macaque |
|   Hominidae | – | – | Archaic *Homo* | Human |
| Carnivora | Carnivora indet. | – | – | – |
|   Canidae | – | *Cuon* sp. | – | Red dog |
| Rodentia | | | | |
|   Muridae | *Niviventer fulvesccens* | *Niviventer fulvescens* | *Niviventer fulvescens* | Chestnut rat |
| | – | *Niviventer andersoni* | – | Chinese rat |
| | *Leopoldamys sabanus* | *Leopoldamys sabanus* | – | Long-tailed giant rat |
| | *Hapalomys delacouri* | – | – | Lesser marmoset mouse |
| | – | – | *Bandicota* sp. | Bandicoot rat |
|   Sciuridae | *Hylopetes phayrei* | – | – | Phayre's flying squirrel |
| | *Hylopetes* sp. | – | – | |
| | Petauristinae indet. | – | – | Flying squirrel |
|   Hystricidae | *Hystrix brachyura* | – | – | Porcupine |
| Insectivora | | | | |
|   Soricidae | *Crocidura* sp. | – | – | Shrew |
| Chiroptera | Pteropodinae indet. | – | – | Bat |
| Squamata | Squamata indet. | – | – | Squamate |
| Ophidia | Ophidia gen. et sp. indet. | – | – | Snake |
| | Colubridae indet. | – | – | Snake |
| | "Colubrinae" | – | – | Snake |
| | Natricinae indet. | – | – | Snake |
| | Viperidae indet. | – | – | Snake |
| Lacertilia | Lacertilia gen. et sp. indet. | – | – | Lizard |
| | Gekkomidae indet. | – | – | Lizard |
| | Anguidae : *Ophisaurus* sp. | – | – | Lizard |
| | Agamidae indet. | – | – | Lizard |
| Amphibia | Anura indet. | – | – | Amphibian |
| | Family indet. | – | – | Amphibian |
| | Ranoidea indet. | – | – | Amphibian |

Three distinct faunas were distinguished by their provenance in the cave: the in situ fauna comes from the walls and the vault, the mixed fauna is a heterogeneous assemblage composed of remains from the breccia of the floor and remains from the silt of the soil (some teeth of macaque), and the roof fauna is a concentration of microvertebrates extracted from the roof of room A1.

The co-occurrence of an Asian elephant (*Elephas* sp.) and large rhinos (*R*. cf. *unicornis* and *R*. cf. *sondaicus*) at Ma U'Oi is also mentioned in some late Middle Pleistocene localities from Southeast Asia: *R*. cf. *unicornis*, *R. sondaicus* and *E*. cf. *maximus*, among a diversified modern fauna at Thum Wiman Nakin in Thailand (Tougard, 1998, 2001); *R*. cf. *sivalensis* (junior synonym of *R. sondaicus*) with *E. namadicus* at Tam Hang in Laos (Tougard, 2001); and *Elephas* sp. and *R. sondaicus guthi* at Phnom Loang in Cambodia (Beden et al., 1972; Beden and Guérin, 1973). The Ma U'Oi fauna also resembles in many aspects that of Lang Trang in northern Vietnam. According to Long et al. (1996), the presence of

*Elephas* is confirmed at this site (cave II, breccia 5), but the species level is uncertain (*E. namadicus* or *E. maximus*).

