J World Prehist (2011) 24:227–274
DOI 10.1007/s10963-011-9054-6

The Origins of the Bronze Age of Southeast Asia

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Published online: 10 December 2011

Abstract White and Hamilton (J World Prehist 22: 357–97, 2009) have proposed a model for the origin of the Southeast Asian Bronze Age founded on seven AMS radiocarbon determinations from the Northeast Thai site of Ban Chiang, which would date the initial Bronze Age there to about 2000 BC. Since this date is too early for the derivation of a bronze industry from the documented exchange that linked Southeast Asia with Chinese states during the 2nd millennium BC, they have identified the Seima-Turbino 3rd millennium BC forest-steppe technology of the area between the Urals and the Altai as the source of the Southeast Asian Bronze Age. We challenge this model by presenting a new chronological framework for Ban Chiang, which supports our model that the knowledge of bronze metallurgy reached Southeast Asia only in the late 2nd millennium BC, through contact with the states of the Yellow and Yangtze valleys.

Keywords Southeast Asia · Bronze Age · Thailand · Ban Non Wat · Ban Chiang · Shang civilization · Seima-Turbino

Introduction

This paper addresses the timing and cultural implications of the initial establishment of the Southeast Asian Bronze Age in response to the model proposed by White and Hamilton

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Fig. 1 The main regions and places mentioned in the text: 1. Lake Kumphawapi; 2. Lopburi Province; 3. Bang Pakong River; 4. Dongting lake; 5. Chengdu Plain; 6. Erhai Lake; 7. Yunnan-Guizhou Plateau; 8. Lake Poyang; 9. Yuanmou; 10. Kanchanaburi; 11. Pasak Valley; 12. Khao Wong Prachan Valley; 13. Mun River; 14. Mekong River; 15. Red River; 16. Gulf of Siam; 17. Loei; 18. Hong Kong; 19. Shandong Peninsula; 20. Liaoning Province; 21. Inner Mongolia; 22. Huanghe Valley; 23. Wei River Valley; 24. Central Plains; 25. Jiang-Han Plain; 26. Nanyang Basin; 27. Wuhan; 28. Ganjiang River; 29. Lishui River; 30. Shimen County; 31. Xiangjiang River; 32. Pearl River; 33. Qi'ao island; 34. Zhuhai; 35. Nanning; 36. Chao'an county

(2009). This involves a considerable area, stretching north from the lower reaches of the Red, Mekong and Chao Phraya rivers to the Urals, and encompassing much of China (Fig. 1). The model is founded on seven radiocarbon determinations, six derived from the organic temper of mortuary vessels and one from rice phytoliths sampled from within a pot excavated at the site of Ban Chiang in Northeast Thailand, from which White and Hamilton conclude that the earliest copper-base artefacts there date between 1800 and 2000 BC. This requires either an indigenous origin of metallurgy in Northeast Thailand, or derivation from a source other than dynastic China. The model proposes that the Seima-Turbino transcultural phenomenon of the Urals provided the stimulus to a movement of skilled metallurgists along a route through Gansu, via Sichuan, Yunnan and Laos into the lowlands of Southeast Asia. This proposed route of introduction runs counter to the natural lines of human communication across western China. In addition, this putative early arrival of metallurgy at sites like Ban Chiang appears not to have had any obvious social consequences. Thus the White and Hamilton model differs sharply from the model that we have previously proposed (Higham 1996; Ciarla 2007a; Pigott and Ciarla 2007), which places the Bronze Age of Southeast Asia a millennium later, its onset stimulated by well-documented exchange contacts with the states of the Yangtze and Yellow River valleys. In this paper we present new high-resolution radiocarbon dates on human skeletons and associated pig bones to further support the idea that the late introduction of metallurgy was a consequence of the emergence of an extensive interaction sphere that linked late Neolithic Southeast Asia with the Bronze Age civilizations of China, and which resulted in the visibly rapid rise of social aggrandizers in the local communities.

The Bronze Age in Southeast Asia was first defined and explored in the wake of the French colonization of Indo-China during the decades following the discovery of the site of Samrong Sen in Cambodia in 1876 (Cartailhac 1890). In 1879, M. Moura investigated the site and recovered from villagers bronze artefacts that were examined and published by Noulet (1879). They represent almost the complete repertoire of bronzes typical of the Southeast Asian Bronze Age: a socketed axe, fishhooks, arrowheads and bangles. The analysis of these items revealed a tin content of 4–12%. E. Fuchs was prominent in attempting to date this newly discovered Bronze Age, suggesting that it belonged in the 1st millennium BC. With the extension of French colonial rule into the interior, progressively more Bronze Age sites were identified. Massie collected socketed axes in the vicinity of Luang Prabang in Laos, while Lefèvre-Pontalis (1894) found socketed axes, a chisel and a spear from sites in the region of the upper Black River. Summarising these finds, Massie (1894) proposed three phases of prehistory, involving first chipped, then polished stone tools followed by a Bronze Age. The chronology was largely dependent on reasoned guesswork, and Pavie (1894) wisely summarized the situation when he wrote 'Certes, le dernier mot de cette question intéressante n'est pas encore dit' ['admittedly, the last word on this interesting question has not yet been spoken'].

This initial interest in the Southeast Asian Bronze Age waned over the period of the two World Wars and the diversion of archaeological energy into the restoration of Angkor Wat and the associated Angkorian monuments. However, the presence of a closely related Bronze Age in Guangdong Province, China was actively pursued by Maglioni (1975) and Schofield (1975), the former concluding that later prehistory incorporated two early Neolithic phases dated between 4000 and 1500 BC, followed by a late Neolithic, then a chalcolithic and finally a full Bronze Age.

Widespread interest in the Bronze Age in Southeast Asia was reignited by claims made on the basis of excavations at two small occupation sites in Northeast Thailand. Excavations at Non Nok Tha in 1965–1968 uncovered a cemetery in which a few of the dead were interred with socketed bronze axes and bivalve casting moulds. The sequence was dated on the basis of accumulated fragments of charcoal from graves or occupation layers. On the basis of two radiocarbon determinations on this material, Solheim (1968, p. 62) proposed that the bronzes dated to the 3rd millennium BC, a thousand years earlier than in Shang China. Four years later, Solheim wrote that a socketed axe from Non Nok Tha dated to about 3500 BC, 'the oldest socketed tool yet found anywhere' (Solheim 1972, p. 36). In 1974–1975, Gorman and Charoenwongsa excavated a second Northeast Thai cemetery site at Ban Chiang, again assembling charcoal samples from grave fill. Their results, in their view, supported a 4th millennium BC date for the Bronze Age (Gorman and Charoenwongsa 1976).

These claims divided the interested scientific community into those prepared to accept the early date and explore the cultural consequences (Bayard and Charoenwongsa 1983; Solheim 1983) and cautious sceptics who did not (Loofs-Wissowa 1983; Higham 1984). White and Hamilton's new model develops the argument for an early date, while we argue that the reliable dating evidence points the other way and clearly supports a late dating. We regard as axiomatic the need both to define a valid Bronze Age context, and to date it accurately. The former requires an undisturbed context containing a copper-base artefact or a facility for casting one. The latter must follow the latest radiocarbon sampling and pretreatment protocols. Where determinations are based on unspeciated charcoal, which applies to the vast majority of available dates, we view each as, at best, a *terminus post quem,* due to the unknown effect of inbuilt age (Ashmore 1999). The same applies to determinations from organics recovered from fired clay artefacts, due to the unknown provenance of the carbon admixed in the clay itself. We stress, therefore, the vital importance of securing radiocarbon determinations from samples with a secure cultural context, with minimal or zero inbuilt age, that are then subjected to rigorous pretreatment protocols before being interpreted with the benefit of Bayesian analysis (Bayliss et al. 2007).

Although there is no consensus on the later prehistoric sequence in Southeast Asia, there is a broad agreement among the majority of specialists that during the 3rd millennium BC there were several expressions of hunter-gatherer adaptation. These ranged from rich, sedentary communities occupying favoured coastal locations through to smaller and more mobile groups in the forested interior. Both types of cultural community interacted with the intrusive Neolithic rice farmers who had originated in the Yangtze Valley and moved south along the major waterways and the coast (Rispoli 2007; Fuller et al. 2010; Zhang and Hung 2010). None of the early farming sites, evident in Southeast Asia from around 2000 BC, provides any evidence for metallurgy, although, in due course, Late Neolithic communities were to become familiar with copper-base metallurgy. Although the timing of the technological change and its social implications are the principal subject of the rest of this paper, we shall also examine related contentions surrounding the start date of the preceding Neolithic period, where similar methodological issues arise, and in relation to the same archaeological sites.

Ban Chiang

The White and Hamilton (2009) model for the origins of the Southeast Asian Bronze Age is founded on a set of radiocarbon determinations from the prehistoric settlement of Ban Chiang. This site is located in the upper reaches of the Songkhram River as it flows north to join the Mekong (Fig. 2). It assumed prominence in the 1960s when Iron Age ceramic vessels bearing complex painted designs were found there, a situation that led to a wave of looting and site destruction. Rescue excavations in 1974–1975, directed by Gorman and Charoenwongsa (1976), were undertaken as a joint project between the University of Pennsylvania Museum, Philadelphia, and the Fine Arts Department of Thailand. Two of us (CH and AK) were members of the excavation team during both seasons. A sequence spanning the Neolithic to the late Iron Age was identified on the basis of human burials and both occupation and industrial remains. Most of the stratigraphy, however, had been lost due to intense bioturbation and to human disturbance, especially the cutting of graves during prehistory. Following Chester Gorman's death in 1981, the Pennsylvania Museum appointed Joyce White to carry through the site analysis and publication. Her doctoral

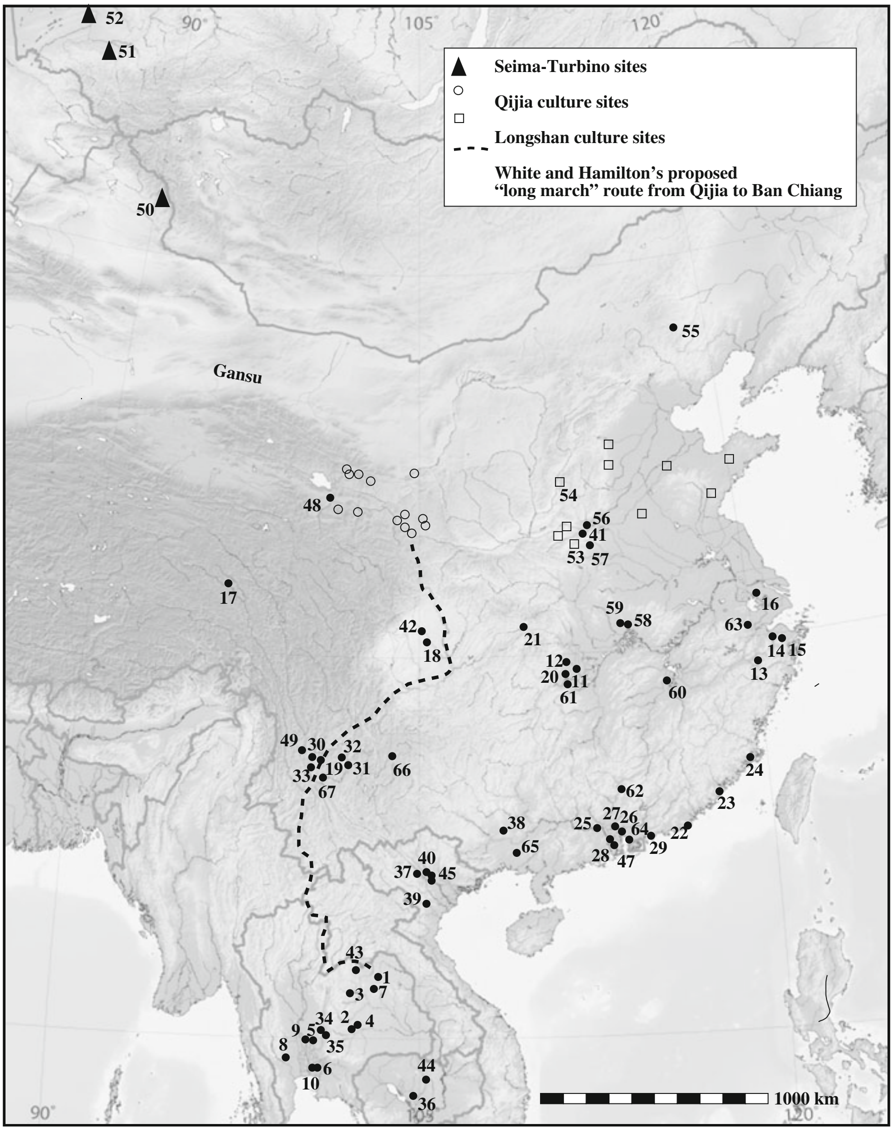

Fig. 2 The location of sites mentioned in the text: 1. Ban Chiang; 2. Ban Non Wat; 3. Non Nok Tha; 4. Ban Lum Khao; 5. Tha Kae, Non Pa Wai, Nil Kham Haeng; 6. Nong Nor; 7. Ban Na Di; 8. Ban Don Ta Phet; 9. Ban Mai Chaimongkol; 10. Khoh Phanom Di; 11. Pengtoushan; 12. Zaoshi; 13. Shangshan; 14. Kuahuqiao; 15. Caoxieshan; 16. Chuodun; 17. Karuo; 18. Baodun; 19. Baiyangcun; 20. Zaoshi; 21. Daxi; 22. Chao'an; 23. Fuguodun; 24. Keqiutou; 25. Xiankezhou, Cuntou; 26. Xiantouling, Dameisha; 27. Dahuangsha, Longxue; 28. Baojingwan; 29. Haifeng; 30. Yinsuodao; 31. Dadunzi; 32. Mopandi; 33. Xinguang; 34. Khok Charoen; 35. Sab Lamyai (Sab Champa); 36. Samrong Sen; 37. Phung Nguyen; 38. Yuanlongpo; 39. Man Bac; 40. Lung Hoa; 41. Erlitou; 42. Sanxingdui; 43. Phu Lon; 44. Mlu Prei; 45. Dong Den; 46. Dong Dau; 47. Sha Po Tsuen, Sham Wan, Tangxiahuan, Yapowan, Nanshawan, Zengchuanbu, Kwo Lo Wan, Wubeiling; 48. Xining; 49. Haimenkou; 50. Novonikolskoe; 51. Verkhnyaya Alabuga; 52. Kamyshnoe, Kurgan Region; 53. Wanchenggang; 54. Taosi; 55. Dadianzi; 56. Xingyang Stadium; 57. Tazhuang; 58. Panlongcheng; 59. Denjiawan; 60. Xin'gan; 61. Zaoshi; 62, Shixia; 63. Liangzhu; 64. Kwo Lo Wan, Sha Po Tsuen; 65. Gantuoyang; 66. Wayao; 67. Hejiashan

Table 1 The cultural sequence of Ban Chiang (after Pietrusewsky and Douglas 2002, p. 5)

Burial phase	Date according to White	Major period[a]
Late period X	300 BC–200 AD	Iron age
Late period IX		
Middle period VIII	900 BC–300 BC	
Middle period VII		
Middle period VI		Bronze Age
Early period V	2100 BC–900 BC	
Early period IV		
Early period III		
Early period II		Neolithic
Early period I		

[a] As far as can be ascertained by CH

dissertation (White 1986) described a sequence of early, middle and late periods, further divided into 10 phases (Table 1). The 'Early Period' (EP) I–II designates the earliest phases of the Neolithic. The earliest burial incorporating a copper-base fragment belongs to EP II–III, although this was not in clear association as a mortuary offering. The burial containing the first copper-base mortuary offering (a socketed spearhead) belongs to EP III.

The initial set of radiocarbon determinations was obtained on the basis of charcoal, much of which came from the fill of inhumation graves, while a small number of samples were collected from in situ hearths. The results do not conform to the cultural sequence, and their incoherence defies rational interpretation (Fig. 3). This could well be a consequence of dating charcoal samples with possible inbuilt age that were taken from uncertain mortuary contexts (Higham 1984); nevertheless, others have considered the samples to have greater integrity (Bronson 1985, p. 207). Subsequently, Hedges et al. (1997) and White (1997, 2008) undertook a second programme of dating, focusing on the organic temper found in ceramic vessels placed in graves. A subset of six AMS determinations selected from a further 20 on the basis of pre-treatment has been published, together with one derived from rice phytoliths. White and Hamilton (2009) have concluded that these date the initial Bronze Age at Ban Chiang at c. 2000 BC (Fig. 4).

Higham (1996), Ciarla (2007b, c) and Pigott and Ciarla (2007) have provided detailed models that see the origins of the Bronze Age in the context of exchange between local Neolithic communities and the state societies of China centred in the Yangtze and Yellow River valleys, which themselves only arose during the 2nd millennium BC. As these state-level societies were not in existence early enough to be the source of an early Southeast Asian Bronze Age, White and Hamilton have identified as their candidate the Seima-Turbino transcultural phenomenon, whose sites are located over a vast area incorporating the Urals, the Altai mountain ranges of Central Asia and southern Siberia (Chernykh 1992, 2009; Kohl 2007; Koryakova and Epimakhov 2009).

For this model to attain traction, there must be both a harmony in the chronological contexts between the donor and recipient, and a similar set of technological practices. However, the Seima-Turbino chronology is not itself well documented yet: in their review of the Bronze Age sites in the general area centred on the Urals, Hanks et al. (2007) list just one radiocarbon determination for a Seima-Turbino site, derived from human bone recovered at Satyga. The determination is 2140–1940 cal. BC (OxA-12529). Three further determinations are now available from Yurino in the upper Volga, and these suggest that the Seima-Turbino sites lie within the 22nd to 17th century BC range (Chernykh 2009).

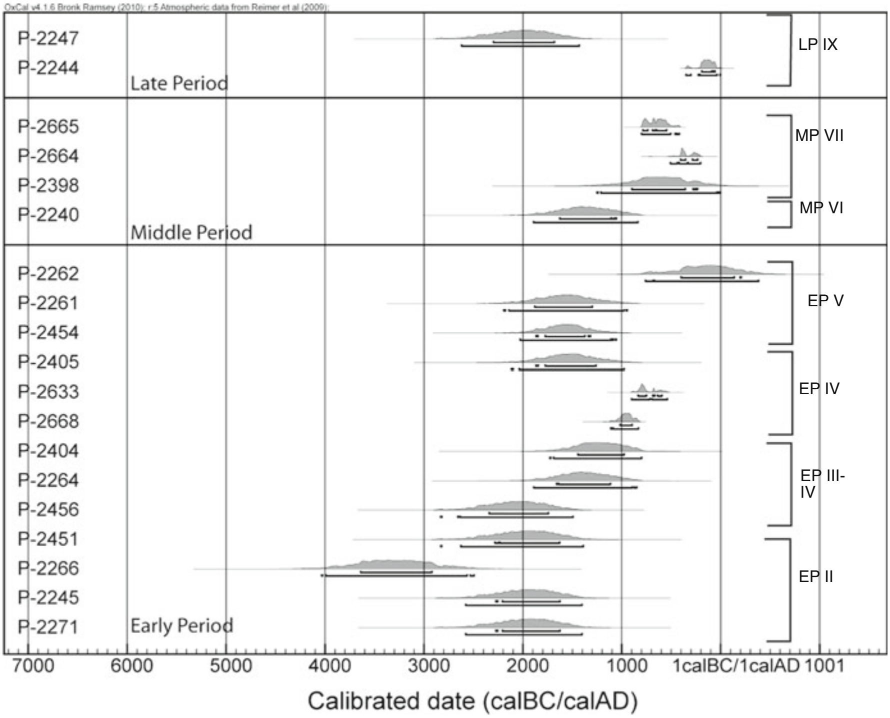

Fig. 3 The charcoal radiocarbon dates derived from Ban Chiang burials

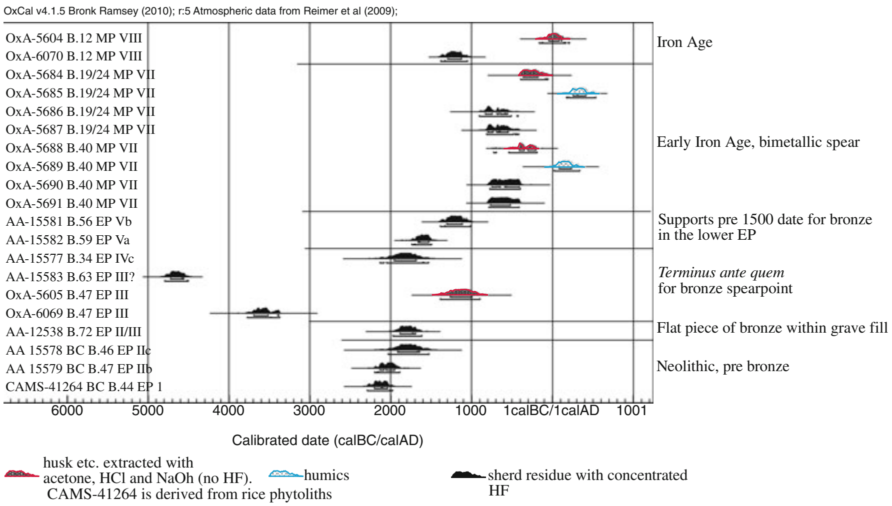

Fig. 4 The radiocarbon dates from Ban Chiang based on the organic fraction of ceramic tempers

Mei (2003) has noted the possibility of Seima-Turbino contact or influence on the early bronze casting tradition of the Qinghai, Xinjiang and Gansu provinces of China. Most sites in question belong to the Qijia and Siba cultures and are dated from about 2200 BC into the first half of the 2nd millennium BC. While many of the bronzes fail to find parallels further west, there is little doubt that there was a current of contact in that direction, seen in socketed spearheads: several from Xining in Qinghai and one each from Shaanxi and Shanxi provinces. The sockets of these weapons are distinguished by a hook, presumably to aid hafting. They are precisely paralleled at Rostovka in Siberia and Charysh in the Altai. The Siba culture in Gansu has also yielded socketed axes (Mei 2003, p. 7).

It is on this basis that White and Hamilton have claimed that several attributes of the Seima-Turbino metallurgical repertoire resonate in Southeast Asia. These include the use of bivalve moulds, and the casting of socketed axes and spearheads. It must, however, be noted that only one spearhead has been found in a Thai Bronze Age site, and it does not have the distinctive Seima-Turbino hook. Tin bronze was a widespread alloy, and both areas employed hollow-core casting of axe and spear hafts by inserting a clay plug between the two moulds. These parallels, linked with the claimed date of 2000 BC for the Ban Chiang bronzes, underwrite a proposal which, in sum, suggests that metal founders either from inner Asia or the region of northwest China under Seima-Turbino influence, travelled rapidly along the eastern margin of the Himalayas to directly introduce the techniques of copper mining, smelting, alloying and casting to the Neolithic inhabitants of Ban Chiang. This would have entailed a journey of at least 2,500 km over difficult and often mountainous terrain (White and Hamilton 2009, p. 384).

Chernykh (1992, p. 215) has suggested that the wide distribution of bronzes typical of the Seima-Turbino 'tribes' reflects their ability to move rapidly across the forest-steppe on horseback or on skis. A bronze knife from the Rostovka cemetery has a model of a man on skis or a sled being pulled by a horse (Koryakova and Epimakhov 2009, p. 107). If they brought their horses to Ban Chiang, none has entered the archaeological record. There would also have been a filter that removed from the Southeast Asian repertoire many features of the Seima-Turbino bronze industry and, indeed, their culture as a whole. Koryakova and Epimakhov (2009) have described the Seima-Turbino phenomenon as characterised by elite warriors, whose superior weaponry underwrote their westward expansion. They were certainly impressive, with their armour fashioned from blades of horn, and their long spears, which could double as daggers, shaft-hole axes and socketed axes. Most of these Seima-Turbino bronze forms are never found in Southeast Asia. The shaft-hole axes, flat knives with waisted tangs and daggers are all absent. Kohl (2007) adopts a more restrained interpretation of what Seima-Turbino might have been, noting that it might equally well represent the actual movement of people, expansion by a mounted warrior elite, or prestige exchange. This unresolved situation reflects the absence of any Seima-Turbino settlement sites.

White and Hamilton's (2009) model is constructed on the foundation of seven radiocarbon determinations from Ban Chiang. Testing it, therefore, has to begin with as thorough a review of chronology as is possible for a site for which no report has been published. If our first concern is to establish an agreed protocol for identifying a Bronze Age context then we must accept that, while this might appear straightforward, our combined experience of excavating relevant sites suggests otherwise. Thus, where Bronze Age pits, postholes and graves were dug deeply into Neolithic layers, as occurred at Ban Chiang, Ban Non Wat, Ban Lum Khao, Tha Kae and Non Nok Tha to name a handful of relevant sites, fragments of bronze, crucibles and moulds regularly find their way into contexts where they do not belong. Ban Chiang was subject to the most intense bioturbation by ground dwelling creatures that we have witnessed over a period of 40 years of fieldwork. It is relevant to note in this context that neither White nor Hamilton excavated at Ban Chiang (or at any other Bronze Age site in Southeast Asia), as this may underscore a

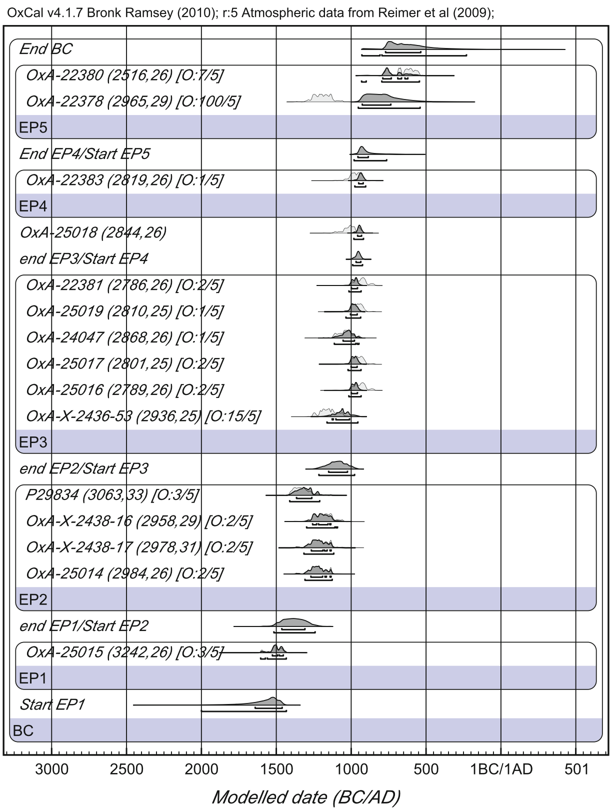

Fig. 5 Probability distribution of dates relating to the cultural sequence at Ban Chiang. Calibration was undertaken using the Reimer et al. (2009) INTCAL09 calibration curve and the OxCal 4.1 software (Bronk Ramsey 2009). OxA-25019 has been assigned to EP II–III and has a flat piece of bronze at the base of the grave; OxA-24047 has a bronze spear as a mortuary offering

difference in approach. We are firmly of the view that we can accept as evidence of knowledge of metals only copper-base artefacts that occur as primary and undisturbed mortuary offerings or inclusions (such as a bangle in place on a wrist), or the identification of an in situ mining, smelting or casting activity area. By contrast, White and Hamilton's criteria allow fragments of bronze and fractured pieces of crucible in disturbed contexts to count as good evidence. Yet following our recommendation for caution, we find that the earliest certain evidence for the Bronze Age at Ban Chiang resides in a socketed spear associated with Burial 76, that of a young man ascribed to EP III. Their criteria would see the Bronze Age commence at the EP II–III transition (Fig. 5).

The next issue relates to the layout of the Bronze Age cemetery. Excavations at Ban Chiang took place in approximately five-month seasons in 1974–1975. CH was present in May/June of each year, AK was there for the entire duration of the fieldwork. The layout of the cemetery uncovered in 1975 has been published by Pietrusewsky and Douglas (2002; see Fig. 6). No plan has yet been made available for the 1974 excavation. The burials in each of three rows uncovered in 1975 have been designated a phase within the Early Period (EP) occupation of the site, ranging from EP II to EP IV. Although it is not easy to derive an overall time span for this cemetery from White's seven published radiocarbon dates, it

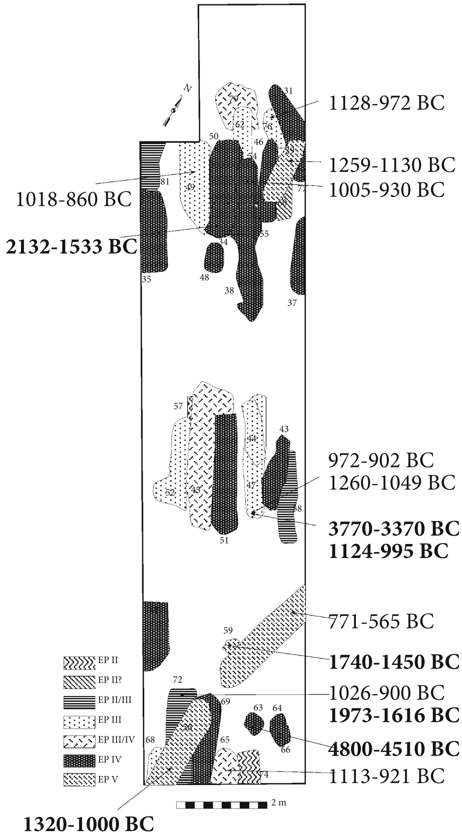

Fig. 6 The layout of early Bronze Age burials at Ban Chiang (1975 season) with associated radiocarbon determinations. Dates in *bold* font are from White based on ceramic temper, dates in *standard* font are derived from human or pig bone

would have endured for well over five centuries, and possibly for as long as a millennium. It is noted that each row contains the graves of men, women, infants and children. There are 7 female graves, 13 male burials and the graves of 15 young individuals ranging from pre-term to a child of about 7 years at death.

This distribution may be compared with other Bronze Age cemeteries in Thailand at Nong Nor, Ban Na Di, Ban Non Wat and Ban Lum Khao (Higham and Kijngam 1984, 2009; Higham and Thosarat 1998, 2005). In each case we find a similar pattern of graves wherein men and women, infants and children, were interred in close proximity in rows. It is also found that in group C at Ban Chiang, four graves formed a line with graves placed head to toe, a pattern replicated at Ban Non Wat and Ban Lum Khao. The distribution of graves in such rows and columns at other Bronze Age sites invariably reflects a relatively short time span measured in a few generations rather then many centuries. It is therefore prima facie likely that the Ban Chiang Bronze Age cemetery illustrated in Fig. 6 also had a relatively brief life.

Our final and most important concern relates to dating methods. Given that until recently it has not been considered possible to make direct date determinations on human bone in these contexts due to the very poor preservation of bone collagen, the history of direct dating has focused on identifying other sources of available carbon. In 1974–1975, charcoal fragments were collected from the fill of graves, and where possible, in situ hearths or similar features. There are two caveats. Unless the charcoal is identified as belonging to a short-lived species, any radiocarbon determination must be seen only as a *terminus post quem* due to the unknown degree of inbuilt age. Moreover, charcoal from a mixed or disturbed cultural context, such as grave fill, will inevitably involve spurious results (Ashmore 1999). This set of determinations presents so many contradictions that it is not possible to deduce from it a coherent chronological framework (Fig. 3). Thus, three determinations for the Neolithic burials from EP II suggest that this period is later than about 2000 BC but a fourth date is a millennium earlier. The three determinations from the early Bronze Age burials from EP III–IV present an offset of almost seven centuries, one suggesting a date in the vicinity of 1000 BC, another being almost a millennium earlier. For EP V the offset from earliest to latest is around 1,200 years.

In order to establish a reliable chronology for this site, White (1997, 2008) has turned to dating organic temper from ceramic vessels placed with the dead. This once seemed prima facie to be a reliable technique; the pots in question were of certain context, and the temper would have no inbuilt age. It was employed to obtain a chronology for Ban Don Ta Phet, where the acidic soils destroyed most organic material (Glover 1990). The absence of in situ charcoal at Nong Nor encouraged one of us (CH) to apply the technique there (Higham and Thosarat 1998), and it was also used to try to identify a chronology for the Bronze Age cemetery of Non Nok Tha (Higham 1996, p. 191).

Glusker and White (1997) began their employment of this dating method for Ban Chiang by experimenting with different chemical pretreatments on sherds taken from the same vessel. In one (Treatment A), fragments of organic matter were teased out of the potsherd and treated with acetone, 0.2 N HCl and 0.5 N NaOH successively to extract lipids, carbonates and humic acids. In the second pretreatment (Treatment B) the above procedure was applied to crushed potsherds, and followed by either a mixture of 4 M HF in 6 M HCl or concentrated hydrofluoric acid followed by multiple washings. This procedure 'aims to concentrate the carbon content of the residue and also makes soluble a considerable quantity of clay-bound humic material' (see comments by White and Glusker in Hedges et al. 1997, p. 259).

This experimental procedure revealed that the pretreatments usually furnish quite different results for the same burial. Thus the determination for a pot from MP VIII, Burial 12 under treatment A is 1970 ± 60 BP (OxA-5604), while that for treatment B is 2980 ± 50 BP (OxA-6070), an offset of a millennium. Again, a vessel from burial 19/24 of MP VII has provided a Treatment A determination of 2190 ± 70 BP (OxA-5684) and 2545 ± 65 BP (OxA-5686) for Treatment B. It is noted that this burial is earlier in the sequence than Burial 12 but the date under Treatment B is four centuries later. At Ban Non Wat, the transition to the Iron Age took place in the second half of the 5th century BC, at which point we have burials with bimetallic spear points (Higham and Kijgnam 2009, p. 198). Burial 24 at Ban Chiang was interred with such a spear. The Treatment B result for this burial is about four centuries too early, but the Treatment A determination appears to be correct. The Treatment B result for Burial 40, also early Iron Age, is also erroneously early.

Contradictions such as these have encouraged White to conclude that Southeast Asian archaeologists must tolerate 'some degree of chronological fuzziness' (White 2008, p. 101). She has continued with this dating technique, identifying Treatment B as the preferred method despite continuing difficulties. For example, the same ceramic vessel from Burial 47 of EP III, the earliest Bronze Age phase at the site, has yielded a result of 4810 ± 90 BP (OxA-6069) on the basis of Treatment B, and 2910 ± 90 BP (OxA-5065) under Treatment A. White's six selected and published determinations from the mortuary vessel fabric are those undertaken on Treatment B, the one which invariably furnishes the earlier date. There is, in our view, only one course of action when confronted with such problems: set the technique aside and explore a reliable alternative.

This policy has the support of virtually all specialists in the field of AMS dating where ceramic fabric is concerned. There are several possible sources of carbon within the fabric of the pot, or present occasionally as surface residues. Often the sherd itself is of low carbon, which means that a larger than usual amount of material is required for a direct date. The clay matrix might contribute old carbon to the material being dated, while the smoke and soot generated when a pot is being fired can be absorbed into the temper. Clearly, if old wood is used in the firing process, the resulting determination can be too early (Bonsall et al. 2002; de Atley 1980). When dating ceramics from Europe, Thailand and China, Hedges et al. (1992) concluded that the results were unreliably early due to the presence of carbon from the clay incorporated during riverine transportation and deposition. As Rice (1987, pp. 438–439) has noted, secondary clays can comprise up to 15% by weight of carbon, which could come from sources derived from essentially any period prior to their inclusion in the clay matrix. Manning et al. (2011, p. 317) have demonstrated in Mali that direct pot fabric radiocarbon dates 300–400 years older than OSL dates on the same sherd. As Berstan et al. (2008, p. 702) note: ‘Direct radiocarbon dating of pottery is relatively uncommon due to the presence of carbon sources with differing ages, for example geological carbon remaining in the clay after firing, added organic temper, carbon from fuel in the kiln and exogenous contaminants absorbed from the burial environment.’

In an experiment comparing four such determinations with the generally accepted chronology for the later Iron Age in Northeast Thailand, at least three were too early by several centuries (Higham et al. 2010). Again, Kuzmin et al. (2001) have shown that a stepped combustion temperature of 400°C produces a much younger date, on the same sherd, than a temperature of 800°C. This is because temper-derived carbon tends to be preferentially removed with a lower temperature combustion than the carbon bonded within the clay fraction. For this reason, Kuzmin (2002) has suggested that the most reliable carbon fraction is obtained using the lower temperature combustion. The Oxford laboratory has always combusted samples for AMS dating at 900°C.

The oldest determination published by White comes from a sample of phytoliths found within a ceramic vessel (White 2008). The methods used to isolate the phytoliths are based on those outlined by Mulholland and Prior (1993). Again, the challenge in dating this material lies in the extremely low levels of carbon that are present ($\leq$1% C by weight). This means that, like the ceramic temper, small amounts of exogenous carbon can deleteriously affect the results. Recent research has shown that there are significant and unresolved problems in radiocarbon dating this material. Santos et al. (2009) have undertaken the most extensive experimental testing of the reliability of this technique and material. They found that dates of three modern samples of recently harvested phytoliths were compromised by old carbon from an unknown source. They suggest that only one sample of phytolith carbon dating to the post 1950 period has ever been dated to check accuracy. There are no published data from the last two decades showing reliable ^{14}C results obtained from modern, independently dated plants. This is a prerequisite for the acceptability of a novel sample material. Attempts to compare phytolith radiocarbon ages with independent chronologies have also shown significant problems, thought to be related to the methods used in the phytolith extraction process. Clearly, this material is not, at present, a reliable one for independent age determination and much further work is required to demonstrate the reliability of techniques for dating samples of unknown age (Santos et al. 2009). The evidence suggests that, in the absence of corroborating chronometric evidence, a potsherd temper or phytolith date should be viewed sceptically, and at best seen as a *terminus post quem.*

A New Series of Dates

White and Hamilton's model is based on dating techniques of questionable reliability. Under these circumstances, and in order to test their model further, we have obtained a new series of radiocarbon determinations from Ban Chiang. Bone is an ideal candidate for dating, because collagen, which is almost always the target for radiocarbon dating, is chemically characterisable. In Oxford, gelatinization followed by an ultrafiltration protocol is applied to extract purified collagen that is reliable for AMS dating (Bronk Ramsey et al. 2004; Higham et al. 2006). One advantage of dating collagen is that, by using a suite of analytical parameters and considering the yields obtained from the bone, it is possible to assess the structural integrity of the collagen, and its preservation state. In Southeast Asia, dating bone is extremely challenging because of the low preservation of the protein. Collagen diagenesis is intimately linked with the thermal history of the bone, as well as the site pH, microbial and bacterial activity. In previous work we have found that collagen rarely survives in Thai sites, and where it does, it is in a low proportion.

Prior to dating, we identified suitable bone for analysis from Ban Chiang by measuring the percentage of nitrogen in whole bone from animal skeletons placed with the dead as mortuary offerings, and from a carefully selected set of human bones from Neolithic and Bronze Age contexts that span the introduction of copper-base metallurgy at this site. The results of the pre-screening are shown in Table 2. Samples of bone containing <0.76% N and C:N atomic ratios above 5–6 are usually not dated (Brock et al. 2010). In this case the bones average 0.8% (modern bone contains 4–4.5% N), which indicates poor preservation. Nevertheless, we were able to isolate several bones with values above 1%, and these were taken for full collagen pretreatment using the Oxford Radiocarbon Accelerator Unit (ORAU) ultrafiltration protocol, and AMS dated. Some of the bones were <1% wt collagen, which is the lower limit for reliability in Oxford, but the yields themselves were all >5 mg, and the other analytical parameters measured were acceptable (e.g. the C:N atomic ratio), so the results are likely to be accurate. The new determinations are set out in Table 2 and Fig. 5. Calibration is undertaken using the Reimer et al. (2009) INTCAL09 calibration curve and the OxCal 4.1 software (Bronk Ramsey 2009).

The 1974 and 1975 seasons at Ban Chiang involved two separate parts of the site. In the former, a set of Neolithic burials was encountered, attributed by White to EP I and II. The other part of the site revealed a Bronze Age cemetery, followed by Iron Age occupation and graves. The earliest dated context in the site is early Neolithic Burial 44 of EP I. The result obtained suggests an age for the initial Neolithic occupation of the site between 1608 and 1442 cal. BC (the 95.4% probable range for this AMS date). The remaining burial determinations come from graves of EP II, II–III, III, IV and V. The later Neolithic EP II falls within the 14th to 11th centuries BC. Burial 72 is a critically important grave, because White has drawn attention to the presence of a 'flat piece of bronze at base of this basal BCES grave' (White 2008, p. 97). Her determination, based on a crushed potsherd, is 1973–1616 cal. BC. The result from the human bone corresponds with a calibrated age range of 1026–900 cal. BC. Burial 76 is also vital, since it contained what has been described by White and Hamilton as 'the earliest metal grave good recovered, a socketed spear point'. They claim that this 'comes from the lower Early Period level with dates around 1800 BC' (White and Hamilton 2009, p. 362). Although they did not have any

Table 2 New radiocarbon determinations from Ban Chiang

OxA/OxA-X-	Sample	Species	CRA BP	Calibrated age (95.4% prob.)	Used (mg)	Coll.yield (mg)	% yield	% C	d13C	CN
22378	BCES burial 29 EPV	*Sus scrofa*	2965 ± 29	1,302–1,057	1,250	16	1.3	44.7	−20.9	3.4
22380	BCES burial 56 EPV	*Sus scrofa*	2516 ± 26	790–541	1,210	8.87	0.7	44.5	−19.4	3.2
22383	BCES burial 54 EPIV	*Sus scrofa*	2819 ± 26	1,045–907	1,450	23.9	1.6	45.2	−19.6	3.1
25018	BCES burial 65 EPIII–IV	*Homo sapiens*	2844 ± 26	1,113–921	1,170	19.5	1.7	44.2	−18.9	3.2
24047	BCES burial 76 EPIII	*Homo sapiens*	2868 ± 26	1,128–936	620	6.07	1	43.2	−18.3	3.2
22381	BCES burial 47 EPIII	*Sus scrofa*	2786 ± 26	1,007–846	1,070	5.5	0.5	44.8	−19.1	3.1
2436–53	BCES burial 47 EPIII	*Homo sapiens*	2936 ± 25	1,260–1,049	1,020	2.5	0.2	43.1	−18.9	3.3
25016	BCES burial 49 EPIII	*Homo sapiens*	2789 ± 26	1,009–848	2,130	42.5	2	41.6	−18.3	3.2
25017	BCES burial 49 EPIII	*Homo sapiens*	2801 ± 25	1,018–860	650	20.4	3.1	43.4	−18.3	3.2
25019	BCES burial 72 EPII–III	*Homo sapiens*	2810 ± 25	1,026–900	1,190	20.33	1.7	42.4	−18.4	3.2
25014	BC burial 43 EPII	*Homo sapiens*	2984 ± 26	1,313–1,125	960	8.5	0.9	44.6	−18.3	3.3
2438–16	BC burial 45 EPII	*Homo sapiens*	2958 ± 29	1,290–1,055	2,200	2.11	0.1	41.1	−18.5	3.3
2438–17	BC burial 47 EPII	*Homo sapiens*	2978 ± 31	1,371–1,114	1,260	4.15	0.3	42.9	−18.0	3.3
25015	BC burial 44 EPI	*Homo sapiens*	3242 ± 26	1,608–1,442	950	11.11	1.2	45.7	−18.3	3.2

All determinations are of ultrafiltered gelatin after Higham et al. (2006). Radiocarbon ages are conventional radiocarbon ages (CRA) expressed in years BP after Stuiver and Polach (1977). Stable isotope ratios are expressed in ‰ relative to vPDB. Mass spectrometric precision is ±0.2‰. *Used* is the amount of bone pretreated in milligrams and the *Coll.yield* represents the weight of gelatin or ultrafiltered gelatin, also in milligrams. *% yield* is the wt% collagen (the amount of collagen extracted as a percentage of the starting weight). *% C* is the carbon present in the combusted gelatin. For ultrafiltered gelatin this averages 41.0 ± 2%. *CN* is the atomic ratio of carbon to nitrogen. At ORAU this is acceptable if it ranges between 2.9 and 3.5. Radiocarbon ages are calibrated using the Reimer al. (2009) curve and shown at 95.4% probability

BC: burials from the 1974 season, BCES: burials from the 1975 season direct date estimate for this adult male burial, we have obtained a direct AMS radiocarbon determination for the human bone corresponding to a calibrated age range of 1128–936 cal BC (95.4% prob.). The remaining determinations for EP III, which represents the early Bronze Age at Ban Chiang, fall in the 9th to 10th centuries BC. The result for human bone from Burial 47 (1260–1049 cal. BC) comes from a sample with a lower than ideal yield of collagen, and compares with a determination on pig bone from the same burial of 1007–846 cal. BC. Thereafter, Burial 65 of EP III–IV is dated to 1113–921 cal. BC, Burial 54 EP IV has been dated, also by reference to a piece of pig bone in the grave, to 1045–907 cal. BC, and for EP V we have two determinations of 1302–1057 cal. BC and another of 790–541 cal. BC. The former appears to be an outlier in comparison with the other data points. We also obtained a result of 790–540 cal. BC for a bovid bone from a possibly early ceramic vessel, for which we have no information on its form or possible cultural context.

This new chronological framework precedes any final publication of the 1974–1975 excavations at Ban Chiang, other than the comprehensive report on the human remains (Pietrusewsky and Douglas 2002). It is therefore a necessary foundation for the detailed consideration of the site in the wider context of Southeast Asian prehistory.

Evaluating the New Chronology

One means of evaluating further the reliability of this new chronology for Ban Chiang is to compare it against other relevant dated sites. We begin by assessing evidence from the Neolithic settlements in Southern China and Southeast Asia, since by definition they predate the establishment of bronze metallurgy in their respective areas. We then consider the chronologies for sites which evidence the presence of copper-base metallurgy. This is not straightforward, and two of us have already suggested that earlier attempts at chronometric dating should be viewed with the greatest caution (Higham and Higham 2009). The problem turns on the impossibility of eliminating inbuilt age of the charcoal so commonly used in radiocarbon dating unless the species has been identified as short-lived. Since virtually no series of determinations meets this prerequisite, we treat charcoal-based chronologies as indicating at best the date after which an event would have occurred. This same stricture applies to chronologies derived from the dating of ceramic tempers (see discussion above). Following this, we provide a detailed review, based on original site reports in Chinese, of the technology and the timing for the spread of bronze casting into Southern China and beyond into Southeast Asia. Where White and Hamilton (2009, p. 378) fail to find an origin for the bivalve mould casting typical of the Southeast Asian tradition in Chinese state societies of the 2nd millennium BC, we find overwhelming evidence for this casting tradition within a coherent chronological framework that supports a late 2nd millennium BC date for the inception of the Southeast Asian Bronze Age.

The Neolithic in Southern China and Southeast Asia

There are two models for the timing of the Neolithic period in Thailand, reflecting divergent opinions on the chronology and the pottery style diagnostic of the Neolithic material culture (Higham 2011a). The first is based on the recently published AMS dates of organic temper pottery from Ban Chiang (White 2008), combined with the interpretation of the archaeological stratigraphy at Ban Mai Chaimongkol (Fig. 2; Onsuwan 2000; Onsuwan Eyre 2006). This model holds that the Neolithic in Thailand began well before 2100/2000 BC (White 2008, p. 97, fig. 3; Onsuwan Eyre 2006, p. 339). In support of this contention, White (1997) has referred to a series of dates obtained from a pollen core taken from Lake Kumphawapi. Pollen evidence indicates burning episodes beginning in the late Pleistocene, one of which, a metre from the top of the core, has been dated in the 5th millennium BC. White has suggested that this was associated with Neolithic forest clearance. Burning of the dry, deciduous dipterocarp forest in this region, however, is a regular occurrence at the end of the dry season as lightning heralds the onset of the monsoon. Moreover, it is well known that burning is widely undertaken by hunter-gatherers in Southeast Asia in order to freshen grass growth and attract game. We believe this is not particularly robust evidence from which to infer the presence of rice cultivation and Neolithic settlement. The second model is based on the newly published chronology for the Ban Non Wat and Ban Lum Khao sites (Higham 2005; Higham and Higham 2009; Higham and Kijngam 2009, pp. 17–25), combined with the recently revised chronology of the Neolithic layers at sites in Lopburi Province in central Thailand (Rispoli et al. 2009, 2010, in prep.) and on the chronology of Khok Phanom Di, on the former estuary of the Bang Pakong River (Higham and Bannanurag 1990). Based on the data available from these sites, the Neolithic period was under way by the early 2nd millennium and ended in the 11th century BC (Fig. 7).

Archaeological, linguistic, and palaeobotanical data unanimously point to a southward dispersal of agriculturalists from the Yangtze Valley that first reached the river systems of Southern China and then penetrated the river valleys of mainland Southeast Asia (Bellwood 2005; Diamond and Bellwood 2003; Higham 2002, 2005, 2006; Higham and Lu 1998; Rispoli 2007; Zhang and Hung 2007, 2010). In the mid-lower Yangtze River valley, between 8000 and 5000 BC, the sequence from cultivation to pre-domestication rice production (Fuller et al. 2007, 2010; Fuller and Qin 2009; Zhang and Hung 2010) is well attested at the Pengtoushan-Zaoshi lower level phase sites on the shores of Dongting Lake (HSWKY et al. 1990; Crawford and Chen 1998, p. 861; Pei 1998), as well as at the Shangshan–Kuahuqiao phase sites, in Zhejiang Province (Zhejiang Sheng et al. 2004; Jiang and Li 2005, 2006). By the end of the 5th to the early 4th millennium BC, agriculture is documented by the discovery of paddy-field systems connected by canals and reservoirs at the Majiabang–Songze sites at Caoxieshan and Chuodun (Gu 2003; Tang 2003) in Jiangsu Province, soon followed by evidence from the Qujialing–Shijiahe culture sites (c. 3400–2000 BC) in the middle Yangtze River region in Hubei and Hunan, and from the Liangzhu site-complexes (3400–2000 BC) in the area of the Yangtze River delta. In the upper Yangtze River valley (southwest China), the earliest evidence of agriculture (^{14}C dated: 3500–2500 BC) has been found at Karuo (Qamdo/Changdu County), in the easternmost fringe of the Himalayas, at an altitude of about 4,300 m above sea level (Xizang et al. 1985).

Here, milling stones and reaping knives in association with remains of millet (*Setaria italica* (L.) P. Beauv.), witnessed the practice of agriculture, associated with domestic pig raising, most probably attributable to an expansion of Neolithic agriculturalists from the Gansu region (Rispoli 2007, p. 285). Slightly later (2500–1500 BC), the first evidence of rice in southwest China has been recovered at sites of the Baodun Culture (Chengdu Shi et al. 1999, 2002; Sun 1992; Wang and Sun 1999; Zhongguo Shehui Kexueyuan et al. 1991), in the Chengdu Plain (Sichuan Province), as well as in Yunnan, at sites of Baiyangcun type in the Dali Basin/Erhai Lake region. From the mid-lower Yangtze River valley—the core area of rice domestication—Neolithic groups spread towards southeast and southwest China (including the belt formed by the present day Yunnan–Guizhou Plateau and Guangxi/Guangdong Provinces) between the 4th and the 3rd millennium BC and later to Southeast Asia.

The Chronology of the Southeast Asian Neolithic

As noted above, we must seek harmony in the chronological contexts between the donor and recipient, and document a similar set of technological practices. One of the main differences between the two models concerning the beginning of the Neolithic in Southeast Asia is the chronology of the incised and impressed (I&I) pottery style. White contends that 'the Ban Chiang evidence indicates that this pottery style, at least in some phases of use at some sites, is contemporaneous with copper-base metallurgy' (White 2008, p. 99) and, on the basis of AMS dating, attributes it to 2032–1526 BC (White 2008, p. 96). Eyre, being aware that there should be an 'Initial Phase' preceding the advent of metal in most of the excavated sites in central Thailand (Onsuwan Eyre 2006, p. 158), mainly on the basis of two controversial typological comparisons (Onsuwan Eyre 2006, p. 147, fig. 5.60, p. 132, fig. 5.54) and of stratigraphic analyses, defined the I&I pottery style as the 'time-specific ceramic attribute' of the Lower–Middle Bronze Age (Onsuwan Eyre 2006, p. 338).

The second model is based on the fact that the I&I pottery style has never been found in association with metal. Moreover, this style, at least in Thailand, suddenly disappeared with the advent of the copper-base metallurgy (Rispoli 2009). During the 2nd millennium BC the I&I pottery style was very popular across a wide area comprising Thailand, Cambodia and Vietnam. Such a widely shared technical and stylistic heritage sustains Rispoli's hypothesis for a 'Southeast Asian Interaction Sphere' (Rispoli 2007, p. 281). The I&I pottery style actually matches the routes already described for the spread of agriculturalists, appearing first in the Zaoshi Lower Level (c. 5700–5500 BC), Daxi Lower Level (c. 5500–5000 BC) and 'classic' Daxi (c. 4900–3100 BC) in the Dongting–Poyang Lakes area (middle Yangtze Valley). Later on, cardial pottery decoration of a comparable type (in terms of technology and decorative style) is present at sites of Chao'an type (Chao'an County, Guangdong Province) dating to c. 5500–4500 BC, and then in archaeological assemblages spread from Southern Fujian to the Hong Kong region, such as Fuguodun and Keqiutou (Fujian Province), dated to c. 4000–3000 BC. Slightly later, the I&I decorative style is present in coastal Guangdong at Xiankezhou, Xiantouling, Dahuangsha, Baojingwan and Haifeng (Rispoli 2007, p. 287). During the first half of the 3rd millennium BC, I&I pottery decoration appears for the first time in Yunnan, at the island site of Yinsuo (Haidong Prefecture) in Lake Erhai (Yunnan Sheng et al. 2009c, p. 27); between the late 3rd and the first half of the 2nd millennium BC, the I&I pottery, together with domesticated rice, is documented at Baiyangcun, Dadunzi and Mopandi, and in the Xinguang Culture sites in the western part of the Dali basin (Rispoli 2007, p. 284). This decorative style, on the basis of its structural and technological characteristics, as well as of its chronological range, can be stylistically compared to the I&I pottery of mainland Southeast Asia, thus representing the best candidate for the prototype of this distinctive 2nd millennium BC Southeast Asian pottery style. All these latter sites post-date 2500–2000 BC.

The Neolithic in Southeast Asia

One means of testing White and Hamilton's early chronology for the Bronze Age at Ban Chiang is to examine the dates of Neolithic sites in China and Southeast Asia. It is stressed that the vast majority of radiocarbon determinations come from unspeciated charcoal. As already stated, we regard such dates, in which inbuilt age is an unknown, as *terminini post quos*; if later than 2000 BC, they would not support the early model. The first site to be examined is Khok Phanom Di, located on the nodal former estuary of the Bang Pakong River (Higham and Thosarat 2004). It is a site of considerable complexity that is often misunderstood. White and Hamilton, for example, assume that it was contemporary with Bronze Age Ban Chiang, and that the complete absence of bronze artefacts there indicates that 'some villages were part of a circuit of production and some were not' (White and Hamilton 2009, p. 370). This is a remarkable suggestion, when it is considered that Khok Phanom Di could hardly have been located in a more strategic position for exchange and contact with other communities. The shell ornaments from this site, for example, are precisely mirrored by those from sites in the Lopburi region that were in due course to become a centre of copper mining, including the production of metal ingots. Again, the stone used for tools from Khok Phanom Di has been sourced in a wide hinterland (Pisnupong 1993), and Vincent (2003) has identified exotic ceramics that reached the site through exchange. Bentley et al. (2007), via the stable isotope analysis of skeletal remains, have even found that some women in the third mortuary phase came to the site from a quite different environment. If copper items were circulating in exchange networks during the occupation of this site, they would surely have reached it. But through three excavations in different parts of this site, not one fragment of metal has been found.

Khok Phanom Di is a deeply stratified mound covering about 5 hectares. It has been dated on the basis of mixed charcoal samples derived from in situ hearths. Each is now seen as a *terminus post quem* for the layer in which it was found. The re-evaluation of these determinations using Bayesian methods, with provision for the likelihood that the charcoal dates have inbuilt age, reveals that the site was initially occupied in the 19th or 18th century BC and that the same community lived there for about five centuries (Fig. 7). Since the mound accumulated very rapidly, due largely to the deposition of shell middens, we think that the human burials there accumulated directly over their predecessors for about 17 generations (Higham and Thosarat 2004).

Although the sea level rose and fell during the five centuries of occupation, for the most part the inhabitants lived in an environment dominated by mangroves (Thompson 1996). During the first three phases of occupation, the biological evidence supports the presence of a marine hunter-gatherer-fisher community. There is no evidence for rice agriculture or domestic animals. The occupants suffered very high infant mortality, probably due to the prevalence of thalassaemia, an anaemic condition that provides resistance to malaria (Tayles 1999). It is suggested that these people were descended from those adapted to marine hunting and gathering for millennia along the shores of the drowned continent of Sundaland. They made fine ceramic vessels quite unlike those of the inland Neolithic sites, and used polished stone adzes. With phase 3B, dated after about 1700 BC, we find a series of significant changes. The sea level fell and freshwater indicators rose strongly. The strontium isotopes in the human teeth indicate that it was at this point that some women came to the site from elsewhere (Bentley et al. 2007); at this point we find shell reaping knives and granite hoes being used, and the remains of domesticated rice in human stomach contents and faeces. Clearly rice cultivation had reached Khok Phanom Di at or after the 18th century BC. Shortly afterwards, the sea level rose and the community reverted to marine hunting and gathering. The inhabitants were heavily involved in exchange for stone, marine shell and ceramics (Vincent 2003), but occupation was too early for involvement with bronze.

Ban Kao is a Neolithic settlement and cemetery in Kanchanaburi, excavated in the early 1960s by Sørensen (Sørensen and Hatting 1967), who obtained radiocarbon determinations relating to both the Neolithic phases. These indicate settlement within the first half of the 2nd millennium BC or slightly later (Fig. 8). This is confirmed much further south in

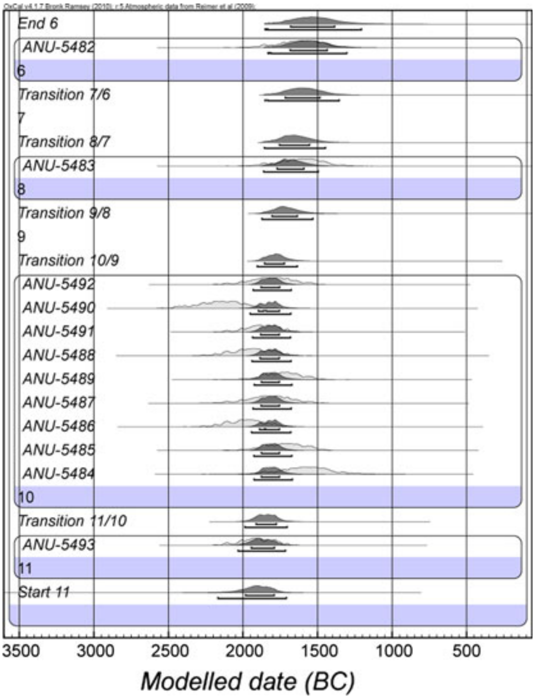

Fig. 7 The calibrated radiocarbon determinations and spans based on charcoal from Khok Phanom Di, following the application of an outlier model specific to charcoal determinations, which gives an exponential tail to the data, saying effectively that it is more likely to be older than younger (Bronk Ramsey 2009)

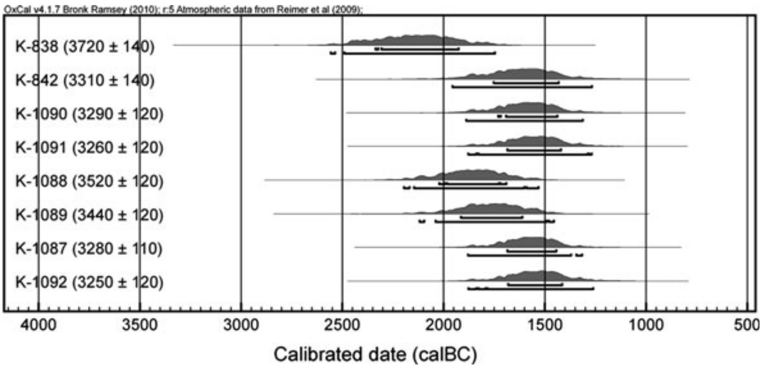

Fig. 8 The radiocarbon determinations based on charcoal from the Neolithic site of Ban Kao. The earliest context is at the top of the illustration

Malaysia, where similar pottery vessels recovered from Jenderam Hilir are dated by AMS radiocarbon determinations on charcoal to 2207–1866, 1456–1191 and 1406–1031 cal. BC, respectively (Leong 1991). Khok Charoen is a Neolithic site in the central Thai Pasak Valley. No bronze was found in any of the 44 burials recovered. Some of the ceramic motifs are matched at late Khok Phanom Di and Neolithic 1 Ban Non Wat. There are no radiocarbon determinations from this site, but two TL dates are 1480–800 and 1380–780 cal. BC (Ho 1984).

The Neolithic Period in central Thailand, comprising the Takli Undulating Terrain, the Khao Wong Prachan intermontane valley and the course of the lower Lopburi River, demonstrates initial human occupation in the lacustrine margins of the Lopburi river system by the beginning of the 2nd millennium BC. This occupation is evidenced mainly in the basal layers of Tha Kae, Non Pa Wai, Khok Charoen and Sab Lamyai; this latter site was previously known and published as Sab Champa II (Lertcharnrit, pers. comm.).

At Tha Kae, Neolithic material culture is mainly characterized by ceramic vessel types and ornaments excavated from the graves. The ceramic vessel typology is characterised by simple contours, consisting of pedestalled hemispherical/conical bowls and ovoid jars with surface finish made by cord-marks and/or a rather thick red burnished slip. The decorative style comprises I&I geometric and meandering motifs and simple to complex geometric red painted designs (Rispoli 1997, pp. 67–71; 2007). In the grave goods, ceramic containers of this type are associated with personal ornaments (small disk-shaped shell beads) and the ritual deposition of freshwater bivalve shells. Despite the lack of ^{14}C dates for Neolithic contexts at Tha Kae, this assemblage finds comparisons with similar ceramic containers excavated at Non Pa Wai, Ban Kao Early Period (Sørensen and Hatting 1967, pp. 61–62, pls. 62, 94, 55/A1); Sab Lamyai (Veraprasert 1982, pp. 124–125, figs. 193–194); Khok Phanom Di (Hall 1993, p. 101/g 3, p. 17, 255; Vincent 2003, p. 350); Ban Chiang Early Period (White 1982, p. 59); Ban Non Wat Neolithic 1 (Higham and Kijngam 2009, p. 158, 207); and with most of the I&I pedestalled bowls found at Khok Charoen (Ho 1984, fig. 3.14/1–2). Moreover, the Tha Kae I&I pottery style can be compared with decorative motifs documented at Samrong Sen in Cambodia (Ho 1984, fig. 9.8c) as well as at sites of the Phung Nguyen Culture in northern Vietnam (Ha Van Tan 1997, p. 650) and of the Xinguang Culture in Yunnan (Yunnan Sheng et al. 2002). Relying on these comparisons, the Neolithic Period at Tha Kae has been assigned to a time span between 1800/1700 and 1100 BC.

Sab Lamyai is a small site strategically located to control the mountain passes between central Thailand and the Khorat Plateau, in the vicinity of the modern village and c. 2 km south of the well-known moated site of Sab Champa. A limited excavation in 1971 identified a Neolithic cemetery and a metal age occupation floor (Lertrit et al. 2001; Lertrit 2004; Maleipan 1979; Veraprasert 1982). The Neolithic occupation is represented by 17 burials that may be tentatively divided into two phases: an earlier phase represented by a single flexed burial, comparable to the flexed burials recently excavated at Ban Non Wat, with no grave goods; and a second phase characterized by 16 extended burials accompanied by fine I&I pottery style jars—most of which are closely comparable to Non Pa Wai, Tha Kae and Khok Phanom Di—small stone adzes, and 'blades made of fresh water shell' (Maleipan 1979, p. 340), which might be recognized either as reaping knives similar to the ones found at Khok Phanom Di or as decayed shells deposited as ritual offerings. Despite the absence of any radiocarbon determinations from this layer, the artefact inventory and the comparanda just mentioned indicate that the Neolithic period at Lamyai probably falls between 1800/1700 and 1100 cal. BC.

Non Pa Wai is a c. 5 ha site with a depth of 4 m, located in the amphitheatre of the Khao Wong Prachan Valley, northeast of the city of Lopburi. An area of c. 350 m^2 was excavated in 15 operations in 1986 and 1992 (Pigott et al. 1997). Excavation of the main mound yielded 25 burials datable to the Neolithic and Bronze Age 1, 2 Periods, between the early 2nd and the mid-1st millennium BC. The Neolithic cemetery to the northwest, the so-called 'Non Pa Wai Outlier', yielded 27 burials. These graves are characterized by single, extended inhumations accompanied by pottery decorated with a thick red burnished slip and I&I decorative motifs arranged to form simple to complex designs on the shoulder and/or the body of the pot, associated with personal ornaments including marble disk-shaped pendants, disk- and H-shaped shell beads, and small polished stone adzes. Freshwater bivalve shells positioned on the body and/or on the eye were included in the grave goods with probable ritual significance. The pottery typology finds strict comparisons both in its shape and in the I&I decorative motifs with the ceramic containers excavated in a number of sites, as recently documented in Rispoli (2009), Rispoli et al. (2010, in prep.). These include: Sab Lamyai (Veraprasert 1982, p. 124, figs. 190–192), Huai Yai (Natapintu 1988, p. 116) and Tha Kae (Siripanish 1985, p. 126). The complex I&I designs—but not the forms—are comparable with those from Khok Charoen, Type 10 (Ho 1984, fig. 3.2); Ban Kao, Early Period Type 10, Burial 35 (Sørensen and Hatting 1967, p. 54, plates 55, 102); Ban Non Wat (Higham 2004, p. 26, fig. 7); and Non Nok Tha (Solheim 1980, p. 38, plate VIIb); as well as from the Phung Nguyen Culture sites in north Vietnam, such as Go Bong and Xom Ren (Ha Van Tan 1997, pp. 553–554, p. 556, figs. 27, 31). In southwestern China these I&I designs are comparable with those found at Neolithic sites of the Baiyangcun cultural type in Yunnan, namely Dadunzi (Yunnan Sheng Bowuguan 1977, p. 66, n.5) and Mopandi (Yunnan Sheng et al. 2003, p. 287 n.9), both in the area of Erhai Lake/Dali Basin. These comparisons allow us to assign the Neolithic occupation at Non Pa Wai to between 1800/1700 and 1100 BC (Rispoli et al. 2009, 2010, in prep).

The Khorat Plateau

Two sites in the Mun Valley of northeast Thailand have provided evidence for the chronology of the Neolithic occupation there. The most comprehensive dating programme so far undertaken centres on the site of Ban Non Wat (Higham and Higham 2009; Higham and Kijngam 2009). This large, moated settlement has at least 12 prehistoric phases of occupation. These begin with a set of flexed burials that might represent an indigenous hunter-gatherer group. There are two Neolithic phases, the later of which developed seamlessly into Bronze Age 1. A total of 76 radiocarbon determinations from in situ charcoal and the freshwater shells placed as offerings with the dead have been analysed within a Bayesian model (Fig. 9). The problems inherent in unspeciated charcoal dates are clearly illustrated by two determinations from Burial 28, a man interred within a large lidded jar. A piece of charcoal found near the cranium is dated to 2150–1935 cal. BC, while a bivalve shell near his hands is dated to 1499–1407 cal. BC, an offset of six centuries. In a situation where initial Neolithic settlers were felling the prime forest, the possible burning of old wood cannot be ruled out. The overall results for Ban Non Wat reveal that the initial Neolithic settlement began in the mid-17th century BC and lasted around 150 years, while the Neolithic 1 burials date from about 1460 cal. BC, and lasted for two generations or about 50 years. The later Neolithic occupation is dated to about 1400 cal. BC, with a very brief time span. This was followed by Neolithic 2 graves, which are dated to 1259–1056 cal. BC. The transition from the late Neolithic to the Early Bronze Age settlement took place between 1053 and 996 cal. BC.

Ban Lum Khao is located about 20 km to the east of Ban Non Wat (Higham and Thosarat 2005). The earliest phase equates with the Neolithic 2 at Ban Non Wat, and charcoal from pits of this period reveal that the transition into the Bronze Age took place after about 1200 BC (Higham 2005).

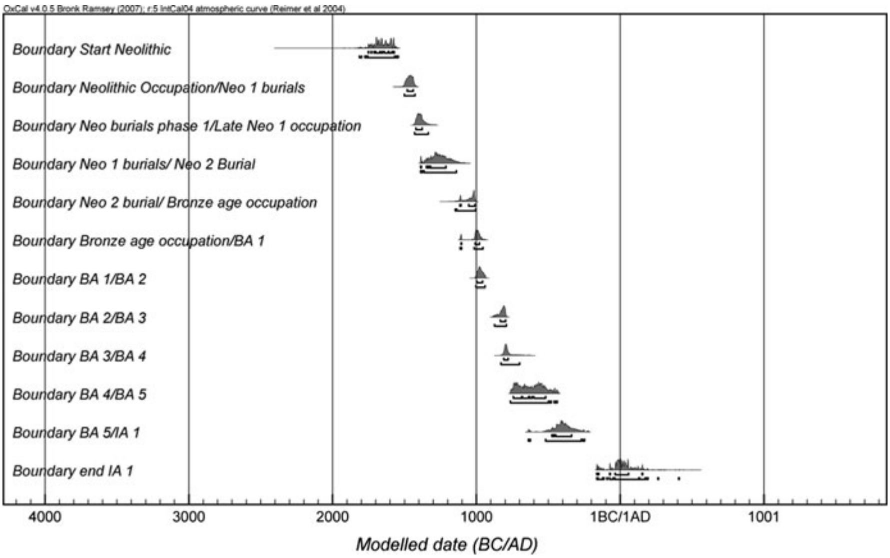

Fig. 9 The boundaries between the successive occupation and mortuary phases at Ban Non Wat, based on 76 radiocarbon determinations from charcoal and freshwater shell

Two sites in the northern part of the Khorat Plateau have furnished evidence for Neolithic settlement. At Ban Chiang, a few Neolithic burials were found during the 1974 season. Since the charcoal-derived dates fail to provide a clear pattern, White (2008) has obtained two determinations from rice chaff temper obtained from EP II burial pots: 2050–1500 and 2190–1880 cal. BC. We have dated EP I and EP II Neolithic burials on the basis of human bone. The earliest context, EP I burial 44, is 1608–1442 cal. BC, and the EP II burials 43, 45 and 47 are respectively 1313–1215 cal. BC, 1290–1055 cal. BC and 1371–1114 cal. BC. It is suggested that the Neolithic occupation of this site dates from the 16th (at the earliest) to the 11th centuries BC. This provides a good parallel with Ban Non Wat. The chronology of the second site, Non Nok Tha, remains in limbo. The charcoal determinations come from very small samples assembled largely from grave-fill and have no scientific credibility. A second attempt to date the site on the basis of chaff-tempered potsherds from occupation layers is barely more credible, and given the unreliability of such dates, each must be seen at best as a *terminus post quem* later than the first half of the 2nd millennium BC.

Vietnam

An Son is a central site for evaluating the chronology of the Neolithic settlement of southern Vietnam. This large and deeply stratified mound is strategically located near the mouth of the Mekong River. It cannot by any measure be seen as remote from either coastal or riverine communication and trade routes. The Neolithic sequence of occupation covers three phases in four metres of cultural layers (Masanari and Nguyen 2002). The decoration on the ceramic vessels falls clearly into the Southeast Asian Neolithic tradition of I&I designs. Despite the large area of the site opened during the course of several seasons, no bronze has been found. The associated radiocarbon determinations from charcoal suggest that initial occupation took place after the mid-3rd millennium BC. A recent series of determinations from human tooth enamel indicate that the site was occupied until about 1000 BC (Bellwood pers. comm.; Oxenham pers. comm.). This appears to be a good match with the Neolithic chronology at Ban Non Wat.

In the general region of the Red River valley, the Neolithic occupation seems to fall within the 2nd millennium BC. The Neolithic site of Man Bac is certainly later than 1800–1500 cal. BC. The principal Neolithic culture of this nodal area is named after the site of Phung Nguyen. We lack a large sample of well-provenanced dates for the relevant sites. However, a late Phung Nguyen cemetery at Lung Hoa included a burial with an exotic jade *yazhang* blade. These ceremonial jades are found at Erlitou in the Central Plains, and Sanxingdui in Sichuan, and therefore belong to the mid-to-late 2nd millennium BC (Sichuan Sheng et al. 1998b).

In reviewing the chronology of the Neolithic and Bronze Ages in the Red River region, Masanari (2005) has most sensibly dismissed assigning the late Phung Nguyen culture to the early Bronze Age on the basis of a few fragments of bronze from uncertain contexts. In his own words:

> Some Vietnamese regard the Phung Nguyen as a Bronze Age culture, based on a very few uncertain finds of tiny fragments of bronze. In my view however the absence of casting moulds and complete bronze artefacts in Phung Nguyen sites indicates that the Phung Nguyen is actually the final phase of the Neolithic (Masanari 2005, p. 102).

He refers to the radiocarbon determinations from Ma Dong, Trang Kenh and Phung Nguyen that place the Neolithic in this region within the period 2500–1000 BC.

The Neolithic: Summary

There is a growing and consistent body of evidence indicating a series of expansionary movements south from the Yangtze Valley into Lingnan by groups of rice farmers. Fuller et al. (2010) refer to this move as the fifth of several thrusts emanating from this same source. It has been dated to the first half of the third millennium BC. The further expansion into Southeast Asia, presumably by coastal and riverine routes, was underway certainly by the early 2nd millennium BC, and possibly a few centuries earlier. This is seen in the initial Neolithic settlement at Ban Non Wat in the mid-17th century BC, and the evidence for rice cultivation at Khok Phanom Di at about the same time. Neolithic communities in the Lopburi region have been dated at Tha Kae and Non Pa Wai to the 18th century BC. Given this structure, it is held to be unlikely that the Bronze Age at Ban Chiang pre-dates the Neolithic settlement of Southeast Asia.

The Bronze Age in China

Two models for the emergence of copper-base metallurgy in Thailand and, more generally, in Southeast Asia, have been proposed by White and Hamilton (2009), on one hand, and on the other, by Higham (1996), Pigott and Ciarla (2007) and Ciarla (2007b, c). Both models envisage a transmission of the technology of copper-base metallurgy from outside the Southeast Asian region: the first model seeks a direct import—either of the technology or of the actual founders—from the northwest, namely from the Inner Asian Seima-Turbino complex prior to 2000 BC; while the second hypothesizes a southwards transmission of the copper/bronze smelting technology, in the later 2nd millennium BC, from the copper-rich regions of the mid-Yangtze Valley via Lingnan. Recent discoveries of early copper/bronze smelting, radiocarbon dated to the last quarter of the 2nd millennium BC, in the Cang'er region (western Yunnan–Guizhou Plateau), namely at Haimenkou in Jiangchuan Basin (Yunnan Sheng Bowuguan 1995; Yunnan sheng et al. 2009a, b), might hint at a second transmission route towards mainland Southeast Asia. From the physiographic point of view both the Lingnan region and the Yunnan–Guizhou Plateau can be considered the northernmost part of mainland Southeast Asia. The methodological inconsistency of the Ban Chiang AMS ^{14}C determinations provided by White and Hamilton (2009) to sustain the inception of the Southeast Asian Bronze Age at the very beginning of the 2nd millennium BC has already been demonstrated. However, one cannot avoid noticing that the date of the 'Seima-Turbino trans-cultural phenomenon' in the late 3rd millennium BC, on which White and Hamilton built their model, is still debated, and in White and Hamilton (2009, p. 381) it is based on the single radiocarbon date from Hanks et al. (2007, p. 360). Chernykh, however, proposed a date 'roughly between the 16th and the 14th century BC' (1992, p. 194). Although Chernykh's dates most probably need to be revised in the light of new data and radiometric determinations, a similar chronological range is considered valid by Frachetti (2008, p. 52), who dates the 'Seima-Turbino complex' to c. 1900–1700 BC, while Shelach (2009, p. 129) is closer to the dates c. 15th to 14th centuries BC proposed by Chernykh. Therefore, from a chronological point of view, there is little ground for anchoring the beginning of the Southeast Asian Bronze Age to a long distance, direct transmission from the bronze cultures of the Eurasian steppes. Rather, one can envision a long-term, extended process of gradual dissemination of bronze working and its associated tool-kit, off the steppes and into China proper, filtering ultimately into Southeast Asia via Lingnan, as argued most recently by Ciarla and Pigott (Pigott and Ciarla 2007; Ciarla 2007b, c). White and Hamilton (2009), although their model is clearly at risk based on arguments advanced here, have outlined the fundamental, anthropologically defined cultural processes by which such a dissemination of technology could have transpired. At the same time, an alternative to their proposal can be considered. The direction of the transmission of certain technological traits from the Eurasian steppe to the eastern and southeastern regions of the Far East could even have been reversed: as Irene Good noted, Zdanovich 'sees eastern (Chinese) metallurgical influences in the socketed bronzes of the early 2nd millennium BC Seima-Turbino-Samus culture', however, Good also accepts the dating of the Seima-Turbino-Samus culture to the late 3rd millennium BC, as proposed by Parzinger and Boroffka (2003) (Good 2010, p. 30).

Testing between the two models must incorporate a detailed review of the evidence for the adoption and spread of copper-base metallurgy in China. Summary efforts to this effect can be found in Higham (1996), Pigott and Ciarla (2007) and Ciarla (2007b, c). This discussion is reviewed and updated in greater detail below. The emergence of early copper-base metallurgy in the 4th–early 3rd millennium BC has been claimed on the basis of isolated metal artefacts excavated from several sites in northern China. In 1954–1957 excavations at the middle Neolithic site of Banpo (Xi'an, Shaanxi Province), one fragment of a flat rod-like metallic artefact was found in the filling of Grave 156. According to XRF qualitative analyses, the rod is composed of an alloy of Cu, Zn, Ni (traces of Fe, Co and Mn) (An 1981, p. 270). At Jiangzhai (Lintong, Shaanxi Province), fragments of two metal artefacts were found from two different Period 1 contexts (Banpo phase): the first on the floor of the semi-subterranean house F29 (^{14}C dated 4020 $\pm$ 110 BC), and the second from the middle layer (Layer 3) of Test Trench 259 (Banpo Bowuguan et al. 1988, p. 149).

According to analysis carried out by the Beijing Institute of Iron and Steel Technology (BIIST), both artefacts have been identified as brass (respectively: 66.54% Cu, 25.56% Zn, 5.92% Pb, and 69% Cu, 32% Zn, 0.5–0.6% S) derived, possibly through repeated smelting, from ores naturally containing copper and zinc (Han and Ke 1988). In 1977 local archaeologists discovered a complete bronze knife at the site of Linjia (Gansu Province) under the northern wall of a badly preserved house floor (F20), dated to the Majiayao phase (c. 2800 BC) of the Majiayao culture (Gansu sheng Gongzuodui et al. 1984, p. 125). This artefact and a few fragments of copper slag from the same site were analysed by the BIIST; a 6–10% tin content was estimated for the knife, while the slag was identified as oxidized remains of a smelted metal containing copper and iron (Beijing Gangdie 1984). Yan Wenming (Yan 1984, p. 37), in his overview of the beginning of copper use in China, also mentioned slag adhering on a potsherd excavated in 1942 at the site of Yanwozhen (Yuci, Shanxi Province). This latter, on the basis of typological comparisons of the artefact inventory, has been assigned to the end of the Yangshao period around 3000 BC. The slag has been subjected to quantitative analysis revealing rather high ratios of Cu (47.67%), Si (26.81%), Ca (12.39%) and Fe (8.00%).

Both Yan (1984) and, more recently, Zhang (2005, p. 66) consider the above-mentioned findings to be evidence of the earliest emergence of metallurgy in northern China, although due to the availability of local zinciferous copper ores, the smelting process of copper-zinc is recognized as possibly unintentional. An (1981) not only considered unintentional these early examples of copper alloys, but rightly also stressed the rather uncertain provenience of, at least, the copper-base artefacts from Banpo and Jiangzhai (An 1981, pp. 270–271; see also Chang 1986, p. 143). As a matter of fact, only the copper–tin knife from Linjia has a secure stratigraphic provenience; as such it was included in the group of 299 copper artefacts from Gansu, Shandong and Shanxi sites dated between 2900 and 1600 BC analysed by the BIIST in the late 1970s (Beijing Gangdie 1981).

Several scholars agree that thus far early copper/bronze artefacts from controlled excavations are limited to contexts datable from the mid-3rd and the first half of the 2nd millennium BC (An 1981, pp. 272—276; Shao 2002; Mei 2004; Thorp 2006, p. 54).

By the late 3rd to the beginning of the 2nd millennium BC, four main centres of copper/bronze metallurgy emerged in northern China (Bai 2003). The earliest (the ‘Northwestern Region’) is represented by several sites distributed from the Gansu–Qinghai Uplands to the western part of the Loess Plateau, in modern Shaanxi Province, and are attributed to the Machang phase (c. 2300–2000 BC) of the Majiayao cultural sequence; the Zongri culture (c. 2500–2000 BC); the Qijia culture (c. 2300/2200–1700/1600 BC); and the Siba culture (c. 2000/1950–1600/1550 BC) (Mei 2004; Bai 2003, pp. 157–158; An 1993). The great majority of the earliest metal artefacts from these cultural areas come from contexts closer to the end of the 3rd millennium BC. The second centre corresponds to the ‘Northern Zone’ (from central/southeastern Inner Mongolia to western Liaoning), where early copper/bronze metallurgy is generally dated to between 1900 BC and 1600 BC in contexts attributable to the Zhukaigou culture [periods 3–4, c. 1735–1565 BC: Bai (2003, p. 158); early and middle phases respectively 1900–1700 BC and 1700–1500 BC: Shelach (2009, p. 19)] in the Ordos region, and to the Xiajiadian Lower Level culture (c. 2200–1600 BC) in the Chifeng region (Inner Mongolia). The third centre—the ‘Coastal Region’—comprises the coastal plains in eastern Henan and the Shandong peninsula, where c. 20 bronze artefacts, a few copper artefacts (awls and scraps), and two (albeit very controversial: Mei 2004, p. 113) brass awls (dated 2405–2300 BC) from Longshan cultural contexts, have been excavated at sites of the Yueshi culture (c. 1900–1600 BC) (Bai 2003, p. 161). In the fourth centre, the ‘Central Plains Region’, from the mid-Wei Valley to the mid-Huanghe

Valley, copper-base artefacts in Longshan contexts are rather elusive but include the well-known copper bell (Cu 97.86%) from Grave M3296 at Taosi, dated 2085 BC, and a bronze scrap (Cu–Sn) from Wangchenggang, dated 1900 BC (Bai 2003, pp. 161–162). A mature copper-base metallurgy in the fourth centre involved abundant remains of copper/bronze tools, weapons, ornaments and vessels in at least five sites of the Erlitou culture (c. 1900–1600 BC), centred between the Yi-Luo drainage and the middle Huanghe Valley (Thorp 2006, pp. 21–61). Of the 45 metal artefacts analyzed from this region, 37 were copper–tin or copper–tin–lead alloys, seven brass and one arsenical copper (Bai 2003, p. 163). While it cannot be ruled out that the first centre might have stimulated the metallurgical developments of the other three, the differences between these areas of early metallurgical production and use point to appreciable trends towards regionalization.

The Machang–Zongri–Qijia–Siba metal artefacts were, in fact, tools, weapons (non-socketed and, in Siba production, socketed) and simple personal ornaments, mostly of pure copper, followed by tin and tin–lead alloys, often containing arsenical copper (Mei 2004, pp. 111–112), cast in open or bivalve stone moulds; finishing by hammering was not the rule. The same assortment of tools characterizes the 'Northern Zone', where at Dadianzi, a Xiajiadian Lower Level site, the use of socketed tools is attested (Bai 2003, figs. 5.1, 5.8–.9, 5.13), while only non-socketed tools and simple personal ornaments are present in the few copper/bronze finds of the Coastal Region.

A dramatic technological change, with accompanying increase in the quantity and quality of the artefact inventory, marks the Central Plains bronze casting, with the discoveries at Erlitou (periods I–III, c. 1900–1700 BC) of several small bronze tools, weapons and five bells (three period II and two period IV) associated with turquoise inlaid bronze plaques (copper, copper–zinc and copper–tin alloys); only by period III–IV (c. 1700–1500 BC) did Erlitou metallurgy start using a copper–tin–lead alloy cast into ceramic piece-moulds to produce ritual vessels of complex shapes that remained the preferential metallurgical set of the Shang founders. Socketed tools/weapons comparable to north and northwestern types are virtually absent in the Central Plains bronzes, although it might be reasonable to expect them, considering the bells excavated at Taosi and at Erlitou are hollow-core cast into bivalve moulds with a central core. However, in the Central Plains Region the use of bivalve moulds with a suspended core for the production of blind deep-socketed implements is unquestionably attested in early Shang contexts (Erligang phase c. 1600–1300 BC), as for example in a 'pick' (*jue*) excavated at Erligang in 1957; an adze (*ben*) excavated at the Xingyang Stadium site in 1976; another 'pick' found in 1974 at Tazhuang (Henan 1981, figs. 78, 86, 100); and a spear point (*mao*) from Tomb M3.8 at Panlongcheng (Zhu 1995, pl. 10.57). A real explosion in the casting of socketed tools and weapons occurred with the inception of the Shang-Yin phase (1300–1045 cal. BC). Such a marked increase of new shapes and functions (Zhu 1995, pls. 4.48–4.50, 4.54–4.59, 10.60) was most likely an effect of the continued contacts and exchanges that the Shang state maintained with the cultures of the Northern Zone Complex, thus linking the agricultural society of the Central Plains to the steppe populations, and, through them, exchange networks and migration routes that extended the length of one of the major tin belts of the Old World, connecting, via steppe and forest zones, Siberia, Central Asia and eastern Europe (see Pigott and Ciarla 2007, p. 80, fig. 6). It is in the rich inventory of the Shang-Yin blind-socketed implements—including several types of spear points and adzes, picks, axes (*fu*), chisels (*zao*), spades (*chan*), shovels (*cha*) and weeding hoes (*nou*)—that strict comparisons can be found with the socketed tools and weapons of the Northern Zone and eventually, through these, with the 'Seima-Turbino' prototypes cited in White and Hamilton (2009, fig. 4), although dated later than 1500 cal. BC (Shelach 2009, pp. 23–33, 128–129). As the comparison between the 'Seima-Turbino' and the Non Nok Tha/Ban Chiang hollow-core cast implements in the model proposed by White and Hamilton is untenable chronologically, as well as morphometrically and typologically,we must look elsewhere for the origin of copper-base metallurgy in mainland Southeast Asia. By the late 3rd or early 2nd millennium BC there is much evidence suggesting contacts between Neolithic societies in the mid–low Yangtze Valley and their counterparts in mainland Southeast Asia, including Lingnan and the Yunnan–Guizhou Plateau, through north–south interaction circuits along the hub of narrow river valleys looping southwards from eastern Tibet towards Yunnan and northern Southeast Asia, as well as along the southern system of rivers radiating out and into the lakes region of the mid–low Yangtze (see Pigott and Ciarla 2007, p. 81, fig. 7).

In our hypothesis, the fully developed metallurgical technology filtered southward along these same interaction circuits. Out of this technology, local communities selected only the components suited to their social structure and specific technological needs. It was this process of transmission that laid the foundation for the 'southern metallurgical tradition' (White 1988). This tradition was based characteristically on a rather limited set of operations and tools: community-based ore-extraction and processing; smelting in crucibles/bowl furnaces; casting into bivalve moulds; and a very limited repertoire of blind-socketed tools (Ciarla 2007b, c, p. 315).

South of the four northern Chinese regions of early copper-base metallurgy discussed above, no evidence exists for metallurgical knowledge prior to the mid-2nd millennium BC. However, rather early evidence of copper-base metallurgical 'experimentation' comes from the late 3rd millennium BC finds at Dengjiawan, one of the many sites of the Shijiahe Culture (c. 2500–2000 cal. BC), located within the large pounded earth enclosure of Shijiahe (8 km^2) in the Jiang-Han Plain. At Dengjiawan, a few pieces of copper slag, several chips of copper ore (including malachite), and one large fragment of a copper tool (possibly a knife) have been excavated (Shijiahe 2003, p. 4, 144, 243, pls. XXX.1, XXXI.1; Sun 2003), as well as one entire and two fragmentary ceramic conical-shaped artefacts recognized by the excavators as 'moulds' (Shijiahe 2003, p. 232, figs. 184.1–184.3). This assemblage (including the 'moulds' that vaguely recall the shape of the much later 'cup-moulds' excavated at Non Pa Wai: Pigott et al. 1997, p. 126, fig. 11) hints at a local copper-base metallurgy in a region which was in direct contact with the very rich copper deposits of the mid-Yangtze Valley, and via the Nanyang Basin with the Central Plains region. In any case, only by the 15th century BC is a mature bronze metallurgy archaeologically attested in the mid-Yangtze Valley by the outpost of Erligang culture (c. 1600–1300 cal. BC) represented by the walled settlement of Panlongcheng in Wuhan County, Hubei Province.

Meanwhile, in the upper Yangtze, another bronze-producing regional centre, whose astonishing jade-, bronze- and goldworking manifests a cultural matrix separate from that of the Central Plains, is represented by Periods II and III of the Sanxingdui/Jinsha culture in the Chengdu Plain, Sichuan Province (c. 1700–1200 cal. BC) (Chengdu et al. 2002, pp. 12–13). The role played in the eventual southwards transmission of the copper smelting technology by this important, but poorly understood, advanced centre of bronze production has not yet been fully evaluated. However, the Sanxingdui/Jinsha bronze inventory neither displays connections with the northwest (e.g., with the Siba culture c. 2000/1950–1600/1550 cal. BC), nor includes blind-socketed tools of any sort. In contrast, stylistic comparisons can be found lower down the Yangtze from the Chengdu Plain. In particular, two turquoise inlaid bronze plaques (Sichuan Sheng et al. 1998b, fig. 3) excavated at Sanxingdui are comparable to the typical insect-shaped plaques of Erlitou. The ritual vessels from the two Sanxingdui sacrificial pits (two *zun*, respectively from Pit 1 and Pit 2, and two *lei* from Pit 2: Sanxingdui 2005, pls. 53–56), and another *lei* from a survey at Shuantatang on the middle Daning River (Sichuan Sheng et al. 1998a, pp. 8–9, figs. 10–11), find comparisons with ritual bronze vessels dated to the very beginning of the Yin phase found in several sites in southern Hunan and northern Jiangxi Provinces (Zhang 2004a). These include the big grave at Xin'gan, one of the main sites of the Wucheng-Xin'gan culture (Jiangxi Sheng 1997; Peng 2005, p. 24, pp. 70–91).

The bronze production of the Wucheng-Xin'gan culture is characterized by the hybridisation of local elements with Erligang-derived bronze technology and artefact types. Alongside bronze artefacts (vessels and other ritual paraphernalia) cast in piece-moulds, it displays a rich inventory of blind-socketed tools and weapons (e.g. Jiangxi Sheng 1997, figs. 47, 52, 58, 60, 61, 62, 64, 66) cast into bivalve moulds with suspended core, of which c. 300 pieces made of stone have been excavated thus far at sites distributed from the Poyang Lake to the upper Ganjiang Valley (Peng 2005, pp. 34–37). This culture, whose four phases span c. 1600–1000 cal. BC (Shi 2003, pp. 88–101; Peng 2005, pp. 98–105), is distributed in the valley of the Ganjiang, which flows from the south into Poyang Lake, one of the major siphons of the mid-Yangtze Valley. Here the local copper deposits probably stimulated the southern expansion of the Erligang culture and the flourishing of the local Wucheng-Xin'gan culture (Thorp 2006, pp. 107–116; Pigott and Ciarla 2007, pp. 80–81). To the west of the Dongting Lake, in the middle Lishui Valley, a few 14th/13th century BC fragments of stone bivalve moulds, some copper slag and a poorly preserved furnace possibly associated with copper smelting have been excavated at Zaoshi (Shimen County, Hunan Province) (Hunan Sheng 1992, p. 191, 216). Both the Xiang and the Gan rivers have been suggested by Rispoli as the most probable route of the earliest Neolithic expansion towards the northern Southeast Asian regions (Rispoli 2004, 2007).

These rivers, connecting the middle Yangtze to the Guangxi–Guangdong region south of the Nanling, are still the most suitable candidates for the transmission of copper/bronze metallurgy to Southeast Asia in the frame of interregional exchange circuits among societies of unequal social and economic complexity. This hypothesis has been harshly criticized by White and Hamilton as a Sinocentric approach '… rooted in the theoretical paradigms that perceive explanations of the past in terms of core/periphery dynamics' (White and Hamilton 2009, p. 377). However, the way in which this criticism is formulated reveals a rather idiosyncratic perception of cultural developments in Southeast Asian prehistory between the early 3rd and the late 2nd millennium BC. White and Hamilton appear not to comprehend that the explanations of the emergence of interregional interactions among societies at different levels of complexity do not necessarily require 'the theoretical paradigms' of the core-periphery models. For example, Allard (1997) has already pointed out that in the graves of the early phases of the Shixia Neolithic culture (c. 3000–1500 BC) in northern Guangdong there is no evidence of social hierarchy; on the contrary, an increase in the size and richness of certain graves is coincident with the presence of ritual stone 'tubes' or *cong*, either real jade *cong* imported from Liangzhu or less skilful local imitations made from inferior raw materials. This phenomenon was clearly linked to the growing demand for 'exotics' of high symbolic power by the emergent local elite. In this case of interaction between the simple societies in the Lingnan region and the much more complex societies to their north, Shelach (2011) notes that the acquisition of prestige goods may have facilitated the exploitation by the local would-be elite of commoners in their region, but not the exploitation of the region by external societies. The active participants in the interaction were, in fact, the Lingnan aggrandizers;

meanwhile, there is no evidence that the more advanced societies in the Yangtze Valley were even aware that their ritual artefacts might have travelled such distances. The same observations could be made in the case of the transmission of the copper-base technology to Southeast Asia from a northern source, e.g. the Lingnan or the Yunnan–Guizhou Plateau. As in neither case is there evidence of direct or indirect exploitation by external societies, either of the local (Southeast Asian) societies or of the local resources, then as Shelach (2011) puts it '… the core–periphery models, at least in their classic formulation, are inapplicable here.'

Eastern Lingnan

Several post-Neolithic sites in the Lingnan region have been investigated and these have often been regarded as representatives of various, but similar, local cultural manifestations, most of which were contemporary with the Shang dynasty period (Li 1995; Peng 1987; Zhang 2000a). In 2001, Li Yan convincingly proposed to aggregate the different early Bronze Age cultural manifestations thus far known for the Guangdong province (which forms the main territory of Lingnan) into three regional 'cultural types' (*leixing*), namely: the Fubin type in eastern Guangdong; the middle-Shixia type in northern Guangdong; and the Cuntou type in the Pearl River/Zhujiang Delta and the coasts immediately to the south (Li 2001).

Bronze tools and weapons of small size have been recovered from sites belonging to each of the three 'cultural types', but direct evidence of early copper smelting activities in the Lingnan region is still relatively scarce. Thus far only the Cuntou-type cultural area, in easternmost Lingnan, has provided plentiful evidence of copper/bronze metallurgy. Around 80 bronze tools and weapons of small size have been recovered from the c. 15 excavated Cuntou-type sites (only a 6th to 5th century cal. BC bronze spear-head, 35 cm long, from Dameisha near Shenzheng city, is considered evidence of a large weapon), covering a time span from the mid–late 2nd to the mid-1st millennium cal. BC. Similarly dated evidence of local copper-base metallurgy is provided by fewer than 40 single halves of sandstone bivalve moulds (most of which were intended to cast socketed axe-adzes/*fu*) recovered from the surveyed and/or excavated sites, and by one ceramic plug from Dalangwan (Hong Kong), a few pieces of copper slag from Shabucun/Sha Po Tsuen (Hong Kong), and some copper prills from Shenwan/Sham Wan in Nanya/Lamma island (Hong Kong) (Yang 1997, pp. 88–89). However, only a few of these findings witness the beginning of copper-base metallurgy in the region.

At Tangxiahuan, a sandbar site c. 3 km southwest of Pingsha township (Zhuhai city, Guangdong), one half of a reddish sandstone bivalve mould for casting an axe-adze (slightly convex sides and curved blade) and one fragment of a second, similar mould have been found in Layer 4 (overlapping the Neolithic Layer 5). These were found in association with stone tools, including small stone adzes (with pronounced shoulder and quadrangular profiles), split-earrings (*jue*), and potsherds with paddle-impressions, decorated with various carved geometric motifs, among which 'squared' (triangular and quadrangular) spiral motifs clearly imitate the classic *yun-leiwen* motifs which cover the background of the Wucheng and Shang ritual bronzes. Based on the deposit's stratigraphy and on the typology of the ceramic and stone tools, the excavators assigned Layer 4 and associated finds to the mid–late Shang period (Guangdong et al. 1998), that is to say, approximately the 14th–11th century BC. As for the complete bivalve mould half, a comparison with an almost twin, but incomplete, stone mould from Dong Dau (Vinh Phuc, Vietnam), dated c. 1500–1000 cal. BC, has been already advanced elsewhere (Ciarla 2007b, c, pp. 312, 317). Further evidence of local copper-bronze smelting was found in the Zhuhai city region.

In the stratigraphic Group 2 of the site of Yapowan (on the coast of Qi'ao island), potsherds with paddle impressions, including *yun-leiwen* and 'concentric lozenge' motifs, and fragments of ash-glazed ware, were associated with four reddish sandstone bivalve mould halves, of which the only complete one shows a casting space for a 'fan-shaped' axe-adze (Tang and Li 1991, pp. 61–64; Li 1995, p. 89, figs. 2–3). Another sandstone bivalve mould of the same type, but lacking the upper inlet portion, was found at Nanshawan on the coast of the Wanshan Peninsula (southern coast of the Pearl River delta), and was associated with one stone shouldered adze and various potsherds with stamped motifs of 'concentric lozenges' (Liang 1991, p. 82). Still in the Zhuhai area, an almost complete sandstone bivalve mould half, found at the Zengchuanbu site (Doumen County), is comparable, in terms of type and chronology, to the complete half bivalve mould excavated at Tangxiahuan (Li 1995, p. 90). Less than 40 km north of Zhuhai, two halves of a sandstone bivalve mould have been excavated at the site of Longxue (Zhongshan city). One half was intended to cast a fan-shaped axe-adze, while the casting space of the second mould suggests that it might have been used to cast a kind of chisel (Li 1995, p. 91; Yang 1997, p. 89). A space near the inlet for casting a projectile point is the result of a later reuse of the mould.

All of these sandstone bivalve moulds have been dated to the second half of the 2nd millennium BC, on the basis of their association with layers characterized by potsherds with impressed motifs (e.g. *yun-leiwen*, concentric lozenges with or without central raised nipple); and/or by ash glazed sherds, some of which are related to high collared containers (*zun*), and jars with concave base; as well as by stone arrow/spear heads, and 'halberds' of *ge* type; or with layers that overlap secure Neolithic remains, and/or are overlapped by layers containing ceramics stamped with the 'double-f' motifs of the early to mid-1st millennium BC (Xu 1984, pp. 65–67).

On the northern side of the delta, in the Hong Kong archipelago, 24 sandstone bivalve moulds (seven pairs and ten single halves) and a single ceramic plug were found between the early 1930s and the end of the last century. On the basis of stratigraphic and/or artefact associations, as well as radiometric dates, the bivalve moulds excavated in 1989 at Shabucun/Sha Po Tsuen and in 1990 at Guoluwan/Kwo Lo Wan can be assigned with certainty to the early Bronze Age.

Sha Po Tsuen is a sandbar site where the 1989 excavation exposed a relatively reliable stratigraphy spanning from early historical periods (Layers 2–3) down to the Bronze Age (Layer 4) and the Late Neolithic (Layers 6–7) (Meacham 1993). Associated with stoneware potsherds characterised by stamped geometric motifs (including 'double-f' and lozenge patterns) and coarse potsherds with stamped geometric motifs, four grey sandstone bivalve moulds were found, two of which formed a pair (Meacham 1993, figs. 22–23). These moulds, all intended to cast 'fan-shaped' axe-adzes, bear notches at both sides of the inlet to house a suspended plug. In one case two pairs of parallel incised lines are present in the upper section of the mould (on the shaft of the cast tool), while in another there is only one incised line which marks the narrower part of the casting space (at the base of the tool's shaft) (Meacham 1993, figs. 22 right, 23 right). Thus far we have no convincing explanation for the presence of these lines, also present on the bivalve moulds excavated at Non Pa Wai (Lopburi, Thailand) and at Dong Den (Ha Tay, Vietnam) (Ciarla 2007b, c, figs. 11, 15; Pigott et al. 1997, pp. 123–124, fig. 9; Rispoli et al. 2010), but a connection with the system for assembling the moulds in pairs seems the most plausible explanation. At Sha Po

Tsuen other evidence of in situ metallurgical activities, associated with the bivalve moulds, was provided by several pieces of slag on the inner surface of coarse potsherds, that in at least one case can be recognized as a crucible (Meacham 1993, fig. 21 right). Four slag samples were submitted for atomic absorption analysis, which revealed the presence of copper, tin and lead in proportions that can be justified only by the casting of molten bronze rather than by smelting (Meacham 1993, p. 51). Five ^{14}C dates for Layer 4—obtained from charcoal samples (Beta-31475 1240–830 cal. BC; Beta-78217 780–380 cal. BC; Beta-81206 1370–980 cal. BC) and from charred fish-bones (OxA-5850 2820 $\pm$ 360 BP [uncal]; OxA-5849 3060 $\pm$ 120 BP, 1598–937 cal. BC)—provide a chronological range between the late 2nd and early 1st millennium BC. The presence at Sha Po Tsuen of stamped stoneware fragments with 'double-f' patterning suggests that the dating of the site, and of the associated bivalve moulds, should fall in the early 1st millennium BC, at the earliest, rather than the late 2nd millennium BC.

At Kwo Lo Wan, another coastal site in Hong Kong, the 1990 excavation season investigated nine Bronze Age burials accompanied by a total of 49 artefacts as grave offerings. Three pairs of sandstone bivalve moulds were excavated from three different graves: two pairs were intended for casting 'fan-shaped' axe-adzes and one for a 'shovel' with convex waists and curved blade (Yang 1997, figs. 2–3; Zheng 1993). Three charcoal samples from the level associated with the bivalve moulds yielded radiocarbon measurements in the range 1450–1033 BC (Beta-60794: 3220 $\pm$ 80 BP 1677–1311 cal BC; Beta-46868: 3020 $\pm$ 70 BP 1430–1040 cal BC; Beta-45149: 2840 $\pm$ 60 BP 1253–847 cal BC). In spite of the problem of inbuilt age inherent in charcoal determinations (Higham and Higham 2009; Higham 2011b), the lower limit of the time span indicated by the three radiometric dates is compatible with the relative dating of the site to the local early Bronze Age, established on the basis of typological comparisons with the ceramic types in Phase II and III of the cemetery excavated at Wubeiling (Shenzhen city), assigned by the excavators to the Shang period (Li et al. 2004). Indeed, the ceramic inventory which characterizes all the above mentioned sites and supplies evidence of copper-base metallurgy is part of the sequence of different ceramic categories (mainly local stamped wares and imported stamped stoneware) established for the early Bronze Age 'Cuntou type' of Hong Kong and the Zhujiang delta region (Peng 1987; Zhang 2000b, c).

The ceramic sequence of the Cuntou type, which spans c. 1600/1500 BC to c. 800/700 cal. BC, is firmly based on the stratigraphic succession of diagnostic artefacts, some of which—such as the stoneware ritual vessels (e.g. the different types of the *zun*, *lei* and *dou* vessels)—originated in the Wucheng culture production centres along the Gangjiang River valley (Peng 1987; Zhang 2004a, b; Lao 2004). These valuable stoneware ritual vessels initially arrived in eastern Lingnan through a Gangjiang–Zhujiang exchange network and/or via the 'Fubin type' of northern (and northeastern) Guangdong, chronologically falling between the mid-Shang period and the early Western Zhou (Li 2001, p. 63), that is to say c. 1400–1000 cal. BC. It is reasonable to suggest, therefore, that copper-base metallurgy might have been transmitted, together with the stoneware ritual vessels, from the Gangjiang River valley to eastern Lingnan, via the 'middle Shixia type' of northern Guangdong (e.g. topmost cultural layer at Shixia in Qujiang county, dated c. 1200–900 cal. BC), where both the glazed stoneware and the small bronze tools and weapons found have close typological similarities with Guangdong assemblages. In this perspective, the Kwo Lo Wan bivalve moulds associated with grave offerings undoubtedly provide further evidence for the presence in eastern Lingnan of 'founder burials', similar to those excavated in Thailand, for example at Non Pa Wai (Pigott et al. 1997; Ciarla 2007b, c, pp. 316–317); at Ban Non Wat (Higham 2009); and in western Lingnan, at Yuanlongpo (Guangxi et al. 1988).

Based on the occurrences of such founder burials, Pigott and Ciarla (2007, pp. 82–85) have argued for a connection to the Eurasian Steppe, where a similar mortuary behaviour was practised. Moreover, these graves, all dated between the end of the 2nd and the early 1st millennium BC, allow us to hypothesize that they might represent the establishment within low-ranked societies, with still limited lines of specialized craft production, of individual ‘aggrandizers’. These metal founders of distinct status might be responsible for the transmission of the copper-base metallurgy to mainland Southeast Asia, either by ‘local aggrandizers’ through mechanisms of selective acquisition of the new technology, or by migrant/itinerant specialized individuals (‘external aggrandizers’) seeking a special status position in the receiving societies. One or both mechanisms might have been responsible for the ‘localization’ of the alien copper/bronze technology in Southeast Asian social contexts.

Western Lingnan

In western Lingnan, largely corresponding to modern Guangxi, several Bronze Age sites are dated from the mid-2nd millennium BC on the basis of the presence of stamped pottery (stoneware, soft-paste fine ware, and sandy ware), chronologically differentiated according to the sequences and assortments of different types of geometric patterns which mirror the chrono-typological sequences of eastern Lingnan (Guangxi 2004; Wei 2006). However, evidence of early copper-base metallurgy in western Lingnan can be dated, at the earliest, to the 10th–8th century BC, as evidenced by one fragment of a sandstone mould excavated at Gantuoyang cave, Napo County (Guangxi et al. 2003), and by six, thus far unique, reddish sandstone bivalve moulds from Yuanlongpo (Guangxi et al. 1988; Ciarla 2007b, c, pp. 309–312).

The Gantuoyang mould fragment was excavated from habitation Layer 3, assigned by the excavators to the early Phase II of the site, located in the hilly karst landform where Yunnan, Guangxi and Vietnam meet. According to the excavation report, Phase II (early and late horizons) dates to between 1800 and 800 cal. BC on the basis of four ^{14}C measurements (Layer 3, freshwater shell D1017 3815 ± 50 BP; Layer 2, carbonized chestnut D1015 3131 ± 50 BP, carbonized millet D1014 3463 ± 50 BP, D1013 2883 ± 50 BP) (Guangxi et al. 2003, p. 55). Phase II is characterized by round-bottomed and ring-footed containers (no tripods are present), mostly covered by I&I designs, cord-marks and incised wavy lines, and painted motifs. The ceramics and stone tools, according to the excavators, find comparisons with the Cuntou cultural type (Zhujiang Delta area) to the east, and with Phung Nguyen culture sites in the lower basin of the Red River (Guangxi et al. 2003, p. 55). These comparisons suggest that the chronological range hinted by the radiocarbon dates is reasonably consistent with a general dating of Period II to the late 2nd—early 1st millennium BC.

Yuanlongpo is the largest cemetery thus far discovered in Lingnan, with 350 graves excavated (altogether 700 pre-Qin graves are known in Guangxi). The site is located on three crests of a hill to the southwest of the Wuming mountains, at the confluence of the small Matou River with the Liangjiang. The six intact reddish sandstone bivalve moulds, and some 30 fragments of broken ones, are probably slightly later than the Gantuoyang mould fragment, as the cemetery has been dated between the Western Zhou and the Spring and Autumn period, corresponding to c. 1000–500 cal. BC. On the basis of the comparison of the only two bivalve mould pairs published in the Yuanlongpo excavation report with the ceramic bivalve moulds from the upper industrial deposit at Non Pa Wai (Lopburi, central Thailand) (Ciarla 2007b, c), whose chronology has been recently revised (Rispoli et al. 2010), we tend to date the two Yuanlongpo bivalve mould pairs to around the 8th century BC. However, we cannot exclude the possibility that the remaining four pairs of bivalve moulds, or the c. 30 fragments of broken ones, might be associated with the earliest chronological limit assigned to the cemetery. This is also suggested by a bronze fan-shaped axe-adze from Grave M279, whose profile and proportion perfectly match the casting space of the sandstone bivalve mould from M1 at Kwo Lo Wan, and by Tang Fang, on the basis of the bronze weapons typology (Tan 2006, p. 476, 491).

The Yunnan–Guizhou Plateau

The Southwest China Region is a tropical mountainous area formed by the Yunnan–Guizhou Plateau (c. 2,500 m. asl) and its northern extension in the southwestern part of Sichuan. The complicated relief of this mountainous plateau gives rise to tropical, quasi-tropical, subtropical and temperate zones. In this large region, the differential processes of the sub-regional units are basically affected by two main variables: topographic conditions made possible by differentiation on a tropical basis, and the sharp vertical zonality (Ren et al. 1985, pp. 314–344). Within the Yunnan–Guizhou Plateau, the course of the Beipan River separates two main pedoformations: to the east the yellow earth of Guizhou and to the west the red earths of the Yunnan region (Ren et al. 1985, p. 149, pp. 322–323). This region is crossed by the upper reaches of the major rivers of East and Southeast Asia, including the Yangtze, the Red River and the Mekong, whose courses are cut into very steep valleys, particularly in the Hengduan mountain chain, which forms the backbone of mainland Southeast Asia (see Pigott and Ciarla 2007, p. 81, fig. 7). Unfortunately, this is also one of the less archaeologically explored regions of the Far East and archaeological excavations with evidence of early copper/bronze metallurgy remain sparse.

In the yellow earth Guizhou plateau, evidence of early bronze use and in situ production, according to Chinese archaeologists, consists of six stone casting moulds (halves of bivalve moulds) excavated in 1984 at Wayao in Bijie County (northwestern Guizhou) (Guizhou Sheng Bowuguan 1987). In the excavation report only one complete mould is illustrated and described as being intended to cast a two-barbed harpoon 6 cm long. Of the remaining five fragmentary moulds, two have been recognized as moulds for casting daggers (in one case the blade section survived, in the other, the hilt). One carbon sample from a ceramic furnace excavated in the same layer of the bivalve moulds provided a calibrated date of 1667–1303 cal. BC that suggested to the excavators a chronological range for the site between the late Shang and the early Zhou period (Guizhou Sheng Bowuguan 1987, p. 310). This date can be optimistically considered the *terminus post quem* for the copper-base metallurgy at Wayao. The presence of bivalve moulds for casting daggers at this site is in fact more consistent with the general picture of the copper smelting activities in the entire region, which is characterized, starting not earlier than the 5th century BC, by a rather intense smelting activity of bronze tools and weapons, including four main types of dagger, into sandstone bivalve moulds with a marked local style (Li 2009). This production is, however, too late to be taken into consideration in the present study.

Archaeological investigations in the Yunnan Plateau have been particularly intensive in the rift lakes area developed in the fractural belt that, from north to south, includes the Erhai, Dianchi, Fuxian and Yangzong lakes. Meanwhile the Hengduan Mountain and the Southern Yunnan Intermontane Basin sub-regions are barely known archaeologically.

Evidence of early copper/bronze production has been found in the northern part of the Yunnan Plateau sub-region, north of the Dali Basin/Erhai Lake area at the site of Haimenkou (Jianchuan County), c. 2 km south of the small Jianhu Lake, less than 100 km east as the crow flies from the upper Mekong River, and c. 50 km south of the Jinsha/upper Yangtze. Following the discovery of 14 copper/bronze artefacts during the first excavation in 1957, further investigation in the late 1970s brought to light 12 more (mainly axe-adzes, chisels and bracelets) and one stone bivalve mould half for casting an axe-adze with rounded profile (Yunnan Sheng Bowuguan 1995, pp. 776–777; Yunnan Sheng et al. 2009b, pl. IV.1). At the transition between the shaft and the body of the tool, the casting space of this mould includes a motif in the shape of goat's horns, comparable to a motif of the same type present in the same position on a similar copper-bronze socketed axe of miniature size excavated at Hejiashan (Midu County, Yunnan), dated to the mid-Warring States period (Zhang 2000a). This artefact is in turn comparable with almost identical artefacts excavated at Nil Kham Haeng (Lopburi Province, central Thailand), datable to the second half of the 1st millennium BC (Pigott et al. 1997, p. 123–124; Ciarla 2007b, c, pp. 320–321). On the basis of two radiocarbon dates, one from a charcoal sample collected in 1957 and the other from the 1978 excavation—respectively 3115 ± 90 BP and 2660 ± 125 BP (Yunnan Sheng Bowuguan 1995, p. 785)—the site's chronology was bracketed between the late Shang and the early Zhou period. At the time of the excavation report, radiocarbon dates from Haimenkou carbon samples had already been published by the Institute of Archaeology, Beijing, but are slightly different from those later published in the excavation report (Zhongguo Shehui Kexueyuan 1991, p. 234) (Table 1). In any case, 11 metal artefacts recognized in the excavation report as all made of copper, and one metal-bearing ore, were later subjected to X-ray fluorescence analysis by Wang Dadao. This detected the presence of tin and lead in some of the artefacts and recognized the ore as a tin-free ore, possibly from a local source (Wang 1985). As recently stated by Chiou-Peng Tzehuey, 'discussions of the Haimenkou site and materials have generated considerable interest as well as disputes,' due to the controversial stratigraphic associations of the carbon samples, as well as of the artefacts excavated during the two excavation seasons (Chiou-Peng 2009). In 2008, a third excavation season was conducted, more stratigraphically controlled than in the past, which led to the definition of three distinct cultural phases, respectively dated 5000–3900 BP, 3800–3200 BP and 3100–2500 BP (Yunnan Sheng 2009b, p. 22). This time, it was possible to ascertain that copper-base tools (a bell, a knife, an awl and a chisel) appear in the upper layer (Layer 6) of Period 2, while the evidence of in situ metallurgical activities—a fragmentary greyish sandstone bivalve mould-half, most probably for casting a 'fan-shaped' axe-adze, and a weak increase of copper-base artefacts types—is attested only by the early stage of Period 3 (Yunnan Sheng 2009a, p. 22).

Further evidence for the use of copper-base tools in the area has been collected recently at Yinsuodao, a shell-midden site that takes its name from the island on Erhai Lake excavated in 2003. Copper-base tools have been recovered from layers the excavators assign to Periods 2–4, respectively dated c. 1500–1100 cal. BC, 1200–900 cal. BC and 900–400 cal. BC (Yunnan Sheng 2009c).

We cannot but recognize that more in-depth (both typologically and archaeometrically) studies of the artefacts mentioned above, as well as more archaeological investigations in the entire Yunnan–Guizhou Plateau, are required to produce informed assessments of the cultural and technological connections between the early Bronze Age cultures of the entire Yangtze River valley and the Lingnan–Yunnan–Guizhou Plateau. Nevertheless, the evidence coming from northwest Yunnan of early copper/bronze use and production, as a whole, witnesses a long period of metallurgical experimentation and use that places southwest China as another possible candidate for the transmission of early metallurgical knowledge towards continental Southeast Asia some time in the second half of the 2nd millennium BC. However, despite the fact that these sites are located on the route of White and Hamilton's proposed 'long march' to Ban Chiang, they are all significantly too late to support their model.

The Bronze Age in Southeast Asia

Within Southeast Asia itself, we turn for the anchor chronology to the site of Ban Non Wat. This is a large, moated site, one of many that jostle each other in the upper reaches of the Mun River. While it was initially excavated in order to examine the Iron Age, a six-phase Bronze Age cemetery underlay the Iron Age occupation layers; this in turn sealed early Neolithic settlement. After seven seasons of excavation, this long sequence was dated by 76 radiocarbon determinations, many on the bivalve shells that were placed with the dead. The Bayesian analysis of these identifies the transition into the initial Bronze Age in the late 11th century BC (Higham and Higham 2009). The Bronze Age Phase 1 ceramic vessels are clearly derived from the preceding late Neolithic range, and indicate a smooth transition from one phase to the next. Again, some motifs painted on Bronze Age 2 pots match those on Neolithic vessels (Higham and Kijngam 2009).

At issue is the extent to which the results of the examination of Ban Non Wat are matched at other excavated Southeast Asian Bronze Age sites. Ban Lum Khao is located about 20 km to the east of Ban Non Wat (Higham and Thosarat 2005). The earliest phase equates with the Neolithic 2 at Ban Non Wat, and charcoal from pits of this period reveals that the transition into the Bronze Age took place after about 1200 cal. BC (Higham 2005). The earliest Bronze Age at this site was contemporary with Bronze Age 2 at Ban Non Wat.

Ban Na Di is located about 23 km south of Ban Chiang. Excavations in 1982 revealed a cultural sequence that began within the Bronze Age, and developed into two Iron Age phases. The radiocarbon dates come from assured contexts: clay-lined furnaces for casting copper-base artefacts, hearths and a thick charcoal layer sealing a pit. With the benefit of hindsight, these must be regarded as mixed samples, with no charcoal being speciated (as defined in Ashmore 1999). This requires that each determination must be interpreted as a *terminus post quem*. There are two phases of the Bronze Age cemetery, which merged seamlessly with graves that contain iron grave goods. Since the burials of the three phases have the same orientation, and the forms of the ceramic vessels only reveal slight variations between each phase, it is suggested that they belong within the period 600–400 cal. BC.

Nong Nor is a site located near the present shore of the Gulf of Siam. There are two cultural periods at this site. The earliest represents coastal hunter gatherers who lived there during the late 3rd millennium BC. Much later, Bronze Age graves were cut into the midden. Very little charcoal was found in situ, but fragments of charcoal in an infant mortuary jar were dated to 940–760 cal. BC. The organic temper in mortuary vessels was therefore dated. Five returned determinations of between 1200 and 800 cal. BC, again underlining the problems of using this material for dating. Under our protocol for interpreting such results, each provides a *terminus post quem*. One of the burials contained carnelian beads, a marker usually associated with the early Iron Age in Thailand. The evidence suggests that this is a relatively late site, probably dating within the 7th–5th centuries BC.

Phu Lon is a copper mining site located near the Mekong River in Loei Province. It was the focus for intensive but probably seasonal copper extraction and processing. The in situ charcoal dates from this complex belong to the 1st millennium BC (Pigott and Weisgerber 1998).

In Lopburi Province, the earliest evidence known thus far for copper processing has been found at Non Pa Wai, in the Khao Wong Prachan Valley. The site is located not only close to the surface copper and iron ore deposit at Khao Tab Kwai, but also near a major copper ore source on Khao Phu Kha, where several mine galleries have been recorded. In addition, it is not far from various other small deposits recorded locally in the Khao Wong Prachan Valley (Natapintu 1988) and in the nearby Khao Sai On mineral district (Ciarla 2007a, 2008). Excavations at Non Pa Wai yielded specimens of host rock, copper ore and pedorelicts of laterite and haematite fragments, suggesting, in particular, prehistoric exploitation of the local copper reserves including that at Khao Tab Kwai (Cremaschi et al. 1992). A cemetery with evidence of copper metallurgy, including bivalve moulds and copper artefacts, documents the Bronze Age occupation in basal Non Pa Wai (Pigott et al. 1997). On the basis of two radiocarbon dates (Rispoli et al. 2011, in prep.) and typological comparisons between 'index fossil' artefacts from the Non Pa Wai graves and artefacts from sites whose chronology is based on reliable radiometric dates, the Non Pa Wai Bronze Age deposit can be divided into two Mortuary Periods. The earlier (MP1) is characterized by burials with evidence of copper-base metallurgy: two founder's burials each contained bivalve moulds for casting large socketed axe/adzes. In one burial the mould pair was broken up and distributed around the body, and in the other the mould was positioned between the knees of the deceased. Three copper artefacts, including a copper axe/adze (Pigott et al. 1997; Pryce et al. 2010a), a fish-hook and a totally corroded 'rod' were found in three different graves. Similar bivalve moulds are known from Ban Lum Khao in the Mun River valley in Thailand (Higham and Thosarat 2005); Mlu Prei in Cambodia (Lévy 1943, fig. 17.33); Dong Den (Go Mun Culture) and Dong Dau in Vietnam (Pigott and Ciarla 2007, pp. 82–84; Ciarla 2007a, pp. 316–318); Tangxiahuan in Zhuhai city, Guangdong Province (Pigott and Ciarla 2007, p. 84, fig. 9b; Ciarla 2007a, p. 312, fig. 13); and Haimenkou in Yunnan (Yunnan Sheng et al. 2009a, b). These related finds date between 1100 and 800 cal. BC, a similar range to the ^{14}C dates from Non Pa Wai. Moreover, the close similarity between two diagnostic pottery types found at Non Pa Wai and those from Ban Lum Khao Mortuary Period 2 (O'Reilly 2004, p. 243, pp. 296–297) and Ban Non Wat Bronze Age 1 (Higham and Kijngam 2009, p. 163, 209) confirms the 1100–800 cal. BC date range for Mortuary Period 1 at Non Pa Wai as robust. The second Mortuary Period, c. 800–500 cal. BC, is characterized by a major change in the manufacturing technology and decorative style of ceramic production. The ceramic ware becomes orange–buff, whereas the main decoration technique consists of large bands of thick red burnished slip on the rim, neck and/or the pedestal of the pots.

At Non Pa Wai, pottery displays typological comparisons with Phu Noi (Rispoli et al. 2009, 2011, in prep.), Ban Lum Khao Mortuary Period 2 ceramic form 1A (O'Reilly 2004, p. 233, 241) and Ban Non Wat Bronze Age 3 (Higham and Kijngam 2009, p. 168, 211). Personal ornaments from Non Pa Wai include stone bracelets and marble bangles carved in imitation of marine conus shell. The period is also marked by the use of bone tools, including harpoon-heads, with comparanda in the bone tools from Dong Dau, Viet Nam (Hoang 2000, fig. XIX).

Further south of Non Pa Wai, on the Lopburi plain, the Bronze Age layer at Tha Kae is represented by a few graves furnished with orange-to-buff pots, decorated at the neck with a thick red burnished slip, and notably displaying clear comparisons with Ban Non Wat Bronze Age 1 (Higham and Kijngam 2009, p. 168, 211). Tha Kae stone bracelets (one repaired with metal wire) have a flat triangular section. Meanwhile, abundant shell ornament manufacturing debris, ^{14}C dated to c. 800–700 cal. BC and excavated from Bronze Age levels at Tha Kae, witnesses a florescence of the craft at this time (Ciarla 1992).

At Phu Noi (Natapintu 1997; Ciarla 2005, pp. 85–88), a site located in the Takli Undulating Terrain along the northwestern edge of the Lopburi Plain, about 48 km from Tha Kae and about 30 km from the mining and metallurgical sites in the Khao Wong Prachan, the pottery in the first Mortuary Period is characterized by globular jars with an applied ribbon that underlies the diagnostic thick red burnished slip on the upper half of the body. This vessel type finds close parallels in the vessels excavated from the Bronze Age 2 burials at Ban Non Wat (Higham and Kijngam 2009).

Personal ornaments consist of shell barrel-shaped beads typologically similar to the ones excavated at Nong Nor (Chang 2001, p. 50). Split earrings made of shell were also found, again with comparanda at Nong Nor (Chang 2001, p. 79) and Ban Non Wat, Bronze Age 4 (Higham and Kijngam 2009, pp. 225, 231). T-section stone bracelets are also present, comparable with similar ornaments excavated in most of the Bronze Age sites in Thailand, particularly at Ban Non Wat, BA2 to BA4 (Higham and Kijngam 2009, p. 226); Ban Lum Khao Mortuary Period 2 (Chang 2004, pp. 226–227); and Ban Na Di (Higham and Kijngam 1984, p. 72), thus dating the chronological horizon of the first Mortuary Period at Phu Noi to c. 800–500 cal. BC.

Summary and Conclusions

A proper chronological framework is the prerequisite for the formulation of a model to account for the spread of bronze technology into Southeast Asia. We have examined the radiocarbon dating method employed at Ban Chiang by White and Hamilton (2009) to underpin their chronological and cultural model, and concluded that it is methodologically flawed. In its place, we have offered AMS determinations from the bones of those who lived at Ban Chiang, and animal bones placed in their graves. These samples were pre-treated with the latest ultrafiltration techniques to extract and purify bone collagen. We conclude from this that the initial Bronze Age at Ban Chiang is about a millennium later than the transition suggested by White (2008), which was employed as the foundation of White and Hamilton's (2009) model for the origins of bronze casting at Ban Chiang in particular, and Southeast Asia in general. Moreover, our determinations on human bone from the earliest Neolithic occupation through to the Bronze Age of the site not only indicate that initial settlement took place in the 16th–15th centuries BC, but also present a near perfect correspondence with the dated sequence for Ban Non Wat.

We proceeded to review the evidence for the establishment of the Neolithic in Southeast Asia, which we see as deriving from the rice and millet farming communities of the Yangtze Valley. This we conclude took place from the early 2nd millennium BC, and set in train an expansion of Neolithic farming communities that lasted until late in the same millennium.

In generating a model for both the expansion of the Neolithic and the later establishment of the Bronze Age, we find recurrent evidence for a consistent pattern; this initially saw four main regions where copper-base metallurgy was established during the 3rd millennium BC west and north of the Chinese Central Plain. The most complex bronze casting then developed in late Erlitou, Shang and Sanxingdui contexts during the 2nd millennium BC. White and Hamilton (2009) underplay the considerable evidence for bivalve mould casting in later Shang sites, but this is a technology that we can trace in detail southward along the Yangtze Valley, then into and through Lingnan–Yunnan and finally, into Southeast Asia. On the basis of the abundant evidence for copper smelting in the Khao Wong Prachan Valley, Pryce et al. (2010b) have summarised how copper-base metallurgy could have originated in the exchange of information and consequent development of a local tradition. During this southward expansion of technical knowledge, we note in the mortuary evidence the rise of what may be termed 'aggrandizers', that is, those who were able through controlling the supply and ownership of this new medium of metal, to enhance their social standing (Higham 2011b). This is clearly seen at Ban Non Wat, a site that occupies a strategic location towards the eastern entrance to a vital pass over the Phetchabun Range. This was the logical point of entry for prestige goods originating in the Chao Phraya Basin. Thus the copper mines of the Khao Wong Prachan Valley were only 150 km to the west, and the settlements there were also potential transit points for marine shell, highly prized then for prestige ornaments. The Phetchabun Range also yields marble, a further material employed for bangles and earrings. To the east, the Mun has its confluence with the arterial route of the Mekong River, beyond which lie the copper mines of Sepon. The upper Mun region has its own prize asset: salt.

This form of natural exchange bottleneck, as stressed by Clarke and Blake (1996), provides the opportunities for social aggrandizers to corner preferential access to prestige goods. Again, Hayden (2009) has identified ceremonial feasting as a means of leveraging social status. The early Bronze Age cemetery at Ban Non Wat is thus a *locus classicus* for tracing the rise of such elites through their mortuary rituals (Higham 2011b). During the first to the third mortuary phases, men, women, infants and children were interred over a period of at least eight generations, with wealth unparalleled in any other Southeast Asian site. The dead were accompanied by up to 80 fine ceramic vessels, some containing food remains, copper-base axes, anklets, bells and chisels, marine shell bangles that covered the arms, and thousands of shell beads. The mortuary rituals involved placing fish, severed pig's limbs, shellfish and chickens with the corpse. The richest individuals were partially exhumed after burial before being reinterred, a possible indication of ancestor worship. We have concluded that at Ban Non Wat, the spread of copper-base technology by the 11th century BC coincided with the rapid rise of social aggrandizers (Higham 2011b). Ban Chiang in the early Bronze Age presents a stark contrast. This site lies in a remote corner of the Khorat Plateau. It has no easy access to prestige valuables, and the poverty of the inhabitants contemporary with the aggrandizers of Ban Non Wat is easily expressed by figures. The 47 burials of Bronze Age 2 and 3A at Ban Non Wat were interred with 772 trochus or tridacna marine shell bangles, 43 marble bangles and 159,135 shell beads. The corresponding figures at Ban Chiang, with a larger number of graves, are 0, 0, and (possibly) 4.

We are not metallurgists, but are guided by the conclusions of Roberts et al. (2009) that the transmission of metallurgical knowledge involves a series of complicated procedures that would virtually inevitably require the presence of skilled practitioners. As they have stressed, 'Even "simple" smelting technology needed to be carried out within a fairly narrow margin of error or else the entire process would fail' (Roberts et al. 2009, p. 1018). The spread of copper-base metallurgy into Southeast Asia resonates with Linduff's conclusion apropos China, that 'Early metal technology in East Asia had both experimental and mature phases, was probably not independently generated but emerged and was tempered in each area by local conditions, customs and degree of receptivity' (Linduff 2002, pp. 608–609). The archaeological record documents exchange contact between the Bronze Age states of China and Neolithic communities in Southeast Asia during the second half of the 2nd millennium BC. We suggest that this was the vehicle for bronze founding specialists to speed the transmission of their skills south, thereby stimulating the Southeast Asian Bronze Age.

In view of the chronological framework presented and strengthened here, White and Hamilton's model appears untenable. However, as has been agreed by all participants in this continuing discussion (Pigott and Ciarla 2007, p. 85; White and Hamilton 2009, p. 390) models will of necessity remain in flux as they adjust to the data emerging across the vast expanse of the Eurasian Steppe, China and Southeast Asia. Such data, more than ever, reinforce the relatively new concept that these regions, at least from the Bronze Age onwards, were participants in the same interaction sphere.

Ban Non Wat may represent a crossing of the Rubicon in terms of methodologies for research into the Bronze Age in Southeast Asia. Thus far it is the only site where a large number of secure radiocarbon determinations covering the transition into the Bronze Age have been obtained and analysed using a Bayesian approach to calibration, a method that allows a robust chronometric framework to be constructed. It also shows that the larger the area opened, the more it becomes possible to minimize sampling error. We are keenly aware that our model is for testing, and provides only the basis for the next step in a hermeneutic spiral (Bayliss et al. 2007, p. 5). This will mean grasping several nettles. Dating methods must be rigorously scrutinized, and those found to be unreliable, such as AMS dating of ground potsherds, rejected. Each series based on mixed unspeciated charcoal samples must be treated as a *terminus post quem* at best. Excavations should be far larger than hitherto in order to obtain reliable evidence, and the sourcing of exotic valuables undertaken, as has begun in the case of copper, in order to trace routes of exchange (Pryce et al. 2011). Even though over a century has elapsed since the Southeast Asian Bronze Age was first identified, we are still in the early stages of understanding it. Each new large-scale excavation that provides the opportunity to build a Bayesian-based chronology, and is actually published in full, will test and refine our understanding of its cultural, chronological and metallurgical characteristics.

Acknowledgments We wish to thank Professor Richard Hodges, Williams Director of the University Museum, Philadelphia, and Dr. Somsuda Leyavanija, Director-General of the Fine Arts Department, Thailand, for granting permission to sample and date the human bones from Ban Chiang. Dr. M. Pietrusewsky kindly agreed to take the relevant human bone samples for dating. Dr. Vincent Pigott, Dr. Oliver Pryce and two anonymous reviewers are thanked for their constructive comments on early versions of the text for this article. We acknowledge the input of all of the staff at the Oxford Radiocarbon Accelerator Unit at the University of Oxford. Charles Higham and Amphan Kijngam thank the late Dr. Chester Gorman and Dr. Pisit Charoenwongsa for inviting them to collaborate in the excavations at Ban Chiang in 1974 and 1975.

References

Allard, F. (1997). Growth and stability among complex societies in prehistoric Lingnan, Southeast China. *Papers from the Institute of Archaeology, 8*, 37–58.

An, Z. M. (1981). Zhongguo zaoji tongqi de jige wenti [Some problems concerning China's early copper-bronze artefacts]. *Kaogu Xuebao, 3*, 269–285.

An, Z. M. (1993). Shilun Zhongguo de zaoqi tongqi [On the early bronze in China]. *Kaogu, 12*, 1110–1119.

Ashmore, P. J. (1999). Radiocarbon dating: Avoiding errors by avoiding mixed samples. *Antiquity, 73*, 124–130.

Bai, Y. X. (2003). A discussion on early metals and the origin of bronze casting in China. *Chinese Archaeology, 3*, 157–165.

Banpo Bowuguan, Shaanxi Sheng Kaogu Yanjiusuo, & Lintong Xian Bowuguan (1988). *Jiangzhai—Xinshiqi Shidai yizhi fajue baogao [Jiangzhai—excavation report of the Neolithic site]*. Beijing: Wewu Chubanshe.

Bayard, D. T., & Charoenwongsa, P. (1983). The development and spread of metallurgy in Southeast Asia: Reply to Loofs-Wissowa. *Journal of Southeast Asian Studies, 14*(1), 12–17.

Bayliss, A., Bronk Ramsey, C., van der Plicht, J., & Whittle, A. (2007). Bradshaw and Bayes: Towards a timetable for the Neolithic. *Cambridge Archaeological Journal, 17*(Suppl 1), 1–28.

Beijing Gangdie Xueyuan Yejinshi Yanjiusuo (1981). Zhongguo zaoqi tongqi de chubu yanjiu [Preliminary study of early Chinese copper/bronze artefacts]. *Kaogu Xuebao, 3*, 287–302.

Beijing Gangdie Xueyuan Yejinshi Yanjiusuo (1984). Gansu sheng Bowuguan songjian wenwu jianding baogao [A report on the identification of the artefacts submitted by the Gansu Provincial Museum]. *Kaoguxue Jikan, 4*, 162.

Bellwood, P. (2005). *First farmers*. Oxford: Blackwell.

Bentley, A., Tayles, N., Higham, C. F. W., Macpherson, C., & Atkinson, T. C. (2007). Shifting gender relations at Khok Phanom Di, Thailand: Isotopic evidence from the skeletons. *Current Anthropology, 48*(2), 301–314.

Berstan, R., Stott, A. W., Minnit, S., Bronk Ramsey, C., Hedges, R. E. M., & Evershed, R. P. (2008). Direct dating of pottery from its organic residues: New precision using compound-specific carbon isotopes. *Antiquity, 82*, 702–713.

Bonsall, C., Cook, G., Manson, J., & Anderson, D. (2002). Direct dating of Neolithic pottery: Progress and prospects. *Documenta Praehistorica, 29*, 47–59.

Brock, F., Higham, T. F. G., & Bronk Ramsey, C. (2010). Pre-screening techniques for identification of samples suitable for radiocarbon dating of poorly preserved bones. *Journal of Archaeological Science, 37*(4), 855–865.

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. *Radiocarbon, 51*(1), 337–360.

Bronk Ramsey, C., Higham, T. F. G., Bowles, A., & Hedges, R. (2004). Improvements to the pretreatment of bone at Oxford. *Radiocarbon, 46*(1), 155–163.

Bronson, B. (1985). Notes on the history of iron in Thailand. *Journal of the Siam Society, 73*, 205–225.

Cartailhac, E. (1890). Les bronzes préhistoriques du Cambodge et les recherches de M. Ludovic Jammes. *L'Anthropologie, 6*, 641–650.

Chang, N. (2001). *Personal ornaments in Thai prehistory: Nong Nor, Ban Lum Khao and Noen U-Loke*. Ph.D. thesis, University of Otago, Dunedin, New Zealand.

Chang, K. C. (1986). *The Archaeology of Ancient China*. New Haven: Yale University Press.

Chang, N. (2004). The personal ornaments. In C. F. W. Higham & R. Thosarat (Eds.), *The origins of the civilization of Angkor. Volume I: The excavation of Ban Lum Khao* (pp. 217–230). Bangkok: Fine Arts Department of Thailand.

Chengdu Shi Wenwu Kaogu Gongzuodui, Aba Zangzu Qiangzu Zizhizhou Wenguansuo, & Maoxian Bowuguan (2002). Sichuan Maoxian Yingpanshan yizhi shijue baogao [Report on trial excavations at the Yingpanshan site in Mao county, Sichuan]. *Chengdu Kaogu Faxian, 2000*, 1–77. Beijing: Kexue Chubanshe.

Chengdu Shi Wenwu Kaogu Gongzuodui & Pixian Bowuguan (1999). Sichuansheng Pixian Gucheng yizhi tiaocha yu shijue [Survey and trial excavation at Gucheng site in Pi county, Sichuan province]. *Wenwu, 1*, 32–42.

Chengdu Shi Wenwu Kaogu Yanjiusuo & Beijing Daxue Kaogu Wenboyuan (2002). *Jinsha Tao Zhen [Panning for treasure at Jinsha]*. Beijing: Wenwu Chubanshe.

Chernykh, E. N. (1992). *Ancient metallurgy in the USSR*. Cambridge: Cambridge University Press.

Chernykh, E. N. (2009). Formation of the Eurasian steppe belt cultures viewed through the lens of archaeometallurgy and radiocarbon dating. In B. Hanks & K. Linduff (Eds.), *Social complexity in prehistoric Eurasia* (pp. 115–145). Cambridge: Cambridge University Press.

Chiou-Peng, T. H. (2009). Incipient metallurgy in Yunnan: New data for old debates. In J. Mei & T. Rehren (Eds.), *Metallurgy and civilisation: Eurasia and beyond* (pp. 79–84). London: Archetype.

Ciarla, R. (1992). The Thai–Italian Lopburi regional archaeological project: Preliminary results. In I. Glover (Ed.), *Southeast Asian Archaeology 1990* (pp. 111–128). Hull: University of Hull.

Ciarla, R. (2005). The Thai–Italian 'Lopburi regional archaeological project': A survey of fifteen years of activities. In I. Piovano (Ed.), *La Cultura Thailandese e le Relazioni Italo–Thai* (pp. 77–104). Torino: Centro Studi Medio ed Estremo Oriente (CESMEO).

Ciarla, R. (2007a). Rethinking Yuanlongpo: The case for technological links between Lingnan (PRC) and Central Thailand during the Bronze Age. *East and West, 57*, 1–23.

Ciarla, R. (2007b). A preliminary report on Lo.R.A.P. archaeological excavations at prehistoric Khao Sai On, Lopburi Province, Central Thailand. *East and West, 57*, 395–401.

Ciarla, R. (2008). The Thai–Italian 'Lopburi Regional Archaeological Project' (LORAP). excavations at Khao Sai on-Noen Din 2008. Preliminary report. *East and West, 58*, 313–336.

Clark, J. E., & Blake, M. (1996). The power of prestige: Competitive generosity and the emergence of rank societies in lowland Mesoamerica. In E. M. Brumfiel & J. W. Fox (Eds.), *Factional competition and political development in the New World* (pp. 17–30). Cambridge: Cambridge University Press.

Crawford, G. W., & Chen, S. (1998). The origin of rice agriculture: Recent progress in East Asia. *Antiquity, 72*, 858–866.

Cremaschi, M., Ciarla, R., & Pigott, V. C. (1992). Palaeoenvironment and late prehistoric sites in the Lopburi region of Central Thailand. In I. Glover (Ed.), *Southeast Asian archaeology 1990* (pp. 167–177). Hull: University of Hull.

De Atley, S. P. (1980). Radiocarbon dating of ceramic materials: Progress and prospects. *Radiocarbon, 22*(3), 987–993.

Diamond, J., & Bellwood, P. (2003). Farmers and their languages: The first expansion. *Science, 300*, 597–603.

Frachetti, M. D. (2008). *Pastoralist landscapes and social interaction in Bronze Age Eurasia*. Berkeley/Los Angeles: University of California Press.

Fuller, D. Q., Harvey, E., & Qin, L. (2007). Presumed domestication? Evidence for wild rice cultivation and domestication in the fifth millennium BC of the lower Yangtze region. *Antiquity, 81*, 316–331.

Fuller, D. Q., & Qin, L. (2009). Water management and labour in the origins and dispersal of Asian rice. *World Archaeology, 41*, 88–111.

Fuller, D. Q., Sato, Y.-I., Castillo, C., Qin, L., Weisskopf, A. R., Kingwell-Banham, E. J., et al. (2010). Consilience of genetics and archaeobotany in the entangled history of rice. *Archaeological and Anthropological Science, 2*, 115–131.

Gansu sheng Gongzuodui, Lingxia Huizu Zizhizhou Wenwuju, & