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Discovery of an outstanding Hoabinhian site from the Late Pleistocene at Doi Pha Kan (Lampang province, northern Thailand).

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Abstract

In Mainland Southeast Asia the Hoabinhian culture corresponds to the legacy of using massive tools made on cobbles, a techno-complex that persisted in a tropical environment for about 30,000 years. During this period, human burial practices also appear to be uniform and limited to burials in “flexed” position. However, stasis in cultural patterns is unlikely over such a long time period and large geographic area, and although new data is emerging on nuances in lithic technologies, the limited number of fully documented burials prevents debate on this issue. In a regional review of Hoabinhian burials we discuss the limitations of using the broad term ‘flexed’ burials, which can conceal important differences/similarities among cases. We use an archaeo-thanatological approach to describe in detail three burials at Doi Pha Kan site, Lampang province, northern Thailand. Differences are observed in the “flexed” positions of the bodies, the anatomical characteristics of the individuals, and the nature of the offerings. General similarities in burial practices among sites in south China and north Vietnam are now documented in northern Thailand at Doi Pha Kan. We promote the archaeo-thanatological approach to generate relevant descriptions of burials, allowing similarities and/or differences in burial practices over time and within/between regions to be accurately assessed. This approach is essential to establish relevant cultural frameworks that can, in the future, be compared with morphological and genetic data to describe population movements and/or cultural indigenous influences on funerary practices in Mainland Southeast Asia.

Keywords: Field anthropology; dating; Southeast Asia; Hoabinhian

Introduction

According to their bio-anthropological study Matsumura et al. (2015) concluded that: “Hoabinhian/Mesolithic populations are key to understanding the peopling of Southeast Asia.” Although the striking similarities between the Hoabinhian culture in Southeast Asia and the Late Palaeolithic and Early Neolithic cultures of South China cannot be overlooked, the lack of archaeological investigations in Mainland Southeast Asia, due to more than half a century of regional political instability, has hampered archaeologists demonstrating links between these ancient cultures. Regional archaeologists acknowledge that data sets in Mainland Southeast Asia are biased due to limited sample sizes and uneven geographic coverage of the finds (White, 2011). Concerning the regional sites Higham (2013, p.26) notes that “We could thus think of characterizing the inland Hoabinhian as being subjected to the tyranny of the rock shelter, and the results are almost certainly biased”. In addition, funerary practices are usually described from large Neolithic sites rather than from the rare isolated Hoabinhian burial sites.

In Mainland Southeast Asia the Hoabinhian techno-complex corresponds to the legacy of using massive tools made on cobbles for about 30,000 years. During this long period, funerary practices appear to be uniform and limited to “flexed” burials. Indeed, as stated by Bellwood (1993), Higham (2002), and Rispoli (2007), the only notable changes observed at the end of this period are related to the start of the Neolithic. These changes originated from China and included a sedentary way of life, the start of agriculture, the final abandonment of the chipping/flaking stone industry, and an increase in burials in the extended position. Although these phenomena are well-documented, our knowledge of the diversity of funerary practices in the Hoabinhian period is incomplete. Firstly, published reports lack of information on position, sex, or age at the time of death. Descriptive terminology is imprecise and a lack of illustrations prevents a review of old data, although in recent decades there has been an increase in the archaeo-thanatological approach in Southeast Asia (Pautreau et al., 1998, 2001; Willis and Tayles, 2009; Harris and Tayles, 2012; Zeitoun et al., 2013). Secondly, descriptions of Hoabinhian burials are rare, and considering the existing record of funerary sites in Thailand, Laos, Vietnam, south China and Peninsular Malaysia, there does not appear to be a single inhumation position. This brings us back to the possibility of having various distinct cultures or populations in Southeast Asia during this period.

In this paper, we first give a regional review of Hoabinhian burials (**Fig. 1**). We demonstrate that imprecise data on the position of buried bodies, and the chronological uncertainty and taphonomic confusion related to inappropriate excavation practices creates inaccurate biocultural backgrounds which should not be compared to new anthropological or genomic data to describe population movements and/or cultural indigenous influences. Second, we describe three graves at the Doi Pha Kan site (N18° 26.95' E 99° 46.62') in Lampang province, northern Thailand (**Fig. 2**) using an archaeo-thanatological approach that identifies cultural diversity in burial practices during the Hoabinhian. This approach generates relevant descriptions of burials, allowing similarities and/or differences in burial practices over time and within/between regions to be accurately assessed.

A review of Hoabinhian burials

In the absence of standardized field anthropological protocols, it is likely that researchers will make false assumptions of similarity between contemporary burials. It also prevents the listing of characters in a summary table to compare different graves. Here we review the descriptions of

Hoabinhian burials in regional literature, to avoid oversimplification due to the term “flexed” burial. In addition to the review’s summary table (**Table 1**), it is necessary to state the initial descriptions of the uncertain ages attributed to the graves and the position of the bodies, since the iconography is not always available in the source texts.

The Hoabinhian techno-complex originated in south China (Ji et al., 2016). An overview of funerary data from this geographical area shows that the term “flexed” covers different burial configurations. In south China in the central Guangxi province, Liyuzui for period I (9000-8000 BP) has yielded several sites characterized by burials with flexed upper and lower limbs (“crouched position”), chipped pebble tools (choppers, points and scrapers) associated with polished stone axes and perforated tools, as well as innovations such as clam-shell reaping knives with one or two dorsal perforations (Rispoli, 2007). Period IV (12,000 - 8000 BP) burials in the Zengpiyan cave (northern part of Guangxi province) include individuals covered with big sealing blocks, lying on their backs with flexed upper and lower limbs (Rispoli, 2007). Isolated skeletons and individuals lying on their sides with fully flexed limbs were also reported (Rispoli, 2007).

Burials from the “Hoabinhian period” in north Thailand include the very incomplete case at Tham Lod rock-shelter; an adult lying on the back with extended limbs, with a hammer stone lying on top of its lower limbs. The associated sediment beneath the skeleton was radiocarbon dated to $12,100 \pm 60$ BP (Shoocongdej, 2006; Khaokhiew pers. comm.). Beneath this burial, an individual buried on its left side in a flexed position was covered by a ring of five large cobbles; the matrix material was radiocarbon dated to $13,640 \pm 80$ BP. Both burials were in a layer that contained artefacts belonging to the Hoabinhian techno-complex. At Ban Rai rock-shelter, in the vicinity of Tham Lod, the single grave of an adult individual buried on its back, the right arm extended with the lower limbs flexed, the feet raised to the level of the pelvis and the neck flexed forward was discovered in archaeological layers characterized by an abundance of Hoabinhian stone tools and numerous faunal remains (Sidisunthorn et al., 2006). The body was buried directly in the soil within a circular pit devoid of any ornaments or grave offerings. The grave sediment was radiocarbon dated to $9,720 \pm 50$ BP (Pureepatpong, 2006).

At Ban Tha Si, in Lampang province, a grave was uncovered in the vicinity of a rock-shelter with a painted wall (Zeitoun et al., 2013). The individual was lying on its right side. The head was missing, but the upper limbs were flexed with the hands close to the initial position of the chin. The lower limbs were also in a flexed position. The individual had been buried directly in the soil in an unsealed grave. According to the field anthropological study, the sediment had rapidly replaced the volume corresponding to the body flesh, and the grave was probably not much longer or wider than the body itself. The archaeological remains around the burial were dated from $11,390 \pm 36$ to $6,673 \pm 25$ BP, but the skeleton was dated to 7047 ± 53 BP (Zeitoun et al., 2012).

In Kanchanaburi province, in cave II at Sai-Yok, a burial was found in an archaeological sequence which included Neolithic artefacts and Hoabinhian stone tools (Van Heekeren, 1961). The individual was lying on its back on a bed of boulders in the Hoabinhian layer. The soil above the head and part of the body was stained with red ochre. A large mammal bone was resting on the individual’s chest and many mollusc shells were present. A heavy quartzite stone slab was placed on the upper part of the body. The face was turned to the right, knees updrawn, and according to Jacob (1969), “the knees were almost vertical with the feet resting flat on the ground. The left arm was flexed across the body, while the right hand was located under the chin”. It has been suggested that the upper and lower layers at Sai-Yok cave date back to 4,000 BP and between 10,000 to 8000 BP, respectively (op.cit.).

In south Thailand, eight adult graves in Hoabinhian deposits were uncovered at Moh Khiew rock-shelter. Radiocarbon dates of the Hoabinhian level 3 ranged from $11,020 \pm 150$ to 8420 ± 90 BP; a single piece of charcoal from a grave was dated to $25,800 \pm 600$ BP, while the dates of the two upper levels spanned from 7060 ± 100 to 4250 ± 150 BP (Pookajorn, 2001). The re-examination of the dating

(Auetrakulvit et al., 2012) determined that the majority of the burials were concentrated in an overlying level dated between $11,220 \pm 510$ and 9470 ± 420 BP. Additional uncovered burials were found in level 3, as those excavated by Pookajorn (1990, 1994, 2001). The new series (Auetrakulvit et al., 2012) includes the incomplete skeleton of an adult lying on its back, a poorly preserved individual lying on its back with extended limbs, and an incomplete individual buried in a flexed position on its left side. According to a taphonomical study and information provided by Pookajorn (2001), some “extended” burials discovered during the initial excavation may date back to around 10,600 BP, i.e. the average age of the layer in which it is embedded, while other “extended” and “flexed” burials are likely to be younger than the top of this level (e.g. around 7000 BP) (Zeitoun et al., 2013). Finally, according to the most recent excavation, it is likely that 4250 ± 150 BP represents the “minimum” age of the former burials. Nevertheless, as the original depth of the burials is inherently variable and there are no reliable means to assess it, it is impossible to determine the precise chronology of the different graves at Moh Khiew (i.e. lying on the side with flexed limbs, lying on the back with flexed limbs and lying on the back with extended limbs).