Concerning murid rodents, walls and floor breccia produced *N. fulvescens*, *N. andersoni*, *L. sabanus* and *Bandicota* sp. (Table 5). *N. fulvescens* and *L. sabanus* are still extant in Vietnam, both presenting a large distribution in the Indochinese and Sundaic subregions, while *N. andersoni* is an endemic Chinese species still present in East Tibet and China (Yunnan, Sichuan, South Gansu and Shaanxi) (Corbet and Hill, 1992). The only well-documented fossil assemblages come from post-Miocene Thai sites (Ginsburg et al., 1982; Chaimanee et al., 1993; Chaimanee, 1998). In Indonesian islands, especially Java and Borneo, few rodents are also listed (Medway, 1972; Musser, 1982; van der Meulen and Musser, 1999). Among all murids found at Thum Wiman Nakin (Chaimanee, 1998), *N. fulvescens* and *L. sabanus* are rather abundant (with *Rattus sikkimensis* and *R. rattus*), while *N. andersoni* is absent (Table 6). In Vietnamese sites, the data are also very scarce (Table 6). One can mention Tham Kuyen site and the more recent Keo Leng, with *Rattus* sp. and *Mus* sp. (Cuong, 1985), while the Lang Trang fauna (cave II, breccia 5) only includes *Rattus sabanus* (Long et al., 1996). *N. andersoni* has been only found in different Chinese localities between 1.8 myr and 10 000 yr (Zheng, 1993). We can underline that the presence of this species at Ma U'Oi is the first mention outside China in Quaternary deposits.

The roof breccia produced microvertebrates among which, except *N. fulvescens*, *L. sabanus* and *H. brachyura*, all the other Ma U'Oi rodents are listed for the first time in the Pleistocene of Vietnam. *L. sabanus* and *N. fulvescens* are the most abundant specimens (Table 6) as at Thum Wiman Nakin (Chaimanee, 1998). Concerning *L. sabanus* recovered at Ma U'Oi, molar dimensions exceed slightly those found in fossil Thai sites. A size difference is also observed between molars of *N. fulvescens* from Ma U'Oi and those from Thai sites (Chaimanee, 1998). *Hystrix subscritata* recovered at Ma U'Oi is also listed at Tham Kuyen (together with *Hystrix* sp. and *Atherurus* sp.), at Tham Hai and Hang Hum II, at Tham Om (with *Atherurus* sp.), and at Keo Leng (with *Atherurus* cf. *macrourus*) (Cuong, 1985; Olsen and Ciochon, 1990) (Table 6).

Ma U'Oi is the northernmost occurrence of the lesser marmoset mouse *H. delacouri* whose present distribution is limited to Central Vietnam, Northern Laos and Hainan (Corbet and Hill, 1992). The oldest occurrence of *H. delacouri* is mentioned in Thailand in the middle Middle Pleistocene site of Khao Noh and in the late Middle Pleistocene site of Thum Wiman Nakin (especially Snake Cave main layer). *H. phayrei* is known at present in Indochina and Thailand (Corbet and Hill, 1992) and its origin dates back to Late Pliocene (Chaimanee, 1998). So, in comparison with fossil faunal community of Thai rodents, the three Ma U'Oi taxa (*L. sabanus*, *N. fulvescens*, and *H. delacouri*) suggest a maximal age of middle Middle Pleistocene (of which upper limit is 250 000 yr). This is consistent with the absolute dating of $193 \pm 17$ kyr (late Middle Pleistocene) (MU1, Fig. 4), an estimate obtained for the microvertebrate fauna.

Among Insectivora, *Crocidura* sp. is present at Ma U'Oi. This soricid is still living in Vietnam with the middle-sized *C. fuliginosa*, *C. horsfieldi*, and with the large-sized *C. attenuata* and *C. murina* (Corbet and Hill, 1992). Concerning mainland Pleistocene data, little information is available in the literature. The most-documented site is that of Thum Wiman Nakin in Thailand (Ginsburg et al., 1982; Chaimanee and Jaeger, 1993; Chaimanee, 1998). The faunal list of this late Middle Pleistocene site includes two Insectivora, the erinaceid *Hylomys suillus* and the soricid *Crocidura fuliginosa*. At Khao Rupchang site, Chaimanee (1998) mentions the presence of some insectivores such as *Hylomys* sp.

