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Biogeography of Middle Pleistocene hominins in mainland Southeast Asia: A review of current evidence

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ABSTRACT

Mainland Southeast Asia is surrounded by Middle Pleistocene archaeology in India, South China and Indonesia, but has surprisingly little to show for itself. A survey of dispersed reports on evidence of hominin activity in mainland Southeast Asia shows how this region fits into the great arc of human dispersal from Africa to Australia. Hominin–mammal associations are an important indicator of hominin evolutionary change. Mainland Southeast Asia is identified as significant because it is a geographically intermediate zone between two different hominin populations, one to the north in China and one to the south in Java. Current hominin evidence from Middle Pleistocene sites in mainland Southeast Asia is used to evaluate three models of major hominin movement and migration. The first model describes the Chao Phraya River basin as the main conduit for the movement of hominins into the region. The second model holds that hominins moved into the region from China via east Vietnam. The third model has hominins approaching the region from the west, along the coast of South Asia and Myanmar. Current evidence does not robustly support any model and continuing testing of the models' hypotheses is required.

1. Introduction

Current models of human evolution focus on evidence from Africa and Europe and these models often marginalise the importance of mainland Southeast Asia in the global development of early modern human populations. This bias diverts research interest away from a key region for understanding the evolutionary history of humans and has an impact on how nations and communities in this region interpret themselves to the world. A renewed interest in mainland Southeast Asia as a theatre of important hominin evolutionary change will enhance understanding of the region's deep human past and the way it articulates historically with the rest of the world.

As a contribution towards promoting the importance of understanding this region, this paper aims to survey current problems relating to Middle Pleistocene hominin activity in mainland Southeast Asia (defined here as the current areas of Myanmar, Thailand, Laos, Cambodia, Vietnam and Malaysia, Fig. 1) and uses current data to derive testable models of hominin settlement patterns and motivate future data collection. A limitation of this survey is that the sites with relevant evidence are located inland so the impact of sea level changes is difficult to determine. Similarly, although there were parts of mainland Southeast Asia where tectonic and volcanic events were important during the Middle Pleistocene (such as the Annamite Chain), the sites described here are all in limestone formations dating from the Cambrian to Permian and are relatively stable by comparison (Gillieson, 2005; Hope, 2005), so the impact of tectonic and volcanic events cannot be reliably determined.

2. Regional setting: Middle Pleistocene faunal turnover and their implications for hominins

One of the most obvious reasons why mainland Southeast Asia features so little in narratives of human evolution is because of the paucity of remains that have been recovered from the region. This is mostly due to historical reasons, with mainland Southeast Asian palaeoanthropology and Pleistocene archaeology receiving relatively little academic and public interest locally and internationally. Glover (1993, 1999) and Miksic (1995) have also suggested that local interest in the past of mainland Southeast Asia has largely been driven by nationalistic themes, focusing work on the monumental remains of more recent prehistoric populations. This neglect of the deeper past is unfortunate and unwarranted since patterns of faunal remains from Middle Pleistocene deposits reveal biogeographic processes that are likely to have significance for hominin evolution.

At the broadest level, the initial migration of hominins into Southeast Asia may have been part of the overall faunal turnover. Reliable dates for the appearance of *Homo erectus* in island

