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Dating, stratigraphy and taphonomy of the Pleistocene site of Ban Fa Suai II (Northern Thailand): contributions to the study of paleobiodiversity in Southeast Asia.

Datation, stratigraphie et taphonomie du site Pléistocène de Ban Fa Suai II (nord de la Thaïlande) : contributions à l'étude de la paléobiodiversité en Asie du Sud-est.

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Résumé :

Depuis la description initiale du complexe *Ailuropoda*-*Stegodon* en tant qu'association faunique ayant une signification biochronologique pour l'Asie du Sud-est, peu de sites ont fourni de données paléontologiques permettant une documentation complète des faunes anciennes. La biodiversité et les reconstitutions paléo-environnementales de la faune du Pléistocène sont, deplus, encore souvent basées sur des assemblages fauniques dont la taphonomie et la datation ne sont soit pas prises en compte, soit mal documentées. Pour être utile dans des perspectives paléo-écologiques, les assemblages fauniques collectés doivent être datés avec une résolution suffisante pour être confronté à des épisodes de changements climatiques d'ampleur comparable. Dans ce travail nous fournissons une étude stratigraphique, taphonomique, et paléontologique détaillée et des datations ESR concernant le site de Ban Fa Suai II découvert près de la grotte du Moine dans le nord de la Thaïlande. Les résultats permettent de documenter les changements de la composition taxonomique de la faune au cours du temps mais également de souligner les biais et les verrous actuels quant à l'emploi des données disponibles pour des reconstructions paléo-écologiques.

Mots-clés : *Stegodon-Ailuropoda-Pongo*-biodiversité- Asie du Sud-est

Abstract

Since the initial description of the complex *Ailuropoda*-*Stegodon* as a faunal association with biochronological significance for the Southeast Asian area, few sites have provided paleontological data allowing for an extensive documentation of past fauna. Biodiversity and paleo-environmental reconstructions of Pleistocene fauna are still generally based on bone assemblages whose taphonomy and dating are not or badly documented. However, in order to be useful in a paleo-eclogical perspective, the dating of collected assemblages should be associated with periods of times corresponding to climatic episodes. In this study, we provide a detailed stratigraphic, taphonomical, paleontological and ESR dating studies concerning the site of Ban Fa Suai II discovered near the cave of the Monk in northern Thailand. Our results demonstrate the changes in the taxonomic composition of the fauna over time and argue against the use of the currently available regional dataset for paleo-ecological reonstructions.

Key-words: *Stegodon-Ailuropoda-Pongo*-biodiversity-Southeast Asia

Introduction

During a systematic field-survey in the Doi Chiang Dao countryside 80 km north of Chiang Mai in Northern Thailand we discovered and excavated a second cave in Ban Fa Suai village (**Figure 1**), the Cave of Ban Fa Suai II, near the Cave of the Monk (Zeitoun et al. 2005). The Cave of the Monk was uncovered in a karstic network, and the deposition mechanism of the faunal assemblage was identified through geological and taphonomic studies (Lenoble et al. 2008). Thanks to the precision of the excavation carried out in Ban Fa Suai II, and to the direct dating of the fossil remains, it was possible to investigate the evolution of the *Ailuropoda-Stegodon* faunal assemblage. In the previously studied Cave of the Monk, *Stegodon*, was never strictly associated with the *Ailuropoda* and *Pongo* in the same stratigraphic layers (Zeitoun et al. 2010). The new results from Ban Fa Suai Cave II provides additional paleontological information regarding the dating of the *Ailuropoda-Stegodon* complex and its potential to describe past environmental modifications. The detailed study of this new assemblage confirms that the paleo-environmental conclusions generally proposed in the recent palaeontological literature of Southeast Asia are still far from being demonstrated (cf Bacon et al. 2015, 2018; Duringer et al. 2012; Louys and Meijaard 2010).

Stratigraphy of the cave

Ban Fa Suai II is a small cave opening at the base of a limestone outcrop around eight hundred meters northwest of the Ban Fa Suai village. A ten meters wide rockshelter forms the entrance of the cave, extended by a diverticulum leading to a 3 meters-long room. This cave is filled with a deposit that we excavated to a depth of 1.5 m. Three lithostratigraphic units were identified (**Figure 2**).

The uppermost twenty centimeters of the deposit (Unit 1) are made up of a loose sometimes finely aggregated grey silts organized into poorly bedded lenses, some of them rich in charcoals due to recent human activity in the cave.

The lower unit (Unit 2) is a 1.1 meter-thick massive clay with two overlaying facies. Its upper part is an aggregated yellow-brown clay containing some centimetric limestone granules and breccia fragments. The sediment is poorly bedded, mainly formed of rounded, several millimeters-large rounded clayey granules, organized into several centimeters-long and a few centimeters-thick lenses. Some patches present a finely aggregated structure of well sorted sub-millimetric fecal pellets. The lower part of the unit is a massive yellow brown to red brown clay containing aggregated clay lenses. Some patches of the base of this unit are cemented with calcite. Biological channels and cavities are present throughout the unit, but prominent in the upper part. The shape and size of these voids, and their irregular walls covered by a thin coating of silt are indicative of termite activity. A reworking of the sediment by the soil fauna is also pointed by the patches of finely aggregated sediment that appears, in thin section, formed of the coalescence of well-calibrated oval micro-aggregates corresponding to the termite balls described by Eschenbrenner (1986).

The lowermost unit (Unit 3), observed over a thickness of 20 centimeters, is a much hardened breccia. Thin section observation shows that this breccia is made up of bedded sediment of graded quartzitic sands and laminated silts and clays with the whole being cemented with large sparite monocrystals. Such features demonstrate this unit formed in an active karst, as indicated by the fluvial sedimentation shown by the non-carbonated nature of the sediment and the excellence of the sediment sorting, as well as the phreatic conditions implied in the formation of large sparitic monocrystals (Verrecchia, 2002).

In contrast, Unit 2 formed in a fossil karst, as pointed by speleothem fragments contained in the sediment implying a cave with chemical sedimentation. Moreover, the cementation no longer corresponds to large monocrystals of calcite, but to micrite cristals coating the voids or bridging the aggregates together, such crystal fabric being indicative of vadose conditions. While the termite activity obliterated almost completely the primary structure of the sediment, some part preserved a cross bedding by overlaying of lenses of clayey aggregates and interlayered massive clay beds showing, under the microscope, a pseudo-lamination indicative of a trampling of the sediment. Such stratification and the size of the lenses made these deposit comparable to those in the Cave of the Monk produced by the accumulation of excavated material from cave-dwelling burrowing animals (Lenoble et al. 2008).