The Ma U'Oi Chiroptera is referred to a pteropodinae indet. Some bats *Pteropus* sp. and several unidentified Microchiroptera are listed at Thum Wiman Nakin (Chaimanee and Jaeger, 1993; Tougard, 1998; Chaimanee, 1998). Chaimanee (1998) also notes the presence of many Insectivora and some Chiroptera in Pleistocene (and Holocene) Thai sites, but without giving more details.

The comparison of amphibians and reptiles listed at Ma U'Oi with those of mainland sites, when they are available in the literature, provides little information for the moment. Indeed, amphibians and reptiles recorded in sites of Southeast Asia are very scarce (Table 6). One Cambodian and two Vietnamese localities yielded reptiles. Carbonel and Guth (1968) reported at Phnom Loang (Cambodia) four dorsal and three caudal vertebrae, which they referred to

Table 6
Rodents listed in principal sites of Southeast Asia (Cuong, 1985; Chaimanee, 1998)

| | Vietnam | | | | | | | China | | Thailand |
|---|---|---|---|---|---|---|---|---|---|---|
| | MU | TK | TH | TO | HH | KL | LS | L | H | TWN |
| *Nesokia* sp. | | | | | | | X | | | |
| *Rattus* sp. | | X | | | | X | | | | X |
| *R. sikkimensis* | | | | | | | | | | X |
| *R. argentiventer* | | | | | | | | | | X |
| *R. rattus* | | | | | | | | | | X |
| *R. koratensis* | | | | | | | | | | X |
| *Mus* sp. | | X | | | | ? | | | | X |
| *M. shortridgei* | | | | | | | | | | X |
| *M. pahari* | | | | | | | | | | X |
| *M. cooki* | | | | | | | | | | X |
| *M. cervicolor* | | | | | | | | | | X |
| *Callosciurus* cf. *finlaysoni* | | | | | | | | | | X |
| *Menetes berdmorei* | | | | | | | | | | X |
| *Belomys pearsonii* | | | | | | | | | | X |
| *Petaurista petaurista* | | | | | | | | | | X |
| *Hylopetes spadiceus* | | | | | | | | | | X |
| *Hylopetes phayrei* | X | | | | | | | | | X |
| *Cannomys badius* | | | | | | | | | | X |
| *Vandeleuria oleracea* | | | | | | | | | | X |
| *Chiromyscus chiropus* | | | | | | | | | | X |
| *Hapalomys delacouri* | X | | | | | | | | | X |
| *Chiropodomys gliroides* | | | | | | | | | | X |
| *Bandicota* sp. | X | | | | | | | | | |
| *B. indica* | | | | | | | | | | X |
| *Berylmys berdmorei* | | | | | | | | | | X |
| *Maxomys surifer* | | | | | | | | | | X |
| *Niviventer bukit* | | | | | | | | | | X |
| *N. confuciacus* | | | | | | | | | | X |
| *N. fulvescens* | X | | | | | | | | | X |
| *N. andersoni* | X | | | | | | | | | |
| *Niviventer gracilis* n. sp. | | | | | | | | | | X |
| *Leopoldamys sabanus* | X | | | | | | | | | X |
| *Hystrix* sp. | | X | | | | X | | | X | |
| *H. brachyura* | X | | | | | | | | | |
| *H.* cf. *subcristata* | | | | | | | | X | | |
| *H. subcristata* | | X | X | X | X | X | | | | |
| *H. hodsoni subcristatus* | | | | | | | | | | X |
| *Atherurus* sp. | | X | | X | ? | | | | | |
| *A.* cf. *macrourus* | | | | | | X | | | | |
| *Rhizomys* sp. | | X | | X | | X | | | | |
| *R. troglodytes* | | | | | | | | X | | |
| *R.* cf. *troglodytes* | | X | | | X | X | | | | |

Vietnam: Ma U'OI (MU), Tham Kuyen (TK), Tham Hai (TH), Tham Om (TO), Hang Hum (HH), Keo Leng (KL), Lang Son (LS); southern China : Liucheng (L), Hoshangtung (H); and Thailand : Tham Wiman Nakin (TWN).