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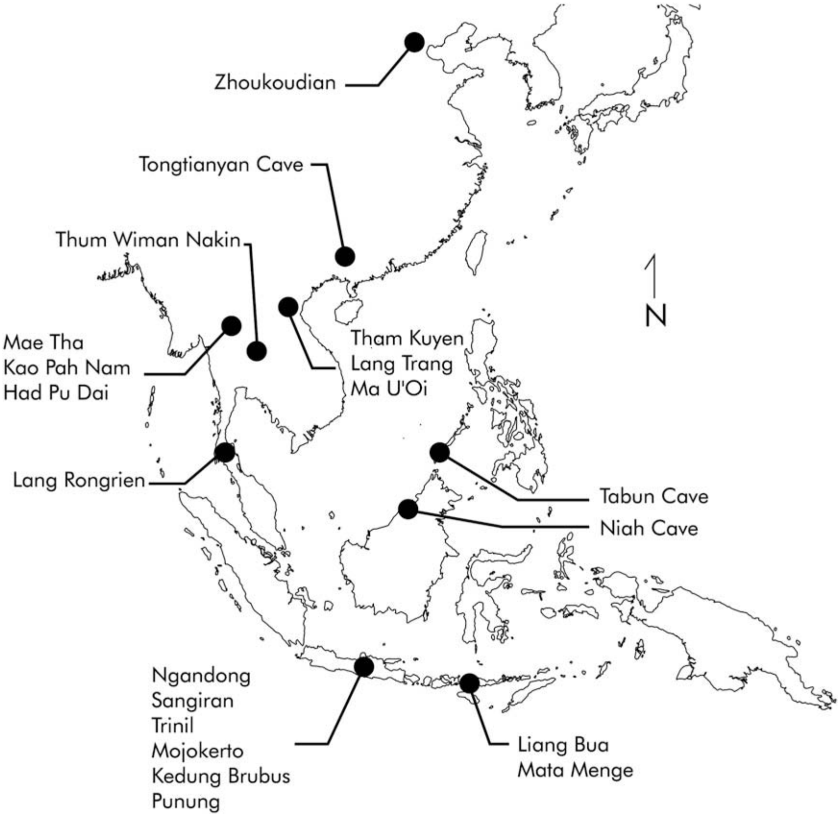

Fig. 1. Southeast Asian Middle Pleistocene locations mentioned in the text.

Southeast Asia derive from 14 flaked stone artefacts recovered from Mata Menge on the island of Flores. The artefacts were recovered from stratified contexts dated by fission track methods to about 0.8 Ma (Morwood et al., 1998). Earlier dates of 1.81 ± 0.04 and 1.66 ± 0.04 Ma have been suggested by Swisher et al. (1994) based on ^{40}Ar/^{39}Ar dating of volcanic rock from Mojokerto and Sangiran, both in Java. However, the stratigraphic relationship between the hominin remains and the dated rock is unclear so these dates are not reliable. At 0.8 Ma the fauna of Flores undergoes a marked turnover with *Geochelone* sp. (giant tortoise) and *Stegodon sondaari* replaced by *Stegodon florensis* and *Hooijeromys nusatenggara* (giant rat) (van den Bergh et al., 2001). Similar new arrivals and extinctions are evidence at the 0.8–0.7 Ma in the Kedung Brubus faunal assemblage (van den Bergh et al., 1996). The appearance of *H. erectus* on Flores and these turnovers at 0.8 Ma may be related to global climate changes in the periodicity of climatic oscillations (from low amplitude 40–50 ka cycles to high amplitude 100 ka cycles) and declines in eustatic sea levels (Chappell and Shackleton, 1986; Haq, 1991). If this association between early hominins and faunal turnovers is robust, then mammal biogeography in Southeast Asia is likely to be relevant in understanding hominin migration and settlement patterns.

Mainland and island Southeast Asia falls in the Oriental biogeographic region, which has been subdivided into four subregions: the Indochinese, Sundaic, Indian and Wallacean provinces (Watts, 1984). Two of these provinces meet on peninsula Thailand, with the Indochinese province to the north and the Sundaic province to the south (Leakagul and McNeely, 1988). The Indochinese province also includes northern Thailand, South China, Myanmar, Vietnam, Laos and Cambodia. The Sundaic province includes southern Thailand, Malaysia, Sumatra, Java and Borneo. Important climatic, botanical and zoological factors distinguish these biogeographical provinces. The Indochinese province has stronger seasonality, lower rainfall and more rainforest than monsoon forest compared to the Sundaic province (Whitmore, 1984; Gray et al., 1994). The boundary between the two provinces is also significant for plants, insects, amphibians, birds and mammals (Leakagul and McNeely, 1988; Corbert and Hill, 1992).