The faunal remains collected in Unit 2 were dispersed and size-sorted in the lenses of granules and

aggregates. This distribution indicates a deposit caused by animal digging. Moreover, this distribution - as well as the presence of areas not affected by termite activity - shows that reworking of the sediments by soil fauna was not complete. This is an important point because it means that the stratigraphic distribution of bone remains was not significantly disturbed after deposition.

On the basis of macro- and microscopic characteristics, the laying down of deposits can be described as a sequence where the base unit is made up of alluvium pointing to an initial infilling of the cave when it had been, at least periodically, the bed of an underground watercourse. The exclusively non-calcareous nature of the sedimentary material indicates that sediment was brought into the karst and was not the result of the degradation of the surrounding rock. This lithology is typical of an active network functioning in loss/resurgence, a frequent situation in the karstic network of the limestone hills surrounding the Doi Chiang Dao mountain (Zeitoun et al. 2008). The environment in which the fossil bearing unit of brown-red clay developed is, on the other hand, that of fossilized karst *id est* abandoned by the underground watercourse. The nature of the stratification by the super-positioning of lenses of massive and aggregated clay and the size of the lenses made this deposit comparable to that in the Cave of the Monk.

Taphonomic and taxonomic analysis

The paleontological remains were discovered between 10 cm and 1.3 m below the surface essentially belonging to the second stratigraphic unit. The gathered material includes **1761** remains, **1482** being dental remains. Bone fragments represents less than **14%** of the remains with **252** remains (**Table 1**), and 27 shells remains were collected in the upper anthropic layer.

The faunal remains show an intense fragmentation with a mean size of 1.7cm and with the biggest remains measuring less than 7 cm length (**Figure 3**). About 7% of the teeth preserve a complete crown and less than 1% still have their roots. Neither marks of digestion nor tooth prints have been observed, which contributes to exclude carnivores as potential accumulating agent especially since the carnivore remains are very scarce in the assemblage and that the ratio Carnivore/Ungulate varies from 0 to 2% in the different stratigraphic subunits. No man-made alterations (such as evidence of fire/combustion, cutting marks, or percussion marks) have been observed on the faunal remains. Finally, although termite activity was noted in Unit 2, we did not observe any trace of termite on the bones or teeth themselves. However, 17% of the whole material was gnawed by large rodents. Similarly, 21% of the bones fragments (**Figure 4** a) were gnawed by large rodents, with the majority of remains reduced to cubic or "diamond tip" remains (**Figure 4** b and d). This is comparable to the marks described by several authors (Pei 1938; Rabinovich and Horwitz 1994; Tong 2008; Tong et al. 2008; Filoux et al. 2015) or to the 16% of gnawed teeth in the Cave of the Monk (Zeitoun et al. 2010). The teeth of carnivores (**Figure 4** c) and suids (**Figure 4** e and h) are gnawed from the root up to the base of the crown sometime until the inner part of the crown. The selenodont and lophodont teeth are also gnawed from the root up to the crown (**Figure 4** f and g) but they are also often broken due to synsedimentary compaction (**Figure 4** i, j, k). This is followed by further gnawing of these dental elements by Hystricidae, which then attack the dentin (**Figure 4** l, m, n). Although smaller in size than the one exhumed from the Cave of the Monk, this collection bears the characteristic stigmas of a Porcupine lair.

The fragmentation and preservation state of the faunal remains prevent in most cases a precise taxonomic attribution. However, several categories were identified among isolated teeth. Artiodactyls constitute 74.8% of the total number of dental elements, 49.2% of which are unidentified. Among the identified teeth, 20.4% are Cervids, 2.6 % are Bovids, 2.7%, are Suids. Perissodactyls constitute 9.3% of the identified teeth, Proboscideans 5.1%, Carnivores 1.1%, Primates 1.2% and Rodents 8.2% (**Table 1**). We have not identified any *Tapirus* remain in the assemblage.

Dating

ESR age calculations were performed for three teeth from the Unit 2e and 2f of the site Ban Fan Suai II. Sample preparation was according to standard techniques reported in Rink et al. (1994). A minimum of 40 microns were removed from the outer and inner enamel layers using a high-speed dental drill in order to remove any external alpha dose contribution. Uranium concentrations in the enamel and dentine, as well as uranium, thorium, and potassium concentrations in collected sediment were determined using instrumental neutron activation analysis at the McMaster Nuclear Reactor (**Table 2**). Alpha and beta dose rates to the enamel layers were determined by calculation from the radioisotope concentrations in the enamel, dentine, and sediment. Gamma dose rates were

determined by *in situ* gamma spectroscopy near the sample locations and the cosmic dose rate was determined using an estimated overburden of 16m for the thickness of the roof above the cavity, 2.6 g/cm^3 for the sediment and, were corrected for latitude and altitude (Prescott and Hutton, 1994). ESR measurements were performed with a JEOL JES-FA100 X-band ESR spectrometer with the following scan parameters: power 2.0mW, modulation amplitude 0.5mT, center field 336.0mT, scan width 5.0mT, scan rate 0.167mT/sec, and time constant 0.1s. Ages were calculated with ROSY v2.0, which incorporates one-group theory for beta particle transport (Brennan et al., 1997). Two model ages are calculated including an early-uptake (EU) age (Bischoff and Rosenbauer, 1981) and a linear-uptake (LU) age (Ikeya, 1982), as is typical for ESR dating (Grün et al. 1987; Grün and McDermott, 1994). For Early-uptake, we assume that uranium enters the tooth immediately after burial, while for the LU age, we assume that uranium enters the tooth at a constant rate over time. As no U-series data were performed on the dental tissues, no US or AU ages can be calculated. Nevertheless, we do not suspect any uranium leaching in the teeth and, as EU model corresponding to a closed system versus uranium uptake by the tissues, p-value = -1, it corresponds to minimum ages. On the other hand, LU model, p-value = 0, corresponding to a linear U-uptake versus time yields ages which are close to those provided by EU model in the error range. Finally it is reasonable to think that the LU ages represent the maximum ages. The dose rates for the EU and LU models, and the calculated ESR ages are given in **Table 3** indicating ages of faunal remains of the Unit 2 older than 49.7 4.0 ka (EU) 55.2 4.7 ka (LU) and younger than 46.8 5.0 ka (EU) 51.0 5.7 ka (LU).

Attempt of paleo-ecological analysis

The evolution of the number of taxa over time follows an upward progression from the Unit 3 to subunit 2f which presents a peak. After a drop in the number of taxa in subunit 2d, the number of taxa is again increasing until subunit 2a in which begins a decrease that continues in Unit 1. Chi² test (p.val<0.01) also indicates that significant differences occur in the faunal composition of the different layers but the number of collected remains is too small for allowing a pair wise comparison of every stratigraphic units. In order to better investigate this evolution we calculated Shannon and evenness indices and computed rarefaction curves using the R software (https://cran.r-project.org) and the package "vegan" (Oksanen et al., 2019). To avoid any bias regarding the different identification taxonomic ranks, only the remains identified at least to the genus level were considered. The qualitative tendencies previously observed are confirmed by the Shannon and evenness indices of the different layers (**Table 1**). Although a significant correlation exists between the number of taxa and the number of remains studied in the different layers (linear regression, R^2=0.82, p.val>0.01), the rarefaction curves (**Figure 5**) confirm the tendencies expressed by the former indices by showing that the differences of the number of taxa identified to the different layers is probably not due to a sampling effect.

From a qualitative point of view, the peaks in taxa numbers observed in stratigraphic subunits 2f, 2a, and 2b, is systematically associated to the occurrences of both arboreal primates and *Ailuropoda*. There is also a difference between subunits 2f and 2e with the temporary disappearance of *Stegodon* who also disappear between subunits 2c and 2b. Suspecting an ecological reason for such variations, we established a cenogram for each stratigraphic subunits. The cenograms were made according to the protocol proposed by Legendre (1986) (**Table 4**) using the mean weight available in Macdonald (2006) for the current fauna, and the number of identified remains in each stratigraphic units. As far as Proboscideans are concerned, we have identified dental remains of *Stegodon* or undetermined Proboscideans, being possibly *Stegodon* or *Elephas*. Considering the difficulty to identify these remains, we assigned the same mean weight to both of these taxa. Since unidentified Artiodactyls and unidentified Bovids refer to several possible taxa with a very wide weight spectrum (from *Bos* cf. *gaurus* to *Pseudoryx* sp.) and, since these taxa are all present in each stratigraphic subunit, unidentified Artiodactyl remains were not included in the analysis. Rhinos are present throughout the sequence with only a single specific identification (*Rhinoceros* cf. *sondaicus*). The cenograms of Units 1 and 3 have similar slopes. Unit 2 is divided into two groups with subunits 2a, 2b, 2f on the one hand and, 2c, 2d, 2e on the other hand (**Figure 6**) which is consistent with the diversity indicators (Shannon indices, evenness indices and rarefaction curves). The obtained cenograms provide additional information regarding humidity of past environments. The occurrence of Primates (*Trachypithecus*+*Macaca* or *Macaca*+*Pongo*) and *Ailuropoda* with the disappearance of *Stegodon* is thus associated to moister environments in subunits 2a, 2b and below 2f. However, because of the accumulating agent: the Porcupine, which excludes very small fauna from its gathering, it is not possible to interpret the cenograms in terms of open *versus* closed environment.

Discussion

The Ban Fa Suai II site is a porcupine lair documenting a typical well-dated *Ailuropoda-Stegodon* fauna from the second part of the Late Pleistocene. The formation conditions of the bone assemblage were constant over time and its accumulating agent is known to form bone assemblages providing a reliable image of nearby environmental conditions (Alexander 1956; Brain 1981). This specific configuration allows for a paleo-environmental reconstruction free of most of the bias frequently impacting such approaches.

Southeast Asian Pleistocene paleontological assemblages are known to be faunal mixtures from different periods and environments for a long time (Colbert 1943; De Vos, 1983, 1984 ; Kahlke, 1961 ; Orchiston and Siesser 1982 ; Patte 1928; Pei 1957). We recently conducted a reappraisal of different sites and taxa belonging to the Southeast Asian regional complex and drew up a list of arguments denying that Pleistocene faunal assemblages can currently be properly used for paleo-ecological or paleo-environmental purposes (cf Zeitoun et al. 2015, 2016), despite the recent progress in geochronology with direct dating methods of fossils (Chen et al., 1987; Chen and Yuan, 1988; Jones et al., 2004; Rink et al. 2008; Wang et al. 2007; Zeitoun et al. 2010). Indeed, the lumping of remains from deposits scattered around different places in one site or even from several caves was still currently practiced. In many sites the stratigraphic association between remains and layers was not possible due to the lack of sedimentological or taphonomical studies. The presented data were often bluried by the use of artificial benchmarks such as Yenchingkuo or Hoshangtung or, due to the deliberate selection or omission of some data (Bacon et al. 2004, 2006, 2011).

In such a context, a preliminary requirement to propose, or test, paleo-environmental hypotheses is to consider each locality separately, as well as each layer separately in a single site (Saegusa, 2001). An additional condition to correctly consider paleoecology is that the time frame of site formation should not be longer than periods of climatic fluctuation (MIS timescale). This is a serious limitation since most of the presumed age of the *Ailuropoda*-*Stegodon* assemblages is rather speculative, or with chronological ranges appearing to be quite wide. For example in Thailand in the site of Tham Wiman Nakin, this complex span from 350 to 8 ka (Esposito et al. 2002), without the possibility to distinguish different layers among the breccia. In China the Wuyun site span also a quite large time as Wang et al. (2007) indicate that the excavated fossil assemblages date from 287.6 ± 60.0 ka to 14.19 ± 4.2 ka.

Although the Pleistocene faunas illustrated by the *Ailuropoda*-*Stegodon* complex in Southeast Asia are difficult to subdivide, due to the long temporal ranges of many taxa and, a reduced number of genera in comparison to faunas from the sites of temperate north China (Rink et al., 2008), variability in the composition of these assemblages was nevertheless pointed among the dated sites (op. cit.). Taphonomic approaches (Bakken 1997; Schepartz et al., 2001, 2003) conducted on the Chinese site of Panxian Dadong showed the evolution of four different assemblages defined before 214 ± 24 ka (EU) 261±31 ka (LU) and after 137± 16 ka (EU) 156±19 ka (LU) respectively (Bekken et al., 2004). With similar precautions Turvey et al. (2013) were able to reconstruct paleo-ecological events for the Late Pleistocene.

Concerning Ban Fa Suai II we tried to push forward the possibility to recognize paleo-ecological signals. Assuming that deposition conditions of faunal remains have been homogeneous over time from one subunit to another and, that only the differential extent of brecciation affects the remains *in situ*, we have tried to determine whether significant variations in biodiversity and environment can appear between the different sedimentary units. To do so, we used a combination of biodiversity indices (taxonomic composition) and paleo-environmental approaches (cenograms). We also performed direct dating of faunal remains in order to connect our observations to global climate fluctuations.

Subunits 2a and 2b of Ban Fa Suai II refer to a signal already observed in the nearby Cave of the Monk, in which detailed excavation had revealed an alternating series of two assemblages that replace each other through time. In this binary sequence the *Stegodon* was never strictly associated with the *Pongo* or the *Ailuropoda* but rather with *Cervus* cf *unicolor* and *Tapirus* sp. On the other hand, at the Cave of the Monk the genus *Elephas* was associated with *Pongo* or *Ailuropoda* between before 37.9 ± 5.0 ka (EU) 38.5±5.1 ka (LU) and beyond 14.8 ± 1.5 ka (EU) 15.1±1.5 ka (LU) (Zeitoun et al. 2010).

At Ban Fa Suai II, the similarity of the cenograms of subunits 2a, 2b and 2f, lacking *Stegodon* but inluding *Pongo* and *Ailuropoda*, as well as other primates (*Macaca* and *Trachypithecus*), could be of ecological significance. Indeed, although the cenograms cannot provide the degree of opening of the biotopes due to the lack of low weighted fauna in the deposit, our data indicate that subunits 2a, 2b and 2f may record moister episodes than subunits 2c, 2d, 2e and

Units 1 and 3. More generally, it is interesting to note that the cenogram of the entire site (**Figure 6**) gives a different signal than the cenograms of the different stratigraphic subunits taken individually. This raises the question of the validity and interest of using a global cenogram for a period of time of several tens of thousands of years (at least longer than a global climate cycle) or even for an uncertain period of time as done by some authors (cf Esposito et al., 2002, Wang et al. 2007). If in an epistemological dimension this type of work was legitimate in the past (Tougard and Montuire 2006), with the methodological development of direct dating, the deliberate mixing of faunal assemblages from different stratigraphic origins on the same site or in different sites that still prevail in the recent literature is a strong limitation to progress in the study of past Souteast Asian fauna and environments. In their reconstruction of the habitat types of 25 Pleistocene sites in Southeast Asia through a synecological method, Louys and Meijaard (2010), advocated that the cave of the Monk was one of the only two sites, with Tam Hang, that could confidently be allocated to a "mixed habitat". This so-called "mixed habitat" of the Cave of the Monk is more certainly the result of the admixture of the two ecological components of the fauna (i.e. *Elephas*/*Pongo*/*Ailuropda* versus *Stegodon*/*Cervus* cf. *unicolor*/*Tapirus*) that alternate over several thousand of years. The admixture of faunas from three localities, the inadequacy between chronological data and faunal assemblages, the absence of taphonomic work, and the lack of record of remains position in the sediment at Tam Hang, are probably the reasons which led to such apparent "mixed habitat".

Such practices and, inadequacy between chronological data and faunal assemblages belies all the alleged demonstrations on the existence of a savannah corridor between continental Southeast Asia and the rest of Sundaland during the Pleistocene (cf. Bacon et al. 2015, p117 and Bacon et al. 2018). Similar reservations can be made regarding the ecological effects of the Toba eruption on the Mammal community structure of Southeast Asian fossil assemblages from the Late Pleistocene (cf Louys 2012).

With its particular sedimentary facies and faunal assemblage, Ban Fa Suai II subunit 2e appears to be a proven break-up with an absence of *Stegodon*. Such a break-up appears after 47.4 3.7 ka (EU) 53.1 4.5 ka (LU) and 49. 7 4.0 ka (EU) 55.2 4.7 ka (LU) which is the dating of faunal remains belonging to subunit 2f and, 46.8 5.0 ka (EU) 51.0 5.7 ka (LU) for faunal remains in subunit 2e. This chronological interval corresponds to the Dansgaard-Oescher climatic oscillations 13 to 12 (WAIS 2015). Thus, the data gathered in Ban Fa Suai II and the Cave of the Monk show that, based on a detailed taphonomic and chronological study, it is possible to recognize the evolution of faunal subgroups within the *Ailuropoda*-*Stegodon* complex. As far as it concerns the Cave of the Monk, the chronological window is quite shorter and the faunal assemblage of Ban Fa Suai Cave II provides complementary data for the Upper Middle Pleistocene. Following the former recommendations not to mix faunas from different locations on the same site and *a fortiori* on different sites, and thanks to the direct dating of fossil material it is therefore possible to observe the record of the global change in a tropical continental environment as it is the case for isotope records of speleothem (Cai et al., 2006; Burns et al. 2003; Wang et al. 2001).

Conclusion

Through regional reappraisals of the available stratigraphic, taphonomical and paleo-environmental data for sites associated with the *Ailuropoda*-*Stegodon* complex we demonstrated that the use of the hazardous and mixed dataset of historical paleontological sites should be avoided in order to establish a consistent regional biochronological frame work (Zeitoun et al. 2015, 2016). Such works without appropriate taphonomical studies or using unfounded historical references lead to highlight the non consistence of recent paleo-ecological or even chronological frames proposed by former authors, including in the last decade. Despite the partial erasing of the faunal information at Ban Fa Suai II due to the breccia formation at the bottom of the deposits and the lack of the low-weight fauna due to the accumulator agent, we have obtained data that are suitable for paleo-environmental studies. The identified deposition mechanism of the paleontological remains and the recording of the data with the highest resolution and, direct dating, are the only way to allow for the description of paleo-ecological changes in tropical continental areas.

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Figure captions

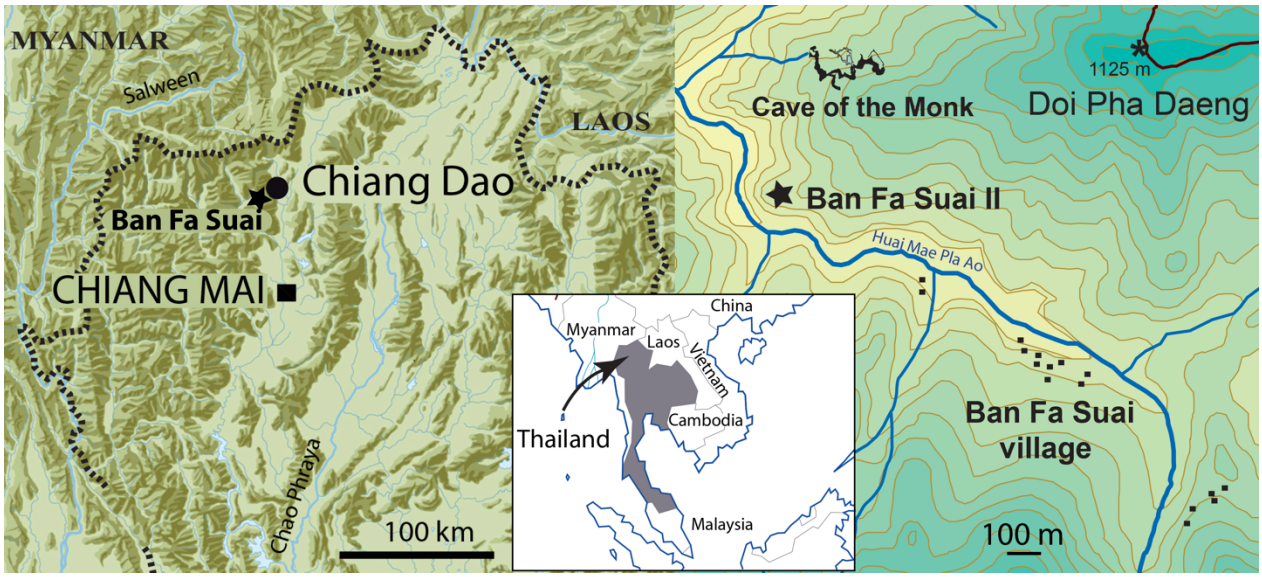

Figure 1: Location of Ban Fa Suai cave II.
Figure 1: Carte de situation de la grotte de Ban Fa Suai II.

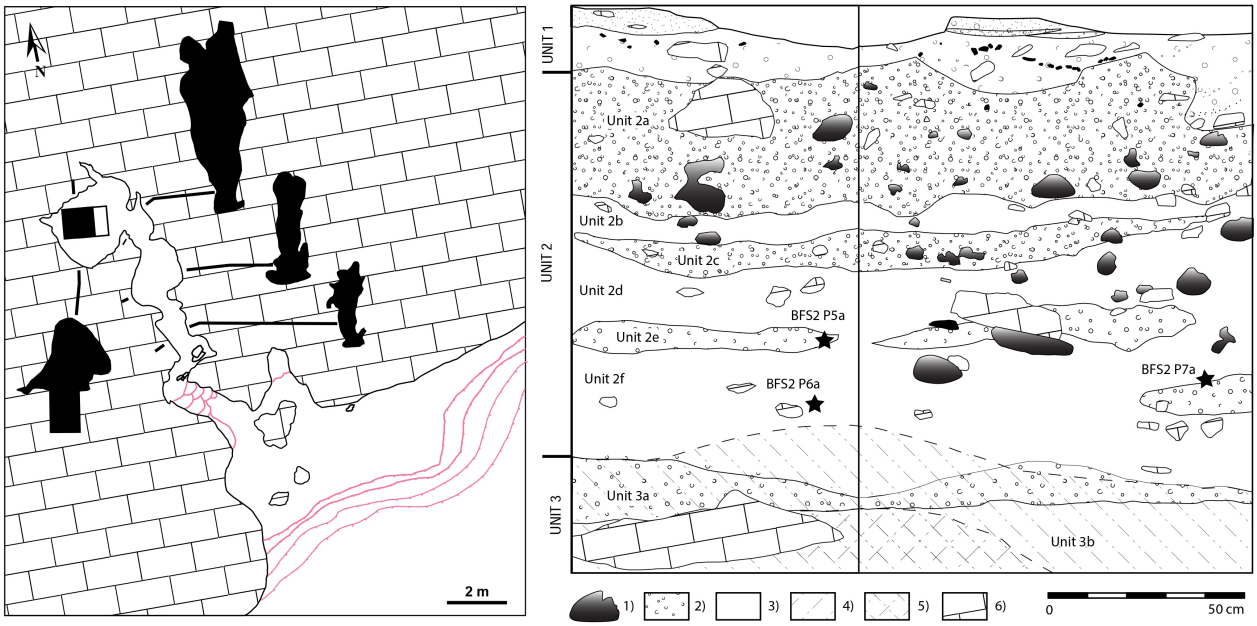

Figure 2: Map of the Ban Fa Suai II cave with location of the excavated pit; Stratigraphic profile of the excavated area 1) bioturbation, 2) aggregated clay; 3) massive clay; 4) induration with nodules; 5) breccia; 6) calcareous stone. The stars indicate the position of the dated remains.
Figure 2: Relevé de la grotte de Ban Fa Suai II avec position de la fouille; coupe stratigraphique de la zone fouillée 1) bioturbation, 2) argile agrégée; 3) argile massive; 4) induration avec nodules; 5) bréche; 6) calcaire. Les étoiles indiquent la position des restes datés.

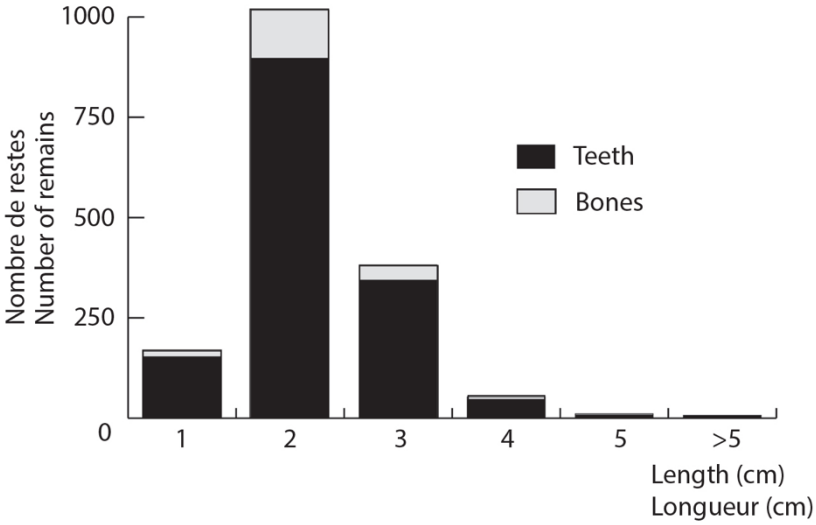

Figure 3: Distribution of the remains by size.
Figure 3: Répartition des restes fauniques par taille.