In central Laos near the Pha Phen rock-shelter in Bolikhamxay province, a single skeleton was found lying on its right side with elbow joints partly flexed so that the forearms were lying across the abdomen (Tayles et al., 2015). The individual’s lower limbs were partly flexed at the hip joints and fully flexed at the knee joints. The individual was about 175 cm tall and was directly dated to 6910 ± 40 BP.

In north Vietnam, in Hoa Binh province, Viet (2015) reported two cases of Hoabinhian burials. At Du Sang rock-shelter an individual was buried under blocks and in association with Hoabinhian remains. According to the authors’ illustration, the body was buried lying on its back with flexed lower limbs. The forward tilt of the head, the outward rotation of the coxal bones, and the slight outward rotation of the upper limbs in extension alongside the body suggest that non-durable covering had been placed on the individual. Nearby, at Xom Trai (op. cit.), a burial was found in a Hoabinhian layer and was dated to $17,100 \pm 545$ BP by a shell sample. The upper part of the body was destroyed but the hip and knee joints were flexed. The individual’s height is estimated at 168 cm. At Hang Cho, in Luong Son district, the burial of an individual lying on its back with flexed limbs and raised knees was directly dated to 9259 ± 206 BP (Matsumura et al., 2008). The grave appears to have been dug at a depth of 92 cm through archaeological layers rich in faunal remains and Hoabinhian lithic artefacts.

At Con Moong Cave in the Thanh Hoa province, on the right bank of the Red River, a grave was found in cultural layer II, while three other graves were found deeper in cultural layer I. Ochre and mollusc shells were found near the human remains. Shells from cultural layer II were dated to $11,090 \pm 185$ BP, while upper cultural layer III was dated to 9905 ± 150 BP and contained edge ground axes, (Thong, 1980). Ha (1980) reported additional dates for shells in cultural layer I, i.e. $11,755 \pm 75$ BP and $11,840 \pm 75$ BP, and provided information about the position of one of the burials intruding into the cultural layer I, with the body lying on its back with flexed lower limbs. In the same province Mai Da Nuoc and Mai Da Dieu yielded skeletons that date back to the beginning of the Hoabinhian culture according to Cuong (1986). At Mai Da Dieu, the burials are confined to an upper archaeological layer which contains Hoabinhian stone tools. Arrangements of small limestone pebbles surrounded by larger stones at the base of the burials were reported, but no details were given on the position of the bodies. At Mai Da Nuoc, an individual lying on its back with extended limbs (84/MDN.M1) was found in association with lithic artefacts. Gravel and large stones were found at the base of the grave and six half-ground seashells were identified just below the individual’s neck.

At Bàu Du, in Quảng Nam Đà Nẵng province, Ha (1995) reported the presence of flexed burials dug in deposits rich in Hoabinhian artefacts, including an unfinished perforated stone. Radiocarbon dates obtained from charcoal collected at this site yielded a very early chronological range for the

Hoabinhian, from 4510 ± 50 to 5030 ± 60 BP. However, it is not mentioned whether these dates relate to the burials or deposits. In the same province, at the Con Co Ngua site, Da But graves were generally only earthen pits with no sign of any covering material. However, five single burials were associated with stone markers on top of or beside the graves. Red mineral powder was spread over at least one burial cluster and ochre was also found in two other separate graves (op. cit.). In general, as observed by Tayles et al. (2015) referring to Oxenham (2000, 2006), the Con Co Ngua burials yielded bodies arranged in a similar way to those at Ban Tha Si, but with the body placed upright with the limbs fully flexed. In general, Con Co Ngua skeletons also correspond to tall individuals. The Da But culture takes its name from the work of Patte (1932) and is partly characterized by edge polished stone tools (Viet, 2005). Da But sites are generally characterized by large shell-midden deposits, edge ground pebble axes, and burials with individuals frequently found in tightly flexed but upright positions, with limited grave offerings and no pottery (Oxenham et al., 2005). Da But culture is considered to be one of the several emergent Neolithic cultures that developed out of the Hoabinhian around 6500 to 6000 BP, and was based on a coastal/marine economy (Oxenham, 2006).

In north Malaysia at Gua Gunung Runtuh in the Lenggong district of the Malaysian state of Perak, an individual was found lying on its back, the upper and lower limbs flexed, with the left hand resting on the abdomen (Jacob and Soepriyo, 1994). The grave included freshwater gastropod shells radiocarbon dated to 9460 ± 90 to $10,120 \pm 110$ BP. The oldest date of $13,600 \pm 120$ BP was obtained from shells found at the bottom of the burial (Zuraina, 1994). Offerings comprised of faunal remains, a flat limestone slab sprinkled with red powder, a quartz hammer stone and one oval unifacial pebble tool placed next to the head of the individual. There were also miscellaneous tools around the body that was covered with shells. The presence of similar artefacts in so-called pre-ceramic levels in other caves of the Perak state, assuming that this can be considered as an indicator of contemporaneity, seems to point to similar practices at Gua Kerbau about 40 km away from Gua Gunung Runtuh where one skeleton was buried with knees drawn up to the chest (Zuraina, 1994). In the lowest level of Go B'ait a skeleton was found buried in "flexed" position (Callenfels, 1939), and at the shell-middens of Gua Kepah Jacob (1967) noted that human remains were associated with grinding stones, sumatraliths, stone axes, and also potteries, beads, and animal remains belonging to the Hoabinhian. At Gua Teluk Kalawar near Lenggong, one individual buried on its back, the right arm in a hyperflexed position brought back to the thorax and the left arm flexed on the left side of the trunk, the lower limbs crossed and flexed to a bent position resting on the right side, and the feet raised below the level of the pelvis was buried with animal remains surrounding its skull. The body was covered in riverine shells, with haematite powder sprinkled on and around the body (Zuraina et al., 2005). The burial intersect layers containing shells and Hoabinhian tools. A date obtained from charcoal indicated an age of $10,245 \pm 80$ BP about 90cm below the burial, while a shell associated to the body was radiocarbon dated to $8,400 \pm 40$ BP (op. cit.).

Burials of the rock-shelter of Gua Cha near the Nenggiri River in Peninsular Malaysia, contained individuals with lower limbs crossed and flexed, the feet raised below the level of the pelvis in the Hoabinhian layers. This Hoabinhian occupation dates back to 10,000 BP, but apart from a charcoal sample from the middle of the deposits, with an age of 6300 ± 170 BP, radiocarbon dating of this site appears equivocal (Bulbeck, 2000).

This regional review of Hoabinhian burials shows that few cases are described in sufficient detail for valid comparisons or conclusions. In addition, some graves cannot be assigned to the Hoabinhian; it is likely that they were Neolithic burials dug in Hoabinhian archaeological levels, for example at Sai Yok. This observation echoes our former conclusions (Zeitoun et al., 2012, 2013) that agree with those of White (2011): detailed data analyses following a modern archaeological approach is needed to establish a relevant chronocultural framework. Such an approach is also needed for bioarchaeological data (Oxenham, 2006).

Materials and methods

At Doi Pha Kan several red-ochre painted figures are present: hands, carnivores, proboscideans, bovids, a gallinaceae associated with anthropomorphic forms, and geometric figures (Surinlert et al., 2018). A similar association between rock-shelter paintings and burials has also been observed at Phratu Pha and Ban Tha Si. Following an archeo-thanatological approach, we describe in detail three exceptional burials discovered at Doi Pha Kan. Due to their characteristics, i.e. the nature of the uncovered offerings, the period they correspond to, and the anthropological features of the remains they contain, they could be related to a population that is distinct from the traditional regional Hoabinhian cultural background. This has been recently proposed based on the geographical distribution of perforated stones in Southeast Asia (Imdirakphol et al., 2017).

Doi Pha Kan deposits are dusty, loamy sediments accumulated over a decadeth of at least 2 m. Due to the loose nature of the deposits the site was excavated very carefully to avoid disturbing the sediments and embedded archaeological remains; small successive trenches less than 90 cm deep were excavated (**Fig. 3**). Another remarkable taphonomical property of the site is that no distinctive layer could be identified during the excavation. All artefacts exceeding a length of 1 cm in at least one dimension were recorded in three dimensions. Smaller objects were collected by sieving out 5 cm thick sediment layers taken from 1 m² plots. The density of all the remains and artefacts was used as a criterion to characterize archaeological layers.

Initially, the excavation work focused on the burials within deposits containing both stone artefacts and faunal remains, logically older than the graves themselves. With 2,144 lithic artefacts and 31,699 faunal remains, the mean density of the material was high, at 3,109 objects per m³. Due to the intersecting position of the graves, the refilling of the graves, and the archaeologically rich sediment, it is not yet possible to provide a valid date for the lithic artefacts nor of the faunal remains of the nearby deposits. Therefore, a short description of this rich lithic and archaeo-zoological material is detailed here.