Important faunal exchanges occurred between the Sundaic and Indochinese provinces during the Late Middle Pleistocene and Late Pleistocene. The palaeontological record of Java is one of the best known in the region and has detailed evidence of these exchanges. Significant faunal turnover occurred between 110 and 70 ka at the sites Kedung Brubus and Punung. The Kedung Brubus faunal assemblage is dated to 80–70 ka and includes *Stegodon trigonocephalus*, *Hexaprotodon sivalensis*, *Elephas hysudrindus* and *Sus macrognathus*. These fauna are interpreted to represent an open woodland environment (van den Bergh et al., 2001). These four species are part of a group of 17, including bovids that are not found amongst the later Punung fauna (125–60 ka), which also has 10 new species (Louys et al., 2007; Westaway et al., 2007). In sharp contrast to the Kedung Brubus fauna, the later Punung fauna include large numbers of primates such as *Pongo* (orangutan), *Hylobates* (gibbon) and *Helarctos malayanus* (sun bear), indicating humid forest conditions (van den Bergh et al., 2001). Palynological data from a Bandung Basin confirm increasing humidity after 125 ka which was probably a key factor in the faunal turnover (van der Kaars and Dam, 1995). The significance of this particular turnover is that the new humid forest fauna derives from southward migrating Indochinese taxa, with remains of these mammals also known from mainland Southeast Asia (Aziz et al., 1995; Long et al., 1996; Tougard, 2001).

There are two implications following this faunal change in Java. First is the question of what route the new mammal species followed in their migration from the mainland to Java. Two options have been proposed: a route via the Philippines (von Koeningswald,

1938) and a route via Thailand, Myanmar and Cambodia (de Terra, 1943). Recent research suggests that the second option is most likely, especially since the sea depth between the Philippine archipelago and Taiwan is too great for a land bridge to have appeared during the Middle Pleistocene (Heaney, 1985; Corbert and Hill, 1992). Javanese fauna from Trinil, Kedung Brubus and Ngandong such as *H. sivalensis*, *Hyaena brevirostris*, *Caprolagus* cf. *sivalensis*, *Homotherium ultimum*, *Nestoritherium* cf. *sivalense*, and the genus *Megantereon* has archaic features that show affinities with faunas of the Indian Subcontinent and Myanmar (Groves, 1985; de Vos, 1995, 1996). Furthermore, Late Middle Pleistocene faunas from Vietnam (Olsen and Ciochon, 1990; Long et al., 1996), Cambodia (Beden and Guérin, 1973) and Thailand (Tougard et al., 1996; Tougard, 2001) include species that are widely distributed across the Indochinese and Sundaic provinces, suggesting that taxa from these assemblages were involved in migration. The identification of this major mammalian migration route is important because it suggests the timing and location of movements of hominin taxa in mainland Southeast Asia that may have contributed to the establishment of later hominin populations.

The second implication relates to the possibility that the Middle Pleistocene faunal turnover documented on Java also involved the replacement of *H. erectus* by *Homo sapiens*. *H. erectus* remains have been recovered from Trinil, Kedung Brubus, Sangiran, Mojokerto and Ngandong in Java and are typically associated with taxa that became extinct during the mammalian turnover accompanying the shift from woodland to rainforest conditions, especially *Stegodon* (de Vos et al., 1994; van den Bergh et al., 2001; Bouteaux et al., 2007). Unusually young dates (27–53 ka) have been proposed for the *H. erectus* remains from Ngandong (Swisher et al., 1996), but these dates derive from ESR and U-series methods applied to water buffalo teeth claimed to be stratigraphically associated with the hominin remains. These late dates seem unlikely because of doubts about the reliability of the dating methods (Grün and Thorne, 1997) and doubts about the integrity of the association between the bovid teeth and hominin remains in the complex taphonomic context of the Ngandong River terrace deposit (Westaway, 2002; Dennell, 2005). Following the extinction of *H. erectus*, remains of early *H. sapiens* in Java appear in association with invading tropical rainforest fauna. Four teeth of *H. sapiens* have been described from the Punung faunal assemblages (Badoux, 1959; Storm et al., 2005) and *H. sapiens* remains are also known from the *Pongo*-dominated assemblages in Sumatra (Hooijer, 1949; de Vos, 2004). Thermoluminescence and OSL dates for the Punung fauna suggest that this replacement of *H. erectus* by *H. sapiens* is likely to have occurred between 128 ± 15 and 118 ± 3 ka (Westaway et al., 2007). This agrees with the chronology of the earliest modern human remains from mainland Southeast Asia. These are an almost complete *H. sapiens* skull and several postcranial bones remains from Tongtianyan Cave (also known at Liujiang) in South China that are securely dated by U-series methods to 111–139 ka (Shen et al., 2002). However, it should be noted that there seems to be a gap between this early evidence and more numerous evidence of modern humans in Southeast Asia at about 30–45 ka at Niah Cave, Borneo (Barker et al., 2007), Lang Rongrien, Thailand (Anderson, 1990) and Tabun Cave on Palawan, The Philippines (Detroit et al., 2004) and elsewhere including Timor (O'Connor et al., 2002), Melanesia (Groube et al., 1986) and Australia (O'Connell and Allen, 2004).