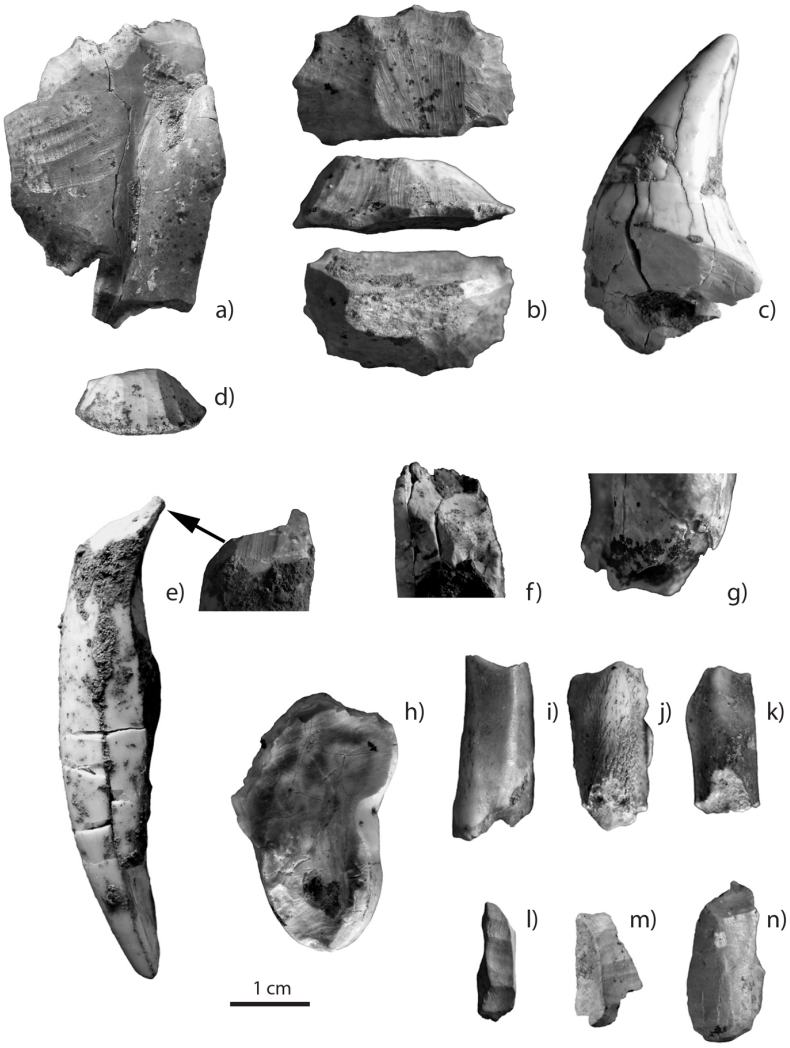

Figure 4 : Illustration of the gnawing on faunal remains. a) piece of bone ; b) diamond tip piece, c) canine of carnivore with gnawed crown ; d) cubic piece ; e) canine of suid with gnawed marks on the crown ; f) suid gnawed dentine ;g) h) i),j),k) teeth broken due to synsedimentary compaction; l), m), n) fragmentary teeth.
Figure 4 : Illustration des restes rongés par les porc-épics. a) fragment osseux; b) fragment d'os usé en pointe de diamant, c) canine de carnivore avec couronne rongée; d) fragment osseux cubique; e) canine de Suidé avec des traces de rongement sur la couronne; f) dent de Suidé avec usure de la dentine;g) h) i),j),k) dents fragmentées par compaction synsedimentaire; l), m), n) fragments dentaires.

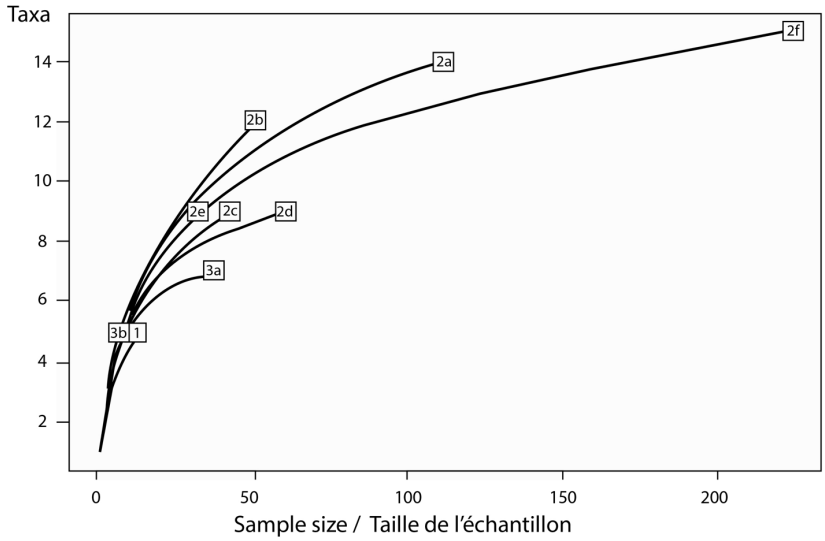

Figure 5: Rarefaction curves of the fauna from the different units at Ban Fa Suai II using statistical analysis on the R software (https://cran.r-project.org) using the package "vegan" (Oksanen et al., 2019).

Figure 5: Courbes de rarefaction de la faune des différentes sous-unités de Ban Fa Suai II obtenues par l'analyse R (https://cran.r-project.org) avec le package "vegan" (Oksanen et al., 2019).

	Unit 1	Subunit 2a	Subunit 2b	Subunit 2c	Subunit 2d	Subunit 2e	Subunit 2f	Subunit 3a	Subunit 3b	Number of remains
Artiodactyla										
Artiodactyla indet.	4	88	118	119	184	65	252	15	12	857
Cervus sp.	0	4	0	8	8	0	5	7	2	34
Cervus cf *nippon*	0	1	1	2	6	6	4	0	0	20
Cervus cf *unicolor*	2	24	2	1	1	1	11	0	0	42
Axis cf *porcinus*	0	1	2	0	0	0	0	0	0	3
Muntiacus cf *muntjak*	0	8	0	0	11	12	0	0	0	31
Naemorhedae indet.	1	3	1	0	1	1	7	1	0	15
Bovidae indet.	3	11	8	9	10	3	12	4	1	61
Bos sp.	2	5	6	2	1	0	8	0	0	24
Sus cf *scrofa*	0	9	6	2	6	5	31	4	2	65
Perissodactyla										
Rhinocerotidae indet.	1	3	1	5	4	1	59	15	2	91
Rhinoceros cf *sondaicus*	0	0	0	0	0	0	9	0	0	9
Proboscidea										
Proboscidea indet.	0	0	0	0	0	0	10	2	0	12
Stegodon sp.	0	0	0	3	2	0	32	3	0	40
Carnivora										
Ursus sp.	0	1	0	1	0	1	3	0	0	6
Ursus cf *thibetanus*	0	0	0	0	0	0	1	0	0	1
Ailuropoda cf *melanoleuca*	0	2	0	0	0	0	1	0	0	3
Cuon cf *alpinus*	0	0	1	1	0	0	1	0	0	3
Panthera cf *tigris*	0	1	1	0	0	0	0	0	0	2
Panthera sp.	0	0	1	0	0	0	1	0	0	2
Primates										
Pongo cf *pygmaeus*	0	0	0	0	0	0	4	0	0	4
Macaca sp.	0	1	2	0	0	0	1	0	0	4
Macaca cf *nemestrina*	0	0	0	0	0	0	1	0	0	1
Macaca cf *mulatta*	0	0	0	0	0	0	1	0	0	1
Trachypithecus sp.	0	4	1	0	0	0	0	0	0	5
Chiroptera										
Chiroptera indet.	0	1	0	0	0	0	0	0	0	1
Rodentia										
Rodentia indet.	0	23	7	2	2	1	1	1	0	37
Hystrix cf *brachyura*	5	34	18	9	11	3	25	2	1	108
Total dental remains	18	224	176	164	247	99	480	54	20	1482
Undetermined bones	4	129	26	5	7	1	55	18	7	252
Gastropoda										
Gastropoda indet.	2	13	5	2	1	1	1	0	0	25
Bivalvia										
Bivalvia indet.	0	2	0	0	0	0	0	0	0	2
Shannon index	1.39	2.05	1.87	1.86	1.92	1.82	2.07	1.67	1.56	
Evenness index	0.86	0.78	0.75	0.84	0.87	0.83	0.77	0.86	0.97	

Table 1: List and number of faunal remains by stratigraphic subunit at Ban Fa Suai II with indication of Shannon indices.

Table 1: Liste et nombre de restes des taxons des diférentes sous-unités stratigraphiques de Ban Fa Suai II avec indication de leurs indices de Shannon.

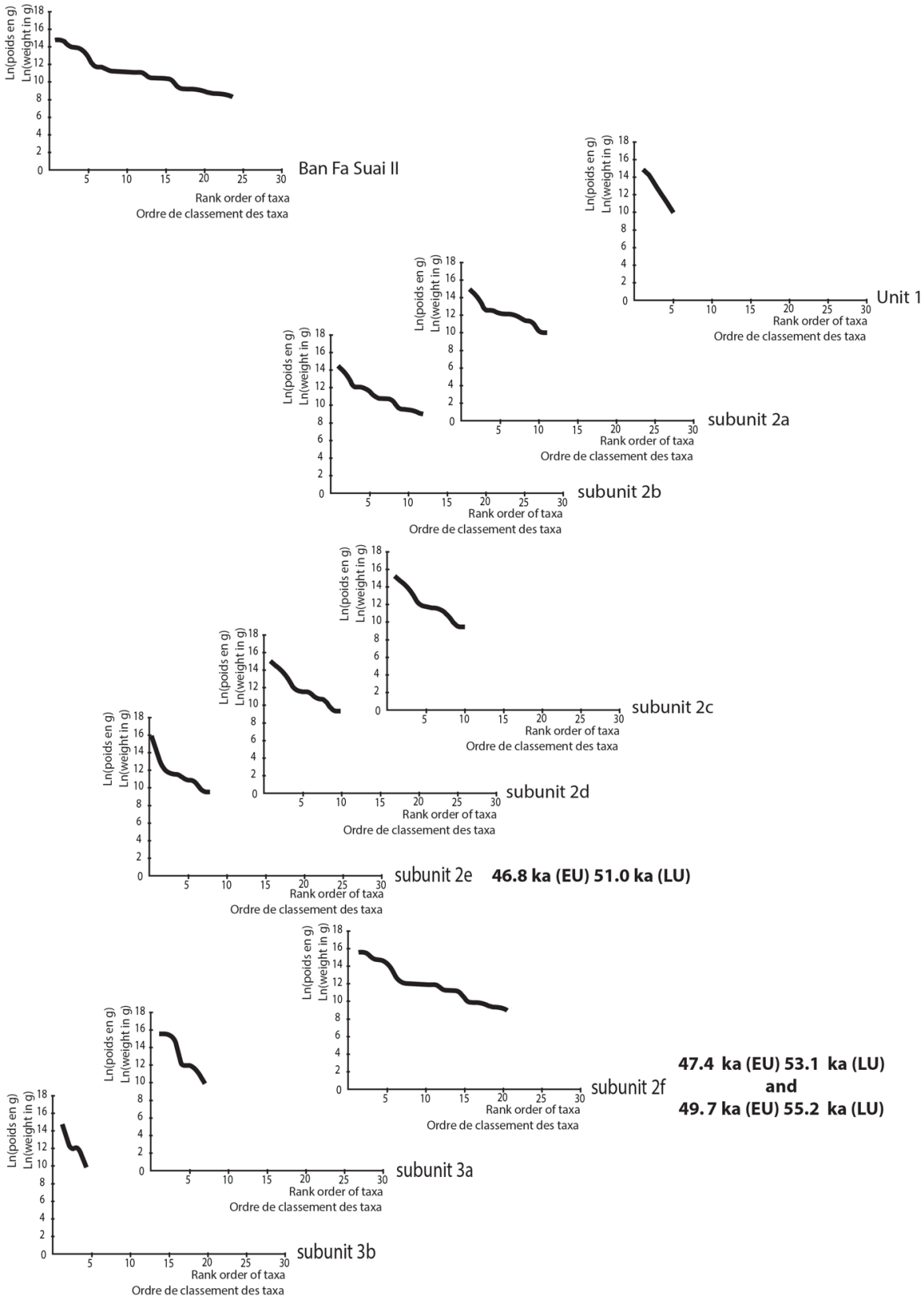

Figure 6 : Cenograms of the different stratigraphic subunits of Ban Fa Suai II.
Figure 6 : Cénogrammes des differentes sous-unités de Ban Fa Suai II.

	Level	Gamma Plus Cosmic Dose Rate (μ Gy/a)	EU, LU β Sed Dose Rate (μGy/a)	Early Uptake				Linear Uptake				EU Age (ka)	LU Age (ka)
				α En Dose Rate (μGy/a)	β En Dose Rate (μGy/a)	β Den Dose Rate (μGy/a)	Total Dose Rate (μGy/a)	α En Dose Rate (μGy/a)	β En Dose Rate (μGy/a)	β Den Dose Rate (μGy/a)	Total Dose Rate (μGy/a)		
P5a	2e	820.47 ± 82.5	181.3	29.30	9.71	133.70	1116.80	12.77	4.45	63.79	1025.11	46.8 ± 5.0	51.0 ± 5.7
P6a	2f	820.47 ± 82.5	121.5	20.66	6.60	201.19	1204.99	9.05	3.03	95.80	1084.43	49. 7 ± 4.0	55.2 ± 4.7
P7a	2f	820.47 ± 82.5	369.5	47.85	15.84	173.90	1170.29	21.08	7.30	83.17	1044.26	47.4 ± 3.7	53.1 ± 4.5

Table 2 : ESR analytical data for Ban Fa Suai II.
D_E = equivalent dose, U = uranium, K = potassium, Th = thorium, Sed = sediment, Den = dentine, Rem = removed, ppm = parts per million, wt % = weight percent, Gy = Gray, m = micrometer. NA = not applicable. Errors in Th and K values range from 2–8% of the value and are not reported here. Errors in U values are 0.1 ppm. ^{238}U concentrations in enamel and dentine and sediment were determined using delayed neutron counting, while ^{232}Th and ^{40}K in sediment were determined using instrumental neutron activation analysis at the McMaster Nuclear Reactor.

Table 2 : Données analytiques ESR pour le site de Ban Fa Suai II.
D_E = dose équivalente, U = uranium, K = potassium, Th = thorium, Sed = sédiment, Den = dentine, Rem = retiré, ppm = partie par million, wt % = pourcentage de poids, Gy = Gigaray, m = micromètre. NA = non applicable. Les écarts d'erreurs en Th et K sont de 2–8% et ne sont pas rapportées ici. Les valeurs d'erreur en U values sont 0.1 ppm. Les concentrations en ^{238}U dans l'émail, la dentine et le sédiment ont été determinées en utilisant le comptage différé des neutrons , alors que ^{232}Th et ^{40}K dans les sédiments ont été determinés en utilisant l'activation neutronique instrumentale du Réacteur nucléaire du McMaster.

	Level	Gamma plus cosmic dose rate (μGy/a)	EU, LU β Sed dose rate (μGy/a)	Early-uptake				Linear-uptake				EU age (ka)	LU age (ka)
				α en dose rate (μGy/a)	β en dose rate (μGy/a)	β den dose rate (μGy/a)	Total dose rate (μGy/a)	α en dose rate (μGy/a)	β en dose rate (μGy/a)	β den dose rate (μGy/a)	Total dose rate (μGy/a)		
P5a	2e	820.47 ± 82.5	181.3	29.30	9.71	133.70	1116.80	12.77	4.45	63.79	1025.11	46.8 ± 5.0	51.0 ± 5.7
P6a	2f	820.47 ± 82.5	121.5	20.66	6.60	201.19	1204.99	9.05	3.03	95.80	1084.43	49. 7 ± 4.0	55.2 ± 4.7
P7a	2f	820.47 ± 82.5	369.5	47.85	15.84	173.90	1170.29	21.08	7.30	83.17	1044.26	47.4 ± 3.7	53.1 ± 4.5

Table 3. ESR Dating Results for Ban Fa Suai II.
EU = early uptake model (Bischoff and Rosenbauer, 1981), LU = linear uptake model (Ikeya, 1982), = beta, = alpha, Cem = cementum, Den = dentine, En = enamel. The moisture content measured from sediment collected from the hole for the beta dose calculations was 5 5%. The use of these dose rates assumes that the in-situ moisture content at the time of measurement was similar to the average moisture content during the burial period.

Table 3. Résultats de la datation ESR pour Ban Fa Suai II.
EU = modèle d'absorption précoce (Bischoff and Rosenbauer, 1981), LU = modèle d'absorption linéaire (Ikeya, 1982), = beta, = alpha, Cem = cementum, Den = dentine, En = émail. La teneur en eau mesurée à partir des sédiments recueillis pour le calcul de la dose bêta était de 5 5%. L'utilisation de cette dose suppose que la teneur en eau *in situ* au moment de la mesure était semblable à la teneur moyenne en eau pendant la période d'enfouissement.

Taxa	weight in g/poids en g	Ln(weight) / Ln(poids)
Stegodon sp.	4 000 000	15,2
Proboscidea indet.	4 000 000	15,2
Rhinocerotidae indet.	1 950 000	14,5
Rhinoceros cf sondaicus	1 600 000	14,3
Bos sp.	802 000	13,6
Cervus cf unicolor	225 000	12,3
Panthera cf tigris	175 000	12,1
Cervus sp.	132 000	11,8
Ailuropoda cf melanoleuca	125 000	11,7
Sus cf scrofa	125 000	11,7
Ursus cf thibetanus	110 000	11,6
Ursus sp.	99 000	11,5
Naemorhedae indet.	62 000	11,0
Pongo cf pygmaeus	60 000	11,0
Cervus cf nippon	48 000	10,8
Axis cf porcinus	40 500	10,6
Muntiacus cf muntjak	18 000	9,8
Cuon cf alpinus	17 000	9,7
Hystrix cf brachyura	14 200	9,6
Panthera sp.	12 300	9,4
Macaca cf nemestrina	8 900	9.2
Macaca sp.	8 300	9.0
Trachypithecus sp.	7 900	9.0
Macaca cf mulatta	6 600	8.8

Table 4. Estimated mean body weights (in kg; calculation in g for the Nepperian logarithm) for taxa (Macdonald 2006) used to construct cenograms (Legendre 1986).

Table 4. Estimation du poids corporel moyen (en kg; calcul en g pour le logarithme népperien) des taxons utilisés (Macdonald, 2006) pour construire les cénogrammes (Legendre, 1986).