*Varanus*. In the Pleistocene of Vietnam, Cuong (1985) and later Olsen and Ciochon (1990) listed some undetermined Chelonia at Keo Leng and a questionable *Testudo* sp. at Tham Khuyen. The only lists including reptiles are available in Chaimanee (1998) for Thai sites, generally at the family or genus level. Thus, we can just mention the presence of snakes (Colubridae and Viperidae) and that of lizards (Gekkonidae and Agamidae) in the Pleistocene of Thailand and Vietnam.

The in situ findings from Ma U'Oi confirm the relative modernity of the fauna with most animals still living in Vietnam (*Rusa unicolor*, *M. muntjak*, *R. sondaicus*, *R.* cf. *unicornis*, *Macaca* sp., *Cuon* sp., *Elephas* sp., and *S. scrofa*) (Corbet and Hill, 1992), with the exception of the extinct elephant *E.* aff. *namadicus* (Table 5). No archaic elements characteristic of the Early to early Middle Pleistocene *Ailuropoda–Stegodon* complex (as *Stegodon praeorientalis*, *Hyaena brevirostris*, *Rhinoceros sivalensis*, *Hexaprotodon sivalensis*, *Equus yunnanensis*, and *Gigantopithecus blacki* for example) were recovered in the Ma U'Oi assemblage (Young, 1932; Pei, 1935; Teilhard de Chardin, 1935; Bien and Chia, 1938; von Koenigswald, 1939; Young and Liu, 1951; Colbert and Hooijer, 1953; Pei and Li, 1958; Kahlke, 1961; Aigner, 1978; de Vos, 1984). Some species as the wild boar (*S. scrofa*), the sambar (*R. unicolor*) and the muntjac (*M. muntjak*) do not provide any stratigraphic information: they occur as far as the early Middle Pleistocene and are still present in the fauna. Others are more informative. The occurrence of *Elephas* suggests that Ma U'Oi is younger than Tham Kuyen and Tham Hai in Vietnam, Liucheng and Changyang in southern China, where this genus is absent (Cuong, 1985; Olsen and Ciochon, 1990). *E. namadicus* is commonly cited in the Middle Pleistocene sites from Southeast Asia (Hang Hum, Tham Om, Hsingan, Hoshangtung, Mogok, Tam Hang, Tambon and Yenchingkuo) and its presence is questionable in the Late Pleistocene, as at Lang Trang where its status is still debated (*E. namadicus* vs. *E. maximus*; de Vos and Long, 1993; Long et al., 1996). The most informative Ma U'Oi taxon, in terms of stratigraphy, is *R.* cf. *sondaicus*. Indeed, this species is only known in three sites dated to late Middle Pleistocene: Phnom Loang in Cambodia (Beden et al., 1972; Beden and Guérin, 1973) and Thum Phra Khai Phet and Thum Wiman Nakin in Thailand (Tougard, 1998, 2001), also dated to 169 kyr by U/Th method (Esposito et al., 1998). Ma U'Oi also resembles in some aspects to Lang Trang in northern Vietnam dated to 80–60 kyr (de Vos and Long, 1993; Long et al., 1996). In the first paper (Bacon et al., 2004), we had estimated that the in situ Ma U'Oi fauna could range between the late Middle Pleistocene and the Late Pleistocene, a biochronological estimate we maintain with new findings. This biochronological range fits in with U/Th dating (C. Falguères, com. Pers;, 2004). The dating (MU2, Fig. 4) obtained from a sample covering the fossiliferous breccia gives a minimal age of $49 \pm 4$ kyr (Late Pleistocene) for the in situ fauna.