3. The problem of Middle Pleistocene hominins in mainland Southeast Asia

The similar timing of the appearance of early modern humans in Java and South China draws attention to the relationship between these two populations and the question of what characteristics the geographically intermediate populations were likely to have had. The importance of these geographically intermediate populations is suggested by the relatively recent (c. 18 ka) *Homo floresiensis* remains from Liang Bua, Flores (Morwood et al., 2004). Although this species represents a unique and ultimately dead-end path of island-based hominin evolution, it also suggests the potential for stark new forms of ancestral hominins elsewhere in Southeast Asia.

Comparison of cranial morphology of *H. erectus* from China and Indonesia supports the possibility of intermediate morphologies existing between these two important centres of variation. For example, *H. erectus* specimens ZHK 11 and ZHK 5 from Zhoukoudian, near Beijing, demonstrate less prominence in the glabella and more lateral development of the torus compared to *H. erectus* specimens Ngandong 6 and 9 and Sangiran 17 (Kramer, 1993). Similarly, the supraorbital region of the Chinese specimens resembles a straight bar while on the Indonesian specimens it is more curved (Kidder and Durband, 2004). Behind this region on the Chinese specimens is a deep ophryonic groove resulting in a pronounced midfrontal convexity that is less prominent on the Indonesian specimens (Antón, 2002; Antón et al., 2002). These differences have been interpreted as evidence of clinal variation due to either environmental adaptations or genetic drift but some maintain that the differences result from the Chinese specimens representing a different species, *Homo pekinensis* (Raghavan et al., 2003; Cameron and Groves, 2004).

In either case, this comparison of hominin specimens from the northern extreme of the Indochinese province with specimens from the southern extreme of the Sundaic province suggests that specimens from the geographically intermediate zone are likely to have novel morphologies and will provide important evidence to test interpretations of Asian hominin variability. This evidence can also address the vexed question of the relationship between non-sapient hominins and *H. sapiens*. Did the latter evolve *in situ* from their Asian antecedents as some suggest, did *H. sapiens* replace earlier hominins in the great diaspora from Africa 120,000 years ago, or did non-sapient hominins co-exist with *H. sapiens* in mainland Southeast as they seem to have in island Southeast Asia?

4. Middle Pleistocene palaeoanthropological and archaeological evidence from mainland Southeast Asia

The correlation between Middle Pleistocene faunal assemblages and hominin species in Java suggests that faunal assemblages from the intermediate zone will also yield hominin specimens. There are numerous sites with extinct fauna that are contemporary with the Middle Pleistocene hominins in Thailand, Vietnam and Laos (i.e. the *Ailuropoda–Stegodon* faunal complex, Fromaget, 1940; Chaimanee and Jaeger, 1994; Tougard, 2001; Bekken et al., 2004; Demeter et al., 2004). As predicted, small amounts of hominin skeletal remains have been found with these faunal deposits (Tobias, 2002; Demeter et al., 2004) but substantial amounts of hominin material culture are yet to be recovered. Although the hominin evidence is not numerous – especially from reliably dated contexts – it does suggest some evolutionary hypotheses to motivate continuing investigation. The following discussion is limited to specimens that have chronological control provided by absolute dating methods (with one exception, see Section 4.2). This excludes a number of biostratigraphically dated hominin specimens (Ciochon and Olsen, 1986; Olsen and Ciochon, 1990). These finds typically derive from cave or river terrace deposits with complex depositional histories that are not described sufficiently to have confidence in the claimed biostratigraphic associations. Also, many of these undated remains are heavily worn teeth, making morphological comparisons unreliable, especially given the similarities between *H. erectus* and *H. sapiens* and between *Homo* and *Pongo* (Olsen and Ciochon, 1990; Schwartz et al., 1995).

4.1. *Mae Tha and Kao Pah Nam, Thailand: 0.8–0.6 Ma*

The earliest evidence for hominins in the intermediate zone is claimed by Pope (1985) and Pope et al. (1978, 1986) to be three flaked stone artefacts recovered from surface fluvial gravel deposits at Mae Tha in Lampang Province, Northwest Thailand. The age of the artefacts is argued to be about 0.8–0.6 Ma because the fluvial gravels that the artefacts in which the artefacts are stratigraphically below a basalt layer that has been magnetically dated to 0.73 Ma (Barr et al., 1976) and radiometrically dated with K–Ar isotopes to 0.8 ± 0.3 and 0.6 ± 0.2 Ma (Sasada et al., 1987). Pope et al. (1978) have also claimed that three flaked stone artefacts and one manuport recovered from excavations at Kao Pah Nam, also in Lampang, have a similar age. This is based on claimed similarities in morphology and lithology to the Ban Mae Tha artefacts, the location of the cave in relation to the dated basalt strata and extinct fauna such as *Crocuta*, *Panthera* and *Hippopotamus* recovered from the excavation.

Although these finds have received some acceptance (Higham, 1996; Tougard et al., 1998), it is suggested here that the physical relationship between the artefacts and the dated strata is too distant to have confidence in a reliable association between them. The stratigraphic relationship between the fluvial gravel and the basalt is known from two wells located 150 and 500 m south of the artefacts (Pope et al., 1986). Similarly the surface context of the Mae Tha artefacts means that they may have been deposited there at any time after that surface was exposed, so 0.8–0.6 Ma is only an oldest possible date for their deposition and there is no stratigraphic reason to impose a youngest possible date. The absence of smaller flakes suggests that the artefacts may have been sorted by water flow or result from secondary deposition. The morphologies and lithologies of these surface finds are not restricted to the Middle Pleistocene since similar morphologies and lithologies are known from throughout the Late Pleistocene and Holocene (Shoocongdej, 2000; Moser, 2001). This means that it is difficult to accept 0.8–0.6 Ma as a reliable date for these surface finds and other claimed Middle Pleistocene surface assemblages in northern Thailand and eastern Cambodia (Sørenson, 2001). On the other hand, the association of stone artefacts with extinct fauna at Kao Pah Nam is more suggestive of a reliable Middle Pleistocene hominin context. The level of description currently does not permit conclusions about stratigraphic associations and integrity at Kao Pah Nam, but it does suggest that further investigations are justified at this location.

4.2. *Had Pu Dai, Thailand: 0.5 Ma*

The next oldest claimed evidence from the intermediate zone is a little-known find of four hominin cranial fragments in a breccia matrix at the front of a cave at Had Pu Dai in Lampang Province, Northwest Thailand (Pramankij and Subhavan, 2001a). The remains are described by Pramankij and Subhavan (2001b) as four pieces that can be conformably refit to resemble the right frontal region of a calvaria with a very thick tabula externa, a thick dipole and very thin tabula interna. The curvature of the vault of the calvaria and the concavity behind the supraorbital torus are suggested by Pramankij and Subhavan (2001b) to resemble Asian *H. erectus* specimens from Java and China. Although no detailed morphometric data are yet available for these pieces, their importance has been signaled by Tobias (2002), who analysed the finds and concurred with the interpretation of Pramankij and Subhavan (2001a,b).

There are no absolute dates available from Had Pu Dai but an age of 500 ka is claimed by Pramankij and Subhavan (2001a,b) based on extinct fauna recovered from the breccias. Detailed descriptions of the fauna are not yet available, but Tobias (2002) refers to *Ailuropoda*, sabre-toothed cats or lions, hyenas, cervids and suids. Other hominoid specimens include a possible *Gigantopithecus* tooth and a possible *Pongo* tooth (Pramankij and Subhavan, 2001a,b). The presence of both *Ailuropoda* and *Pongo* is noteworthy because of the *H. erectus*/*Ailuropoda–Stegodon* association and the *H. sapiens*/*Pongo* association discussed above. The co-occurrence of *Ailuropoda*, *Pongo* and *Homo* at Had Pu Dai suggests that this assemblage might represent the pivotal period when *H. erectus* became extinct and *H. sapiens* appeared. However, despite the possible high significance of these finds and the imprimatur of Tobias, the Had Pu Dai finds must be interpreted with caution until more detailed descriptions and absolute dates are available. Like the finds from Kao Pah Nam, the details currently available from Had Pu Dai suggest that further investigations are justified at this location.

4.3. *Tham Kuyen and Lang Trang, Vietnam: 475 ka*

Five teeth identified as representing *H. erectus* [TK 65/60 (M^1), TK 65/53 (M^1), TK 65/105 (M^2), TK 65/167 (C^1) and TK 65/8 (dm^1)] have been recovered from fossil bearing sediments in Tham Kuyen Cave in Land Son Province, northern Vietnam (Ciochon et al., 1996). The teeth are identified as *H. erectus* because of the peripheral placement of the molar cusps and close morphological affinities and crown area similarities with equivalent teeth from Zhoukoudian. This is one of the better-known fossil sites in mainland Southeast Asia and has been under investigation for over 30 years. The fauna associated with the hominin teeth includes 36 mammal taxa, mostly extinct taxa such as *Ailuropoda*, *Stegodon* and *Pongo* (Olsen and Ciochon, 1990). The faunal assemblage has been dated to 475 ± 125 ka using ESR and U-series methods on teeth and speleothem samples.

A similar assemblage of *Ailuropoda–Stegodon* fauna and *Homo* teeth has also been described from the Lang Trang Caves in northern Vietnam (Ciochon and Olsen, 1991). The hominid specimens are two molars, one premolar, one canine and one incisor and are attributed to *H. erectus* based on the chronology of the site rather than morphology, which is not described. Three breccia samples with embedded fossil teeth were dated using ESR methods from 146 ± 2 to 480 ± 40 ka.

4.4. *Ma U'Oi, Vietnam: 193–49 ka*

The *Homo* remains from Ma U'Oi, Hoa Binh Province in northern Vietnam consist of one maxillary molar (MU57), one left lower first molar (MU18) and a small fragment of skull vault (MU88). These were recovered from excavations of fossiliferous breccias within the cave (Demeter et al., 2004, 2005). The associated *in situ* mammalian fauna includes *Elephas maximus*, *Rhinoceros* cf. *sondaicus* and *Rhinoceros* cf. *unicornis* that are argued to belong to the *Ailuropoda–Stegodon* complex, although neither of these taxa are present (Bacon et al., 2004). The fauna gives poor chronological resolution because most of the species present range through the Middle and Late Pleistocene and many are still extant. Absolute dates come from two samples dated by U-series methods. A piece of fossiliferous breccia gives an age of 193 ± 17 ka and a speleothem covering the fossiliferous breccia gives an age of 49 ± 4 ka (Bacon et al., 2006).

These absolute dates add little to the biostratigraphic chronology and the attributes and affiliation of the *Homo* remains are similarly ambiguous. The M18 molar is heavily worn but displays a mosaic of archaic and modern traits. Its dimensions fall within the range of *H. erectus* from China, Indonesia and Vietnam and the crown is larger than Southeast Asian *H. sapiens* (Demeter et al., 2004). However, the molar crown is square like *H. sapiens* and taurodontism – an archaic feature of Neanderthals and *H. erectus* – is not present. Molar MU57 is more clearly *H. sapiens* because of the crown dimensions falling within the range of Southeast Asian *H. sapiens* and the absence of occlusal wrinkles, peripheral placement of cusps, apices and taurodontism (Demeter et al., 2005). The skull piece is a mid-occipital bone fragment but insufficient features are present to permit taxonomic identification (Demeter et al., 2005).

4.5. Thum Wiman Nakin, Thailand: 169 ka

A single *Homo* tooth (TF3467, RP^4) was recovered from excavations of red clay sediments in the main chamber of Thum Wiman Nakin in Chaiyaphum Province, northern Thailand (Tougard et al., 1998). The associated faunal assemblage suggests a Late Middle Pleistocene chronology and includes numerous extinct taxa including *Pongo pymaeus*, *Ailuropoda melanoleuca baconi*, *Crocuta crocuta ultima* and *Ursus thibetanus*. As at Ma U'Oi, absolute dates have improved little on the biostratigraphic chronology. A large number of samples of travertine and teeth were dated using U-series methods, returning dates ranging from 8 to 350 ka (Esposito et al., 1998, 2002). Based on these dates the context where the *Homo* tooth was recovered was estimated to date to 169 ± 11 ka. The wide range of results in the U-series dates, especially from the teeth, is significant because they demonstrate the complexity of U-series dating in tropical humid climates that result in highly variable rates of uranium uptake and leakage (Esposito et al., 2002).

The *Homo* tooth from Thum Wiman Nakin is heavily worn and exhibits a mix of attributes from *H. erectus* and *H. sapiens*. The direction of the crown's largest dimension and the asymmetric crown shape of F3467 resemble *H. erectus*, but the completely fused root branches and occurrence of only one apex are specific to *H. sapiens* (Tougard et al., 1998). This mosaic of features resembles the M18 molar from Ma U'Oi, but the heavily worn condition of both specimens prevents anything more than tentative attributions to archaic *Homo* sp. for both.

5. Geography and hominin settlement and migration

With so few locations and such small amounts of evidence it is difficult to make robust statements and test hypotheses about evolutionary processes and settlement patterns. However, there are three possibilities for modelling the broad movements of early hominins in mainland Southeast Asia that are relevant to this evidence (Fig. 2).

First is the proposal of Pope et al. (1978) that the Chao Phraya River basin, running from Northwest Thailand down to the Gulf of Thailand, was an important conduit for the migration and mixing of North Asian and Indonesian fauna and for the appearance of intermediate fauna (Leakagul and McNeely, 1988). They also suggest that it was an area where hominins probably moved through seeking prey and other resources. Topographically complex areas, such as the mountainous western flank of the Chao Phraya Basin, are likely to have also been favorable hominin habitats because they are environmental mosaics with varied food resources and abundant water supplies, combined with physical features offering protection from the weather and providing tactical advantages in the pursuit of prey (King and Bailey, 2006). This proposal has slight support from the early chronology of the finds at Hat Pu Dai and Kao Pah Nam compared to Thum Wiman Nakin and the Vietnamese sites. The appearance of hominins at 0.8 Ma in northern Thailand agrees well with a similarly timed appearance of *H. erectus* in island Southeast Asia. However, the Thai chronologies are of uncertain significance because of low reliability of the dating of these sites. Nevertheless, the potential for further testing of this hypothesis is clear from the existing evidence and exploration is ongoing (Zeitoun et al., 2005).

The second possibility has been proposed by Demeter et al. (2003) based on their analysis of 86 crania of anatomically modern human fossils from archaeological contexts in mainland and island East and Southeast Asia dating from 67 to 1.2 ka. They identify two hominin populations, one in China characterised by a high long cranium and a broad face with a thick cranial bone, and one in Southeast Asia characterised by a short and high cranium, a narrow frontal bone and a broad face between the orbit. They propose that the northern population migrated down the eastern coast of mainland Southeast Asia, namely through Vietnam, and underwent admixture with the second population. This model is not precluded by the current evidence and the two *Homo* sp. teeth displaying a mosaic of archaic and modern features lend some support to a model of mixing populations. It is tempting to conclude that this model is verified by number and quality of Middle Pleistocene hominin sites from Vietnam. However, the available sample is very small and the geographical distribution of sites probably reflects more the history of research in the region than actual hominin settlement patterns. Similarly, making conclusions about a multi-

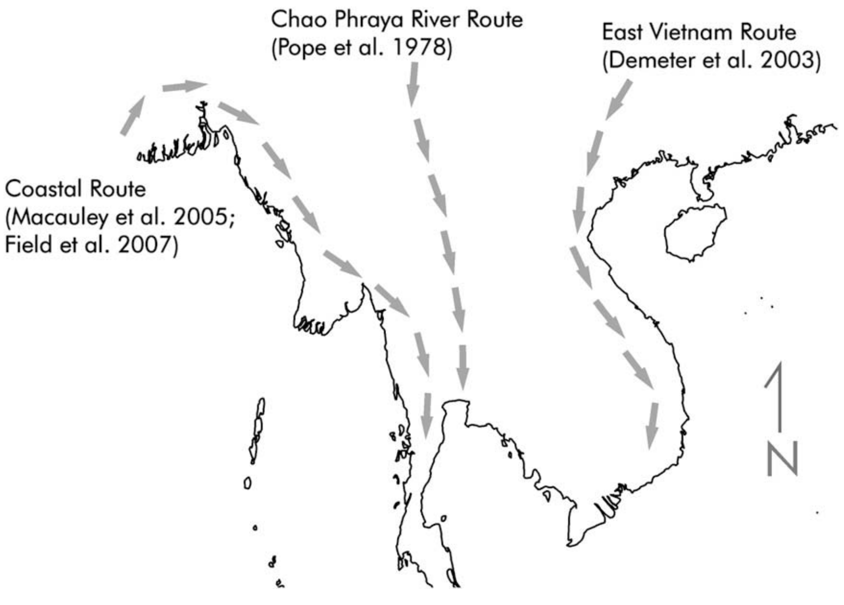

Fig. 2. Schematic map of the three models for major movements of hominins during the Middle Pleistocene.

regional origins' scenario for Middle Pleistocene hominins from Upper Pleistocene material is problematic because the evidence is indirect. As for all three models, more reliably dated sites and more complete cranial remains are required from early dated contexts that are needed to unequivocally test this model.

The third possibility is suggested by genetic (Macaulay et al., 2005) and geographic analyses (Field et al., 2007) that propose a coastal and waterways route for the initial migration of hominins into Southeast Asia from west Asia. This model holds that a major movement of hominins into Southeast Asia occurred along the coast of South Asia and Myanmar. Testing this model is problematic because none of the sites discussed here are located along that proposed route and much of this route is now submerged by sea level rises. However, one promising location where this model could be tested is along a length of coast to the west of the Irrawaddy River delta. This location is significant because the continental shelf is relatively close to the current shoreline (Voris, 2000) and the high biomass of the delta wetlands region means that it is likely to have been an attractive habitat for hominins. Fortuitously there is also a small area of carbonate karst in this area, indicating the possibility of preserved accumulations of Middle Pleistocene deposits in caves and rockshelters that may have been used for hominin habitation (Mouret, 2004).

6. Conclusion

The conclusions about hominin evolutionary and settlement problems that can be drawn from such sparse data are necessarily limited. For example, the evidence from mainland Southeast Asia does not clearly reproduce the basic patterns of hominin/mammal taxonomic associations that are observed on Java. That said the process of reviewing the data is still worthwhile because it has allowed a critical appraisal of evidence that has acquired almost canonical status in Southeast Asian archaeology and palaeontology. It is concluded here that current dating of the evidence from Mae Tha and Kao Pah Nam is inadequate and new dates are required to confirm its Middle Pleistocene age. The available descriptions of material from Had Pu Dai suggest these finds are highly significant because it is the only site in mainland Southeast Asia with skull fragments that have been claimed as *H. erectus*. Further description and dating of these remains and the site where they were recovered will help to realise the full significance of this evidence.

The evidence from Tham Kuyen, Lang Trang, Ma U'Oi and Thum Wiman Nakin is better described and more robust. However, the worn condition of the *Homo* specimens and the complexity of U-series dating mean that caution is required in evaluating their significance. The mix of modern and archaic features in the teeth from Thum Wiman Nakin and Ma U'Oi suggests the presence of clinal variation or evolutionary change. This mix also casts doubt on the replacement of *H. erectus* by *H. sapiens*, but it is not unequivocal proof that it did not occur.

This review has presented and evaluated three different models for major movements of hominins during the Middle Pleistocene and foreshadowed some significant future research directions for the continuing testing of these models. An important factor in finding hominin remains is to identify locations where hominins are likely to have lived *and* where their remains and cultural materials are likely to have been well-preserved. Topographically complex upland areas are significant in the seasonal tropics of mainland Southeast Asia because past climatic cycles had pronounced dry seasons and lowland vegetation was more susceptible to drought stress while uplands had higher precipitation (lowland sites are also likely to be buried under alluvial sediments) (Schepartz et al., 2000). In selecting sites for investigation in these areas it is necessary to consider landscape transformations caused by the fast rate of uplift of the limestone formations combined with the high-energy hydrology that facilitates erosion through catastrophic events (Kiernan, 1991). This means that over a very long period of time the hills have gradually been getting higher while the valleys are getting deeper – sometimes very quickly. This has two significant implications for finding hominin sites in upland topography. First, rockshelters in valleys are likely to have been periodically rinsed clean by energetic river flows and are unlikely to contain undisturbed ancient deposits. Second, formations with rockshelters beyond the reach of high-energy hydrology that were occupied by early hominins are now likely to have been elevated to positions that intuitively appear uninhabitable in the current landscape.

Finally, the study of hominin history and evolution in mainland Southeast Asia is crucial to our understanding of human evolution worldwide. The recovery of additional material will not only contribute more comprehensive picture of human evolution but will also stimulate interest in the prehistory of mainland Southeast Asia and encourage local researchers to engage with international research priorities and foster high levels of communication and the exchange of ideas.

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