We followed a field anthropological or archaeo-thanatological approach: the meticulous observation of the anatomical orientations of bones in a grave, so as to interpret how their original arrangement changed as the body decomposed. The aim is to determine the original burial context (Duday et al., 1990) and uncover new burial modalities (Duday and Guillon, 2006; Duday et al., 1990; Willis and Tayles, 2009; Zeitoun et al., 2013). These modalities are often undocumented, despite Duday et al.'s (1990) assessment that they represent a fundamental component of mortuary practices.

This approach is rather rare in Southeast Asian archaeological research and it is therefore difficult to conduct valid comparisons between detailed studies in this region. In addition, reappraisal of earlier publications and/or data sets is a prerequisite for relevant comparisons with more recent archaeo-thanatological studies (see Auetrakulvit et al., 2012; Bulbeck n.d.; Harris and Tayles, 2012; Lloyd-Smith, 2012; Tayles et al., 2015; Hiep and Huffer, 2015).

Three adult and four child (10 months old) burials were uncovered at Doi Pha Kan. Bone remains were very fragile and only limited biological data could be collected directly on-site. Sexing was determined using the DSP method (Murail et al., 2005) and height was calculated from two regional anthropological tables (Mahakkanukrauh et al., 2011; Pureepatpong et al., 2012) (see **Table 2** for the detailed measurements).

Artefactual and faunal remains in deposits

The deposits were disturbed by digging and refilling of the graves, so we only describe the main traits of the lithic artefacts and faunal remains present in the deposits (see Celiberti et al., 2018 and Frère et al., 2018 for a full description of this material).

A total of 1,297 lithic pieces referenced in three dimensions and 847 pieces smaller than 1 cm were retrieved from sediment layers intersected by the graves. Several *chaînes opératoires*, essentially related to shaping, and *débitage* operations appear to have been conditioned by the morphology (pebble or block) and quality of the raw material (fine-grained sandstone, silicified limestone or quartz) (Celiberti et al., 2018); knapping operations appear to have been conducted without production standardisation from a technological perspective. The observed lack of homogeneity of the raw materials, the low number of unifaces and tools on split cobbles, as well as the presence of composite tools associated to asymmetric pieces or *limaces*, suggest that this material is a regional variant of Hoabinhian, as at Moh Khiew site in southern Thailand (Auetrakulvit et al., 2012).

A total of 31,699 faunal remains (**Table 3**) were uncovered in these deposits, with a prevalence of bone splinters and a few teeth. Taxonomical diagnosis very rarely obtained species identification and the Number of Identified Specific Parts (NISP) was only 4,256. Different taxonomic ranks have been identified: several Bovids and Cervids, rare Suids and some Carnivores, Rhinoceroses and Primates. The fairly large herpetofauna included varanids, turtles and snakes. Freshwater crabs, land snails and freshwater mussels have also been found in large numbers at Doi Pha Kan.

The observed fauna is indicative of a forest environment and the anatomical distributions of *Cervus* and *Bos* remains suggest that butchering was consistently conducted outside of the rock-shelter, similar to the practices identified at Laang Spean cave, Cambodia (Forestier et al., 2015). As a large number of phalanges are burnt, fire could have been used to free phalanges out of ligaments to reach the bone and/or marrow (Marean and Cleghorn, 2003). It is also possible that ligaments, tendons, and skins, or even bones, were used for non-food purposes. The faunal remains indicate that people at Doi Pha Kan were hunter-gatherers (Frère et al., 2018).

Burial descriptions

In this paper the three burials, dpk E-5, dpk D-4 and dpk DE-5, are described using an archaeo-thanatological approach. The former two have been briefly detailed in the previous work of Imdirakphol and colleagues (2017).

The grave dpk DE-5 (**Fig. 4**) was found 40 cm under the soil surface. The skeleton was very badly preserved; the brittle bones crumbled into dusty sediments when displaced. An adult individual was lying on its left side, and the whole skeleton was partially concealed under a layer of red ochre powder. The grave was aligned in an east-west direction. The right upper limbs were not preserved and the lower limbs were flexed. The left upper limbs were flexed, the elbow lowered down to the level of the pelvis and the wrist was at the level of the plexus. The skull was resting on its left side facing southwards. A mortar filled with ochre powder was spilled directly above the individual's humerus (**Fig. 5**). There was no evidence for any structure or container associated to the body however a non-durable wrapping, such as a fibrous wrapping or a basket, could have been present. The individual was determined to be male with a 99 % probability (**Table 2**) with a height of 178.9 ± 3.5 cm and 177 ± 3.5 cm based on the maximal length of his femurs, according to the methods of Mahakkanukrauh et al., (2011) and Pureepatpong et al., (2012), respectively.

The top of the grave dpk E-5 (**Fig. 6**) was identified by a circle of calcareous blocks 85 cm below the soil surface. Ten centimetres below the bottom of these blocks was a grave aligned in a northeast-southwest direction. The skeleton was badly preserved and, covered and surrounded by ochre, and by charcoal on the lower limbs. The individual was lying on its right side with its skull facing west. Only the upper branch of the mandible was preserved, but the temporo-mandibular articulation indicated that the mouth was open. The right lower limbs were fully flexed and the left were not preserved. The right knee was at the level of the mandible. The right upper limbs were flexed with a pronation of the wrist. The right hand was not preserved, but the wrist was at the level of the left rib

cage. Of the left upper limbs only the humerus was present, and its posterior side indicated a complete axial rotation. The humeral head was off-centre compared to its normal anatomical position. The vertebral column and the legs of the individual seem to preserve their initial flexed position, while the movement of the upper limbs suggests that some vacuum existed during the decay of the body. We suggest that the weight of the blocks used to close the grave may have contributed to such a movement during the decay of the flesh, but it should be noted that the complete left lower limb was not preserved. There was also no evidence for any structure or container associated to the body.

The scoring of the right coxal bone indicated the individual was male with a 99.99 % probability (**Table 2**). This individual's height was estimated to be 174.9 ± 3.5 cm and 176.2 ± 3.5 cm according to the methods of Pureepatpong et al. (2012) and Mahakkanukrauh et al. (2011), respectively.

This grave was also characterized by the presence of partially sooty deposits and pockets of ochre powder. The grave was rich in offerings (**Fig. 7**). An adze and an axe with polished cutting edges were located on the left rib cage; a pestle was found at the back of the vertebral column and a second, smaller pestle was present near the coxal bone. A pendant, made out of a bivalve shell, as well as a frontal bone and a shaft of a long bone (*Muntiacus muntjak*) were placed between the leg and thigh bones of the individual. A perforated stone, another complete mollusc shell, and a lump of ochre were located near the foot of the individual.

The grave dpk D-4 (**Fig. 8**) was found 30 cm below the bottom of the grave dpk DE-5. Calcareous blocks partially covered the body of an adult individual. A perforated stone, broken into two pieces, was located on top of these blocks. The grave was oriented southwest-northeast with the individual's head positioned towards the southwest. A large, rounded stone tinged with red ochre was underneath the right side of the skull which lay on its left side facing northwards. The body appears to have been interred on its front. The left scapula appears on its posterior face. The left elbow was flexed at a right angle, with the forearm under the vertebral column and on top of the shaft of the left femur. The left humerus was attached to the left rib cage. The bones of the left hand were under the proximal part of the left tibia. The right humerus was on the radius and ulna with a supination of the wrist indicating that the right hand had originally been placed near the base of the skull. The right foot was exposed on its lateral side and the left foot on its medial side, both at the level of the hipbone. Both the right parietal and temporal bones were driven in by a red ochre-tinged stone, and a second stone coated with a red colour was lying to the right side of the individual (**Fig. 9**). A subtriangular-shaped perforated stone was located under the lower-half of the shaft of the right tibia, in association with a red ochre-coloured grindstone. A tortoise shell was lying under the individual's feet, which were covered by a red-coated calcareous block suggesting that the body was at least partially sprinkled with red ochre powder. The position of the body, with no evidence for any other structure or container associated to the body, suggests a grave with the body buried directly in the deposits under the blocks.

The scoring of the left coxal bone indicated the individual was male with a 99.84 % probability (**Table 2**) with an estimated height of 173.5 ± 3.5 cm and 172.5 ± 3.5 cm according to Mahakkanukrauh et al. (2011) and Pureepatpong et al. (2012), respectively.

In summary, although the three individuals were all buried in a "flexed" position according to the current literature, there are some notable differences between the three cases (**Table 1**). In contrast to DE-5, individuals dpk E-5 and dpk D-4 were buried with numerous offerings and block covers, and their lower limbs were in a fully flexed position. However, individual dpk D-4 was buried on the front, which was not the case for dpk E-5.

The relative spatial distribution of the graves raises the question of grave depth, which is a recurrent issue in burial excavation. At Doi Pha Kan, the graves intersect archaeological layers rich in bone remains and lithic artefacts (average density of remains = 3,109 per m³ of sediment). The deposits are loose with a natural tendency to collapse, so it is unlikely that the burials were dug deeply: a burial

deeper than 90 cm would have been extremely unstable and unpractical. Indeed, the big calcareous blocks sealing the lower graves (i.e. dpk D-4 and dpk E-5) suggest a maximum depth of about 40 cm. The deepest part of the upper burial did not intersect the two lower graves; the bottom of the upper grave was found 65 cm below the shelter's floor surface, i.e. 15 cm above the top of the middle and lower graves (**Fig. 10**).

Dating of burials

Our understanding of the evolution of Southeast Asian mortuary practices depends on the accurate and precise dating of burials. Currently, there is a scarcity of evidence supporting regional sequences and difficulty in interpreting radiocarbon dates from many mortuary sites (Higham and Higham, 2009; White, nd). Direct dating of two of the three Doi Pha Kan burials, i.e. dpk E-5 and dpk D-4, was recently published in Imdirakphol et al. (2017). Here we also use dating on bone apatite due to the lack of preserved bone collagen in the human remains to date burial dpk DE-5.

As post-mortem chemical exchanges between bone and embedding sediment are limited, the structural carbonate present in the mineral fraction of the bone (bioapatite) can be dated (Zazzo and Saliège, 2011). The humid tropics are, *a priori*, suboptimal environments for this type of dating because water is likely to promote carbon exchange via bicarbonate dissolution between the bone and sediment to be tested. Thus multiple samples from different materials (charcoal, shell, bone and tooth apatite) collected in the grave dpk E-5 were dated to assess the relevance of dating bone apatite samples. After preparation at the MNHN Radiocarbon Laboratory following the protocols described in Zazzo (2014), the carbon dioxide emissions resulting from either the combustion or hydrolysis of purified samples were sent to the Artemis AMS facility at Saclay for graphitisation and radiocarbon measurement.

The dates obtained for the three burials ranged from $11,170 \pm 40$ to $12,930 \pm 50$ BP (Table 4). Dates were consistent for charcoal ($12,930 \pm 50$ BP) and shell ($12,920 \pm 80$ BP) and similar to that obtained for the femoral shaft of individual dpk E-5 ($12,540 \pm 50$ BP). It is probable that the slightly earlier values obtained from biopatite are related to the influence of diagenesis; thus the age estimates should be considered as minimum values. Comparing the dates of the femoral shafts in burials dpk DE-5 ($11,955$ - $11,641$ BC cal) and dpk E-5 ($13,169$ - $12,462$ BC cal) with burial dpk D-4 ($12,719$ - $12,081$ BC cal) considering a similar influence of diagenesis in such a restricted area, and including the stratigraphy and location of the three graves (**Fig. 10**), two phases might be present: (1) an older phase with hyperflexed bodies associated (dpk E-5 and dpk D-4) with the use of blocks and many offerings, including perforated stones, and (2) a more recent phase without block covers, only rare offerings, and a flexed (not hyperflexed) position of the body (dpk DE-5).

Discussion

Archaeologists in Southeast Asia acknowledge that there is a lack of established cultural and chronological reference systems. Compared to other regions this delay is due to the low number of researchers focusing on this region and its geopolitical history. Nevertheless, the origin of populations has been debated for more than a century, but no consensus has been made on the relative importance of successive migrations from external sources versus indigenous continuity through time (Bellwood, 2018). Renewed bio-anthropological studies (Matsumura and Oxenham, 2014 ; Matsumura et al. 2015) have been conducted to model the regional population, but they have highlighted two fundamental problems with the regional continuity model : (1) evidence derives from present-day population datasets ; and (2) there is a lack of samples dating prior to the agriculturally driven population dispersals of the Neolithic. However, Matsumura et al. (2015) give evidence for a lineage: north Vietnamese populations from the Bac Son culture (ca 7000 BP) to the Da But culture (ca 6000 BP), as direct descendants of Hoabinhian foragers.

Due to recent technical advances in the analysis of ancient whole-genome DNA from archaeological skeletons in tropical region (Orlando et al. 2015), the affinity of different archaeological individuals has been established (Bellwood 2018) suggesting a more complicated scenario of population movements in Southeast Asia than previously established. However, these undeniable advances can only be validated if the dating and, more generally, the archaeo-chrono-cultural foundation is reliable.

"Flexed" and "extended" burials are common terms in regional archaeo-anthropological literature. Indeed, the start of the Neolithic period in Southeast Asia was fixed according to these two simplified categories (Bellwood, 1993; Higham 2002; Higham and Higham, 2009; Rispoli, 2007); anthropological series formerly excavated were *a posteriori* attributed to Neolithic or to older tombs (cf Bulbeck and use a stable citation). However, this categorisation is an over-simplification which neglects the distinct funerary practices that our review has highlighted (Table 1). Significant cultural differences might be identifiable with a more detailed archaeo-thanatological approach (see Tayles et al., 2015). In future studies, the term "flexed" must be further differentiated to account for the degree of flexion of the limbs: individuals lying on their back with flexed limbs, and individuals lying on one side with flexed upper and lower limbs. The Chinese burials reported by Rispoli (2007) constitute to understanding the origin of funerary practices and populations in Mainland Southeast Asia. However, the debate raised by Higham (2002) on the advent of a Neolithic population and variation in prior funerary practices can only be resolved if these all the burial practices are well-documented i.e. described following archaeo-thanatological approach. We have already discussed the limitations of using the "extended/flexed" position as a chronological marker (Zeitoun et al., 2012, 2013). While "flexed" burials were progressively replaced by "extended" burials in the Neolithic period, isolated "flexed" burials seem to have persisted, suggesting that: (1) the hypothesis of a "new Chinese fashion" of inhumation requires further investigation; and (2) there is still a lack of secure chrono-cultural markers and detailed descriptions of burials in Southeast Asia.

In addition to this chronological attribution, burial type has been tied to specific populations. For example, the analysis of Neolithic and Metal Age sites (Higham and Higham, 2009) suggested that the replacement of "flexed" burials by "extended" burials were a marker of "Chinese Neolithic invaders" within the "indigenous Southeast Asian hunter-gatherers". However, this classification should be refined to include: (1) the archaeo-thanatological approach within and between cemeteries (see Oxenham, 2000; Hiep and Huffer, 2015); and (2) the occurrence of "extended" burials in the ancient period, including groups of graves that do not constitute real cemeteries. Without these data, current attributions are problematic.

While distinct phases in Mainland Southeast Asian Neolithic burial practices have been identified based on the general spatial arrangement of graves (depth, orientation, and superimposition) and on the uncovered artefacts (Higham and O'Reilly, 2004), additional features may provide critical evidence. Burial modalities, i.e. whether the body was interred directly in the soil, in a coffin, or wrapped in fabric, represents important and under-evaluated aspects of funerary practices that are rarely included in Southeast Asian archaeological studies (Willis and Tayles, 2009; Harris and Tayles, 2012; Zeitoun et al., 2012; 2013). The three adult individuals of Doi Pha Kan provide information which, when taken individually are not unique, even for Southeast Asia. Similar to the single burial at Ban Tha Si, the three individuals of Doi Pha Kan have a tall stature. Tayles et al. (2015) noted that tall stature is quite rare for this period in Southeast Asia, following observations at the Da But cultural site of Con Co Ngua in Vietnam and at Pha Phen in northern Laos. Along with other criteria, this trait could be used as a bioanthropological marker to identify specific populations, for example at Xom Trai an individual with an estimated stature of 168 cm was found buried in a Hoabinhian layer (Viet, 2015).

Considering the burial offerings at Doi Pha Kan, the ground edge adze and axe are similar to

discoveries made by Mansuy (1909, 1924) and Colani (1930) in Vietnam, and a number of other sites in Vietnam (Ha, 1980) and south China (Rispoli, 2007). At Liyuzui in the Guangxi province for period I (9000-8000 BP), several sites are characterised by “flexed” burials associated with polished stone axes and perforated stones (Rispoli, 2007). In Southeast Asia the occurrence of perforated stones seems to be restricted to a belt (**Fig. 1**) that encompasses Myanmar, northern Thailand, Vietnam and southern China, excluding southern areas and insular Southeast Asia (Imdirakphol et al., 2017). Nevertheless the question arises as to whether this area is a cultural phenomenon or due to lack of documentation.

Sealing blocks are rarely observed to cover burials in Southeast Asia. The use of blocks to cover “crouched” burials in the Zengpiyan cave (northern part of Guangxi province) from period IV (12,000 - 8000 BP) (Rispoli 2007) is similar to the case of Du Sang where individuals were buried on their backs with flexed lower limbs, associated to Hoabinhian deposits (Viet, 2015). At Doi Pha Kan covering blocks were also present, but the individual dpk D-4 was buried on the front looking down and individual dpk E-5 was lying on its side. Doi Pha Kan sheds light on a specific regional anthropo-cultural diversity that has not been previously recognized, due to the scarcity of data and the lack of appropriate methodology for excavating and analysing such burials. At the regional level, research needs to focus on the possible relationships between the Chinese “crouched” burials of the Lingnan region (Guangxi and Guangdong provinces), the Lampang province in north Thailand and the Da But squatting burials of Vietnam.

According to our regional review, albeit being based on rare available data and the absence of precise descriptions or illustrations of skeletal remains historically attributed to the Neolithic, “Mesolithic”, Palaeolithic, Hoabinhian or Bacsonian (cf Mansuy, 1924; Mansuy and Colani, 1925; Mansuy, 1925a, b, c; Colani, 1927a, b, 1930), Hoabinhian burials correspond to either: individuals lying on their back with extended upper and lower limbs (“extended” burials), individuals with some degree of flexion of the limbs, or individuals lying on one side with some degree of flexion of the limbs.

Conclusion

Our findings at Doi Pha Kan echo the remark of Higham (2013) that “the Dingsishan sites in China and those of the Da But and Bacsonian in north Vietnam are so similar that they must have been developing in tandem”. Our research complements the observations of Higham by broadening the geographic and temporal framework. In particular, the archaeological burials and associated dates in the Phratu Pha valley indicate that this mountainous region of Thailand has been inhabited for a long period that spans as far back as 13,000 BP at Doi Pha Kan, or between 11,000 to 7000 BP at Ban Tha Si. Hyper-flexed burials, tall individuals, covered graves, offerings including perforated stones and edge ground adzes seem, however, to be limited to the geographical region usually attributed to the Hoabinhian (cf Imdirakphol et al., 2017). Our archaeo-thanatological approach identifies evidence of cultural diversity in what has been previously seen as Hoabinhian uniformity.

It is difficult to conceive that there was no variability in burial practices in Mainland southeast Asia for 30,000 years; it is likely that this is an artefact of data scarcity and research gaps. Variability needs to be assessed by further bioanthropological studies, such as those already initiated by Matsumura and Hudson (2005), those mentioned by Belwood (2018) for whole-genome DNA, and also on the lithic material. Archaeological research must continue to build regional chrono-cultural reference frameworks in Mainland Southeast Asia to give historical meaning to the results obtained by biological studies.

Acknowledgments

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Figure captions

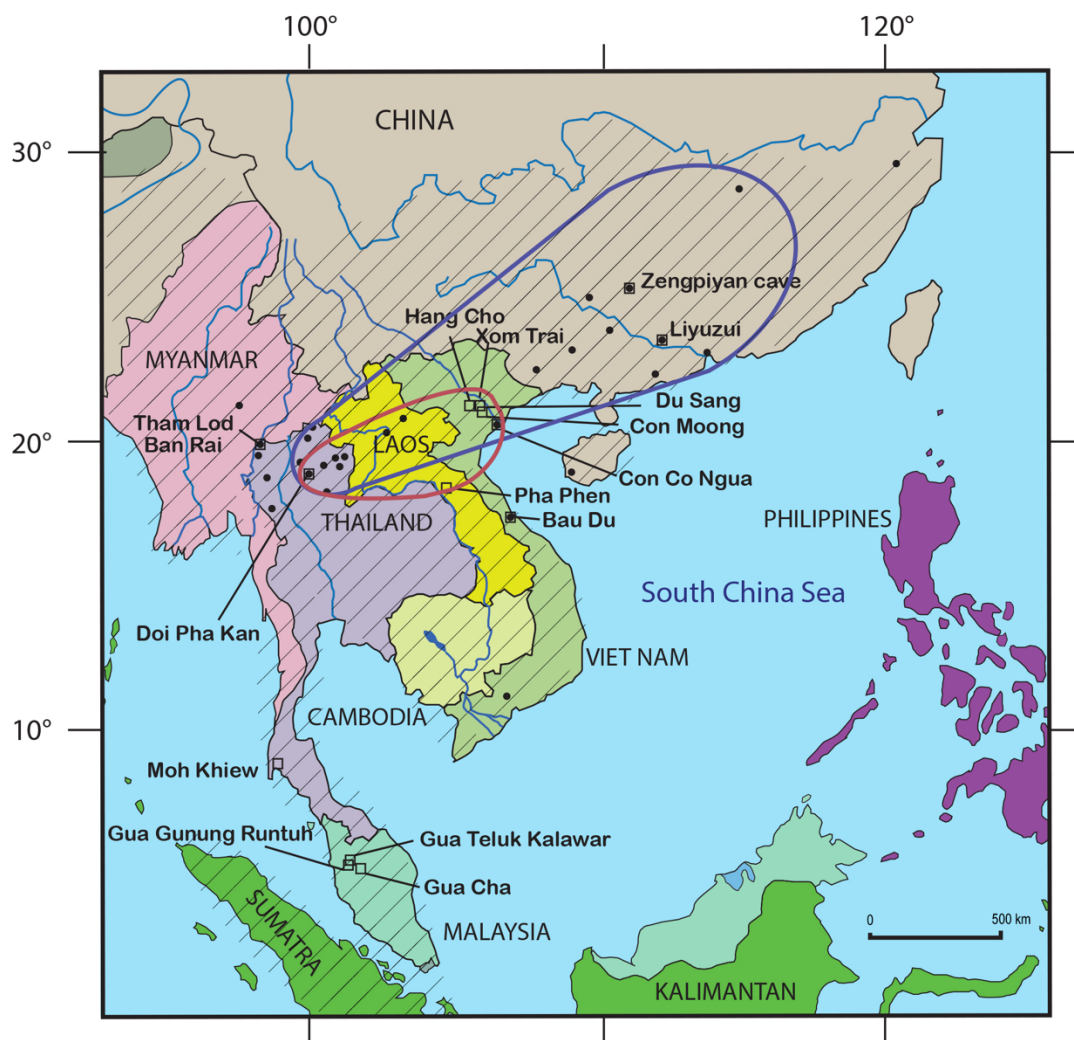


Figure 1 Map of the sites indicated in the text with indication of Hoabinhian cultural area (hatched surface) with sites including perforated stones (point), flexed burial (square)), “tall people” potential area (red line), the covered graves potential area (blue line), modified from Imdirakphol et al. (2017).



Figure 2
Location of Doi Pha Kan site.

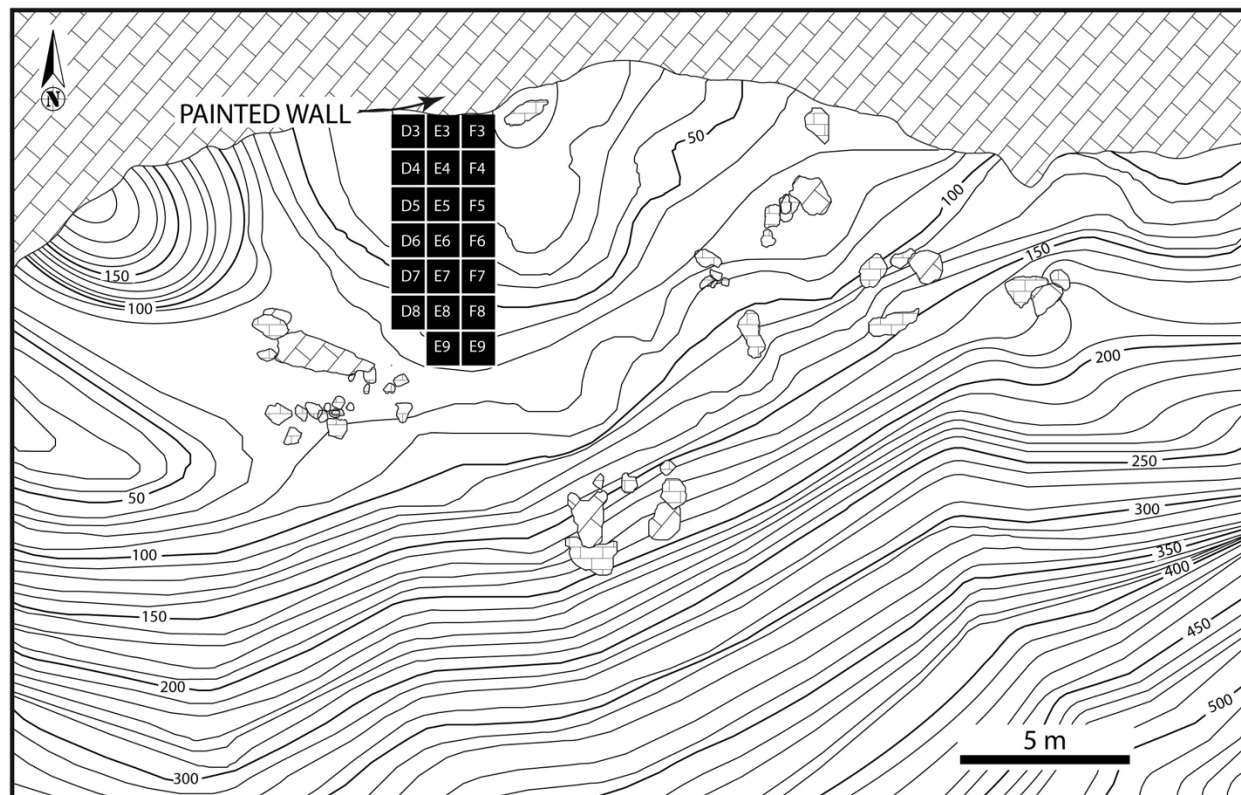


Figure 3
Location of the excavated area at Doi Pha Kan

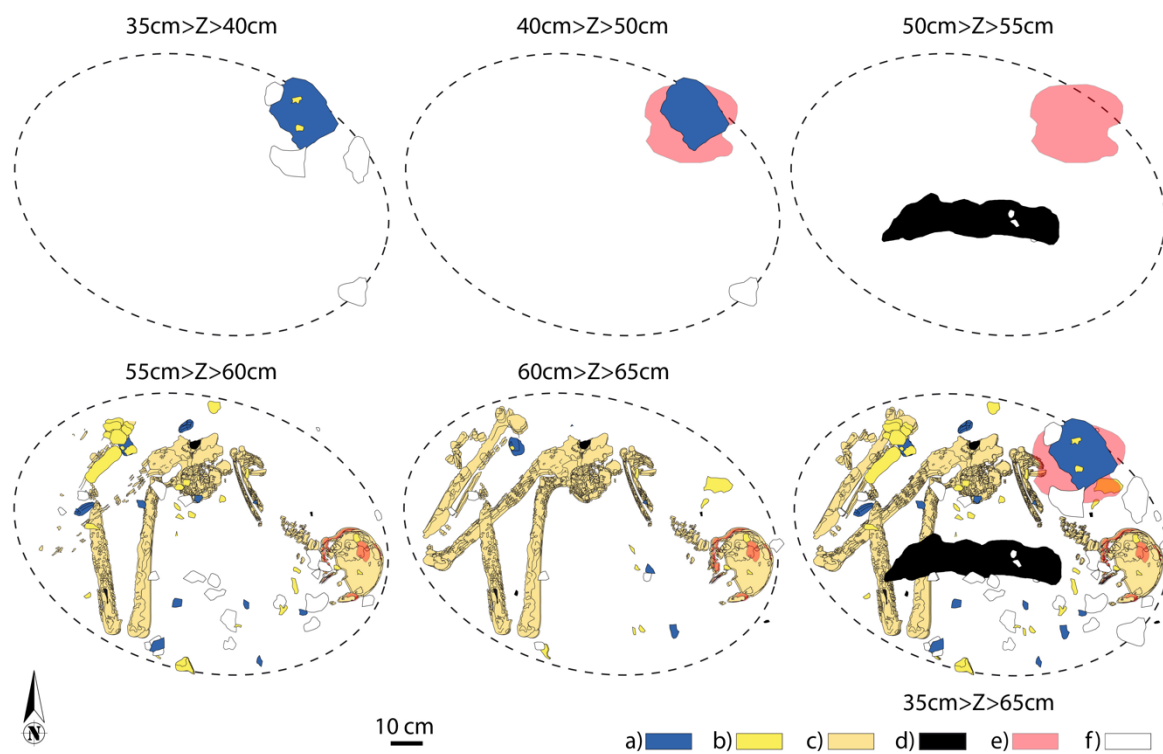


Figure 4

Burial n°1 (dpk DE-5): a) lithic artefacts, b) animal bones c) human bones, d) charcoals, e) ochre, f) limestone.

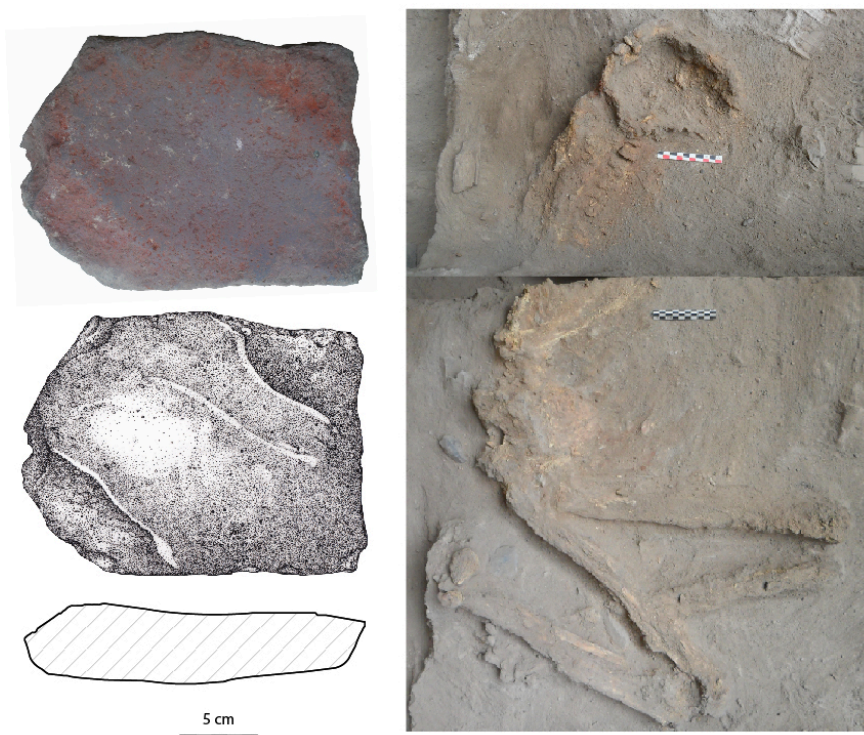


Figure 5

Burial n°1 (dpk DE-5) with the mortar filled with ochre powder.

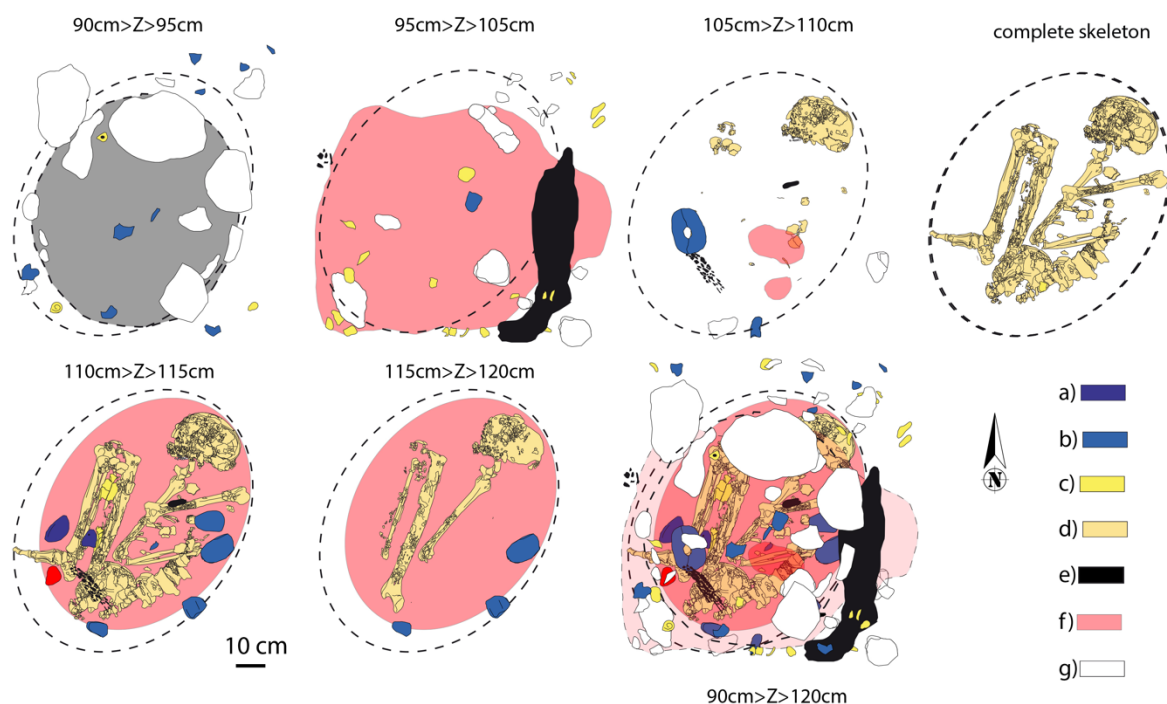


Figure 6

Burial n°2 (dpk E-5): a) shell, b) lithic artefacts, c) animal bones d) human bones, e) charcoals, f) ochre, g) limestone.

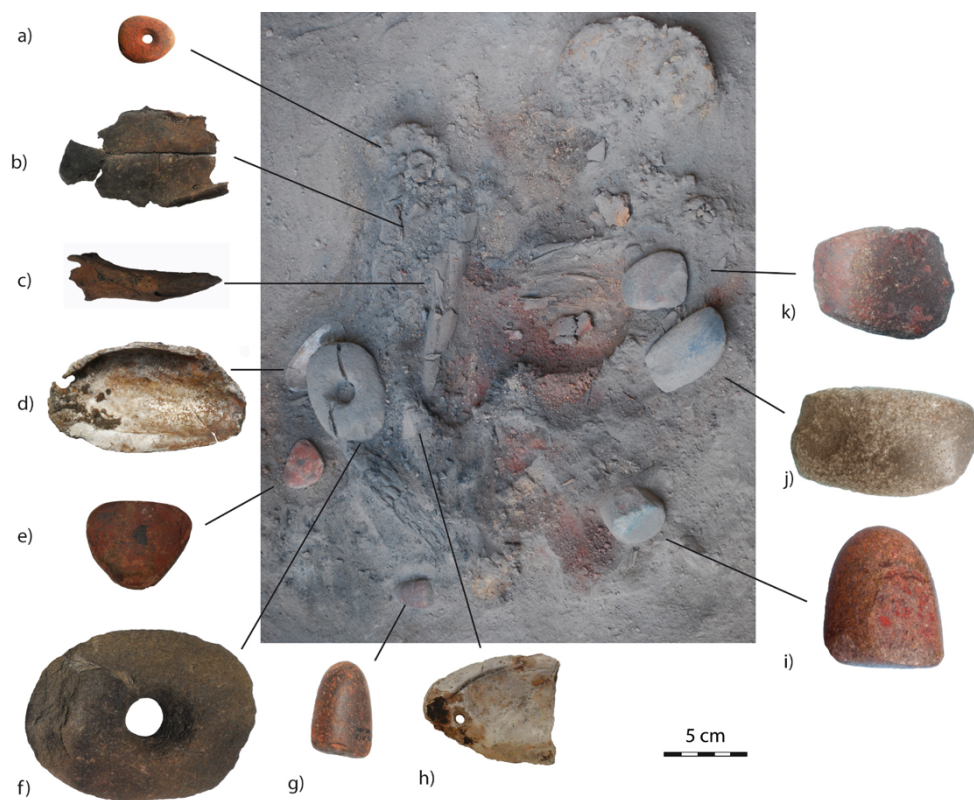


Figure 7

Offerings of burial n°2 (dpk E-5): a) amulet, b) c) Muntjac remains, d) shell, e) lump of ochre f) perforated stone, g) micro pestle, h) shell, i) pestle, j) ax, k) adze.

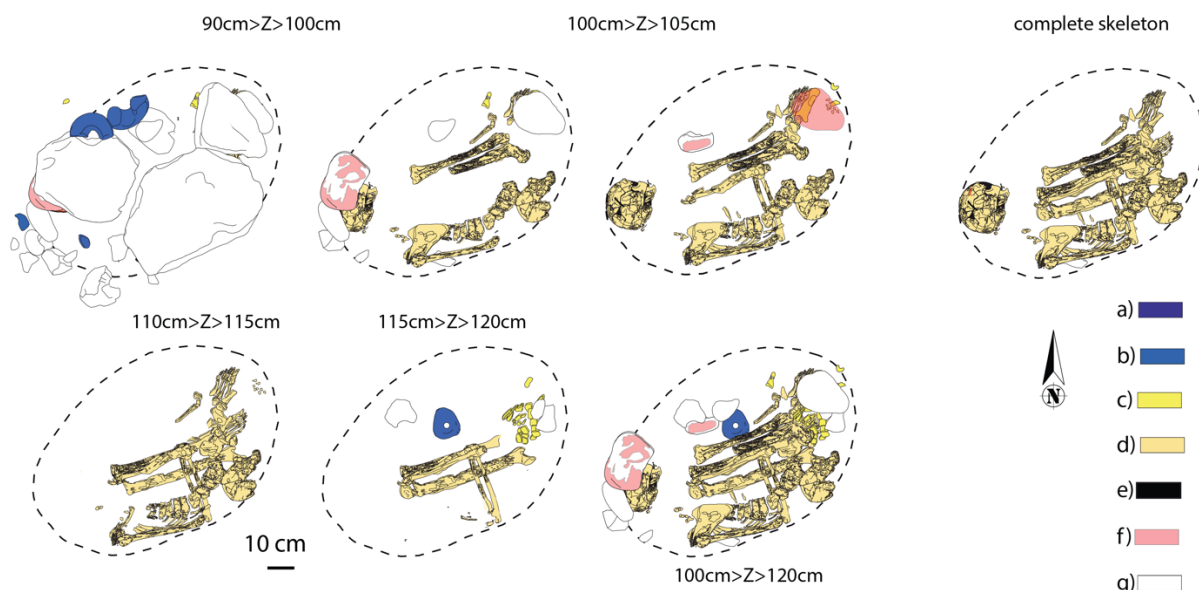
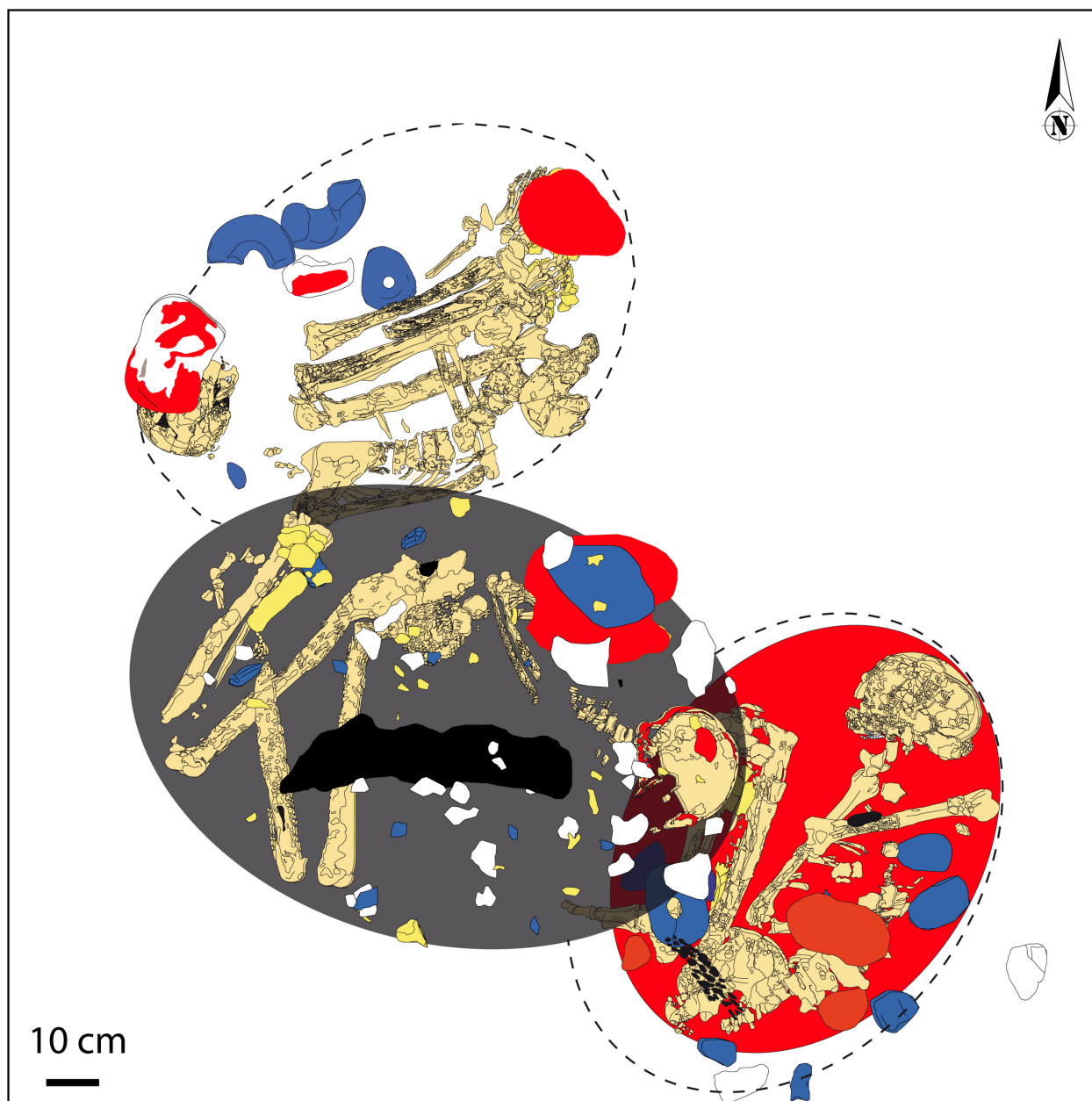


Figure 8 Burial n°3 (dpk D-4): a) shell, b) lithic artefacts, c) animal bones d) human bones, e) charcoals, f) ochre, g) limestone.



Figure 9
Offerings of burial n°3 (dpk D-4): a) ochre tinged stone, b) perforated stone, c) red colored ground stone, d) perforated stone.



a) b) c) d) e) f) g)

Figure 10

Superposition of the burials.

a) shell, b) lithic artefacts, c) animal bones d) human bones, e) charcoals, f) ochre, g) limestone.

Site	date BP	direct/undirect	references	associated material	archaeological context	position of the body			references
						lying on the side or on the back	upper limb	lower limb	
Tham Lod burial 1 burial 2	12100 ± 60 13640 ± 80	soil beneath charcoal	Shoocongdej, 2006 Shoocongdej, 2006	hammer stone ring of large cobble	Hoabinhian Hoabinhian	too much incomplete on the left side	- right arm extended	extended fully flexed	Shoocongdej, 2006 Shoocongdej, 2006
Ban Rai burial 1	9720 ± 50	sediment	Pureepatpong, 2006	none	Hoabinhian	on the back	right arm extended	flexed	Pureepatpong, 2006
Ban Tha Si burial 1	7047 ± 53	direct dating	Zeitoun et al., 2013	none	Hoabinhian	on the right side	flexed	flexed	Zeitoun et al., 2013
DOI PHA KAN dpk DE-5	11895 ± 45	direct dating	this study	mortar filled with ochre powder	Hoabinhian	on the left side	left flexed	flexed at 90°	this study
dpk E-5	12540 ± 50	direct dating	Imdirakphol et al., 2017	circle of blocks, ochre powder, adze, axe, pestles, pendant, perforated stone, faunal offerings	Hoabinhian	on the right side	right flexed	right fully flexed	Imdirakphol et al., 2017
dpk D-4	12340 ± 50	direct dating	Imdirakphol et al., 2017	cover of blocks, ochre powder, grinding stone, perforated stones	Hoabinhian	on the stomach	left at 90°	fully flexed	Imdirakphol et al., 2017
Sai-Yok, cave II one individual	4000 to 10000	cultural estimation	Jacob, 1969	quartzite stone slab, ochre powder, faunal offerings	Hoabinhian/Neolithic	on the back	flexed on the body	extended, knees upward	Jacob, 1969
Moh Khiew (1991) MKC91 B1	25800 ± 600	charcoal	Pookajorn, 2001	big block on the body	Hoabinhian	on the back	extended	-	Pookajorn, 2001
MKC91 B2	younger than 8420	stratigraphy	Pookajorn, 2001	stones on the skull	Hoabinhian	on the left side	right arm flexed	right leg flexed	Pookajorn, 2001
MKC91 B3	8420 to 10530	stratigraphy	Auetrakulvit et al., 2012	none	Hoabinhian	on the back	right extended, left fully flexed	extended	Auetrakulvit et al., 2012
MKC91 B4	8420 to 10530	stratigraphy	Auetrakulvit et al., 2012	none	Hoabinhian	on the back	left extended	-	Auetrakulvit et al., 2012
Moh Khiew (2008) burial 1	younger than 10650 ± 420	stratigraphy	Zeitoun et al., 2013	none	Hoabinhian	on the back	left arm extended	-	Auetrakulvit et al., 2012
burial 3	younger than 10650 ± 420	stratigraphy	Zeitoun et al., 2013	none	Hoabinhian	on the back	right arm flexed	-	Auetrakulvit et al., 2012
burial 4	younger than 10650 ± 420	stratigraphy	Zeitoun et al., 2013	none	Hoabinhian	on the left side	-	flexed	Auetrakulvit et al., 2012
burial 6	younger than 11220 ± 510	stratigraphy	Zeitoun et al., 2013	none	Hoabinhian	on the back	extended	-	Auetrakulvit et al 2012
Pha Phen	6910 ± 40	direct	Tayles et al., 2015	none		on the right side	flexed	fully flexed	Tayles et al., 2015
Du Sang									
	Hoabinhian cultural estimation	stratigraphy	Viet, 2015	under blocks	Hoabinhian	on the back	extended	flexed	Viet, 2015
Xom Trai	17,100 ± 545	shell	Viet, 2015	none	Hoabinhian	too much incomplete	-	fully flexed	Viet, 2015
Hang Cho	9259 ± 206	direct	Matsumura et al., 2008	none	Hoabinhian	on the back	flexed	extended, knees	Matsumura et al., 2008
Con Moong cave burial intruding Layer I	between 9905 ± 150 and 11840 ± 75	stratigraphy	Thong, 1980 & Ha, 1980	ochre powder, shells	Hoabinhian	on the back	-	flexed	Ha, 1980
Mai Da Nuoc 84/MDN.M1	Son Vi cultural estimation	stratigraphy	Cuong, 1986	lithic artefacts, half-ground seashells, large stones at the basis	Hoabinhian	on the back	extended	extended	Cuong, 1986
Con Co Ngua 5 among 94 individuals	6000 to 6500	Da But cultural estimation	Oxenham, 2006	limited grave offerings	Son Vi / Hoabinhian	on the back	flexed	flexed	Tayles et al., 2015
Gua Gunung Runtuh burial 1	9460 ± 90 to 10120 ± 110	shell	Zuraina, 1994	slab sprinkled with red powder, a quartz hammer stone, oval unifacial pebble tool	Hoabinhian	on the back	flexed	flexed	Jacob and Soepriyo, 1994
Gua Teluk Kalawar burial 1	8400 ± 40	shell	Zuraina et al., 2005	Hoabinhian tool, haematite powder	Hoabinhian	on the back	right fully flexed, left flexed	-	Zuraina et al., 2005

Table 1

Comparative samples of Hoabinhian burials.

Due to the lack of an accurate count in the different sites, the "crouched" burials from the Zengpiyan cave (northern part of Guangxi province) from period IV (12,000 - 8000 BP) and from Liyuzui (central Guangxi province) for period I (9000-8000 BP) described by (Rispoli 2007) are not included in the table.

Table 2

Anatomical measurements of the different graves (measurements in mm).

Individual	SPU	DCOX	IIMT	ISMM	SCOX	SS	SA	SIS	VEAC
dpk DE-5		221			146	73		36.5	
dpk D-4	37	210	27		141	53	73	41.5	56
dpk E5		207	27.2	102	124	62.8	61	32	54

SPU: Cotylo-pubic width, DCOX: Innominate or coxal length, IIMT: Greater sciatic notch height, ISMM: Ischium post-acetabular length, SCOX: Iliac or coxal breadth, SS: Spino-sciatic length, SA: Spino-auricular length, SIS: Cotylo-sciatic breadth, VEAC: Vertical acetabular diameter. According to Murail et al. 2005.

Taxa			Number of Remains	%	Weight of Remains (g)	%	average weight	
Artiodactyla	bovidae	<i>Bos</i> sp	395	9,3	4408	42,2	11,2	
		<i>Bos gaurus</i>	5	0,1	128	1,2	25,6	
		<i>Bos javanicus</i>	2	0,0	20	0,2	10,0	
		<i>Capricornis</i> sp	2	0,0	10	0,1	5,0	
	cervidae	large size	534	12,5	2084	20,0	3,9	
		middle size	22	0,5	54	0,5	2,5	
		small size	3	0,1	5	0,0	1,7	
		<i>Cervus unicolor</i>	17	0,4	297	2,8	17,5	
		<i>Cervus eldii</i>	1	0,0	4	0,0	4,0	
		<i>Muntiacus muntjak</i>	2	0,0	4	0,0	2,0	
		<i>Muntiacus</i> sp	60	1,4	100	1,0	1,7	
	bovidae/cervidae		44	1,0	241	2,3	5,5	
	suidae	<i>Sus</i> sp	39	0,9	230	2,2	5,9	
Perissodactyla	rhinocerotidae		3	0,1	178	1,7	59,3	
Primates			16	0,4	31	0,3	1,9	
	cercopithecidae	<i>Trachypithecus</i>	7	0,2	21	0,2	3,0	
		<i>Macaca</i> sp	1	0,0	3	0,0	3,0	
		<i>Nycticebus</i> sp	1	0,0	2	0,0	2,0	
	hylobatidae	<i>Hylobates</i> sp	1	0,0	1	0,0	1,0	
Carnivora			10	0,2	10	0,1	1,0	
	mustelidae	<i>Arctonyx collaris</i>	3	0,1	9	0,1	3,0	
	viverridae		8	0,2	16	0,2	2,0	
	felidae	<i>Prionailurus bengalensis</i>	3	0,1	3	0,0	1,0	
		<i>Panthera pardus</i>	2	0,0	3	0,0	1,5	
	ursidae	<i>Helarctos malayanus</i>	2	0,0	20	0,2	10,0	
Lagomorpha	leporidae	<i>Lepus peguensis</i>	1	0,0	1	0,0	1,0	
Rodentia			91	2,1	43	0,4	0,5	
	hystricidae	<i>Hystrix</i> sp	10	0,2	7	0,1	0,7	
		<i>Atherurus</i> sp	10	0,2	7	0,1	0,7	
	muridae	<i>Cannomys badius</i>	3	0,1	2	0,0	0,7	
	sciuridae	<i>Petaurista</i> sp	1	0,0	2	0,0	2,0	
Chiroptera			4	0,1	2	0,0	0,5	
Insectivora			2	0,0	1	0,0	0,5	
Columbiformes	columbidae		1	0,0	1	0,0	1,0	
Testudines			937	22,0	1413	13,5	1,5	
	testudinidae	<i>Indotestudo elongata</i>	6	0,1	17	0,2	2,8	
Squamata			8	0,2	5	0,0	0,6	
	serpentes		12	0,3	7	0,1	0,6	
	elapidae	<i>Ophiophagus hannah</i>	4	0,1	8	0,1	2,0	
	pythonidae	<i>Malayopython reticulatus</i>	2	0,0	4	0,0	2,0	
	colubridae		10	0,2	11	0,1	1,1	
	viperidae		1	0,0	0	0,0	0,0	
	lacertidae		2	0,0	0	0,0	0,0	
	varanidae	<i>Varanus</i> sp	308	7,2	326	3,1	1,1	
		<i>Varanus bengalensis</i>	2	0,0	2	0,0	1,0	
<i>Varanus salvator</i>		2	0,0	3	0,0	1,5		
Amphibia			15	0,4	7	0,1	0,5	
Siluriformes	bagridae	<i>Mystus</i>	1	0,0	1	0,0	1,0	
Osteichnmyes			14	0,3	10	0,1	0,7	
Brachyura			850	20,0	177	1,7	0,2	
Bivalvia			143	3,4	110	1,1	0,8	
	unionidae		82	1,9	133	1,3	1,6	
Pulmonata	stylomatophora		541	12,7	241	2,3	0,4	
	cyclophoridae	<i>Cyclophorus</i> sp	9	0,2	13	0,1	1,4	
			determined	4255	13,4	10437	33,3	2,5
			undetermined	27443	86,6	20874	66,7	0,8
			Total	31698	100,0	31311	100,0	1,0

Table 3

Faunal remains discovered at Doi Pha Kan (modified from Frère et al. 2018).

Site	Material support	Age BP $\pm 1\sigma$	Age BC (cal)	Lab references
dpk DE-5	Human femoral shaft	11,895 \pm 45	11,955-11,641	SacA 32917
dpk E-5	Human third molar	11,170 \pm 40	11,263-10,929	SacA 27054
	Human femoral shaft	12,540 \pm 50	13,169-12,462	SacA 27053
	Muntjac metapod diaphysis	12,210 \pm 50	12,296-11,895	SacA 27055
	Fresh water oyster shell	12,920 \pm 80	14,242 - 13,077	SacA 27057
	Charcoal	12,930 \pm 50	14,156 - 13,114	SacA 27056
dpk D-4	Human femoral shaft	12,340 \pm 50	12,719-12,081	SacA32916

Table 4

Direct dating of the material from the burials at Doi Pha Kan.

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