Pleistocene faunas are believed to accompany the arrival and migration of first humans in Far East Asia (*H. erectus*) and later that of first modern humans (*H. sapiens*), as far as the island of Java, due to sea level drop (Dubois, 1908; Badoux, 1959; de Vos, 1985; van den Bergh et al., 1996). Among the Ma U'Oi faunal assemblage, two human molars have been discovered in the same layer (Demeter et al., 2004, 2005). Both teeth are attributed to one undetermined type of *Homo*, named "archaic *Homo*": MU18 (m1) with archaic and modern traits and MU57 (M2) with only morphologically modern traits. This determination confirms, in the absence of diagnostic cranial material, the difficulty to determine the status of *Homo* found around the Middle/Late Pleistocene limit, as previously noted by Olsen and Ciochon (1990).

In the literature, affiliation of human teeth has been made many times a priori in reference to a stratigraphical context with this postulate: "Middle Pleistocene-*H. erectus*" and "Late Pleistocene-*H. sapiens*". The Ma U'Oi findings confirm that this postulate is too simple and that it is necessary to redefine the place of humans in Asian faunal associations.

## 7. Palaeoenvironmental implications

The absence of pollens gives no information about the flora around Ma U'Oi during the concerned depositional period. These data are therefore provided via the fauna analysis.

The Ma U'Oi in situ fauna, though not rich, which can be considered slightly older than $49 \pm 4$ kyr, suggests an open woodland close to the present environment in Vietnam. Indeed, all large mammals, *M. muntjak*, *S. scrofa*, *R. unicolor* and *Macaca*, are still present in Vietnam. Among murid rodents, *N. fulvescens* and *L. sabanus* suggest various kinds of forests, lowlands and foothills of evergreen forests (Corbet and Hill, 1992; Chaimanee, 1998). However, while *N. fulvescens* and *L. sabanus* are still

present in Vietnam, the presence of *N. andersoni* is controversial at Ma U'Oi because its environment is far from what the other mammals suggest. Indeed, Musser and Chiu (1979) note "Both *andersoni* and *excelsior* inhabit the high mountains along the eastern edge of the Tibetan Plateau and the Himalayas" and, farther "Examples of *andersoni* have been collected from elevations ranging from 6000 to 10000 ft" (2000 to 3300 m). Corbet and Hill (1992) note that *N. andersoni* can be observed at altitudes of 1800–3000 m. So, the presence of this murid at Ma U'Oi tends to indicate, contrary to the present environment, a more southern boundary of montane forest vegetation with drier conditions before $49 \pm 4$ kyr, as suggested by van der Kaars and Dam (1995). It reflects also that the montane vegetation zone had probably lower altitude than currently due to cooler temperatures. This dryer period follows more tropical conditions largely spread throughout Indochinese and Sundaic subregions, as suggested by the presence of *Pongo* at Lang Trang dated to 60–80 kyr in northern Vietnam (Long et al., 1996), as well as that of *Pongo* at Punung, a Javanese locality dated to 60–125 kyr (de Vos, 1983, 1984).

The Ma U'Oi microvertebrate fauna dated to late Middle Pleistocene ($193 \pm 17$ kyr) seems rather to indicate more forest conditions. The only known comparable fauna of relatively same age, Thum Wiman Nakin (169 kyr; Esposito et al., 1998; Chaimanee, 1998), is situated more southern, which suggests that these environmental conditions could be spread throughout the Indochinese region.

*N. fulvescens* and *L. sabanus*, present in various habitats, are not pertinent for palaeoenvironments. However, the third murid present at Ma U'Oi, *H. delacouri*, is a specialized arboreal rat, which inhabits tropical forest. It can also be found on highlands at elevations up to 1200–1500 m (Chaimanee, 1998). This lesser marmoset mouse is an Indochinese arboreal murine (Central Vietnam, Northern Laos, and Hainan) (Corbet and Hill, 1992). Several flying squirrels (at least 3 taxa) also indicate forest habitat. *H. phayrei* is known in Indochina and Thailand. Most shrews (*Crocidura*) are animals of lowland and montane forest and are nocturnal (Corbet and Hill, 1992). The aquatic snake at Ma U'Oi suggests the presence of a nearby river as confirmed by associated fluvial deposits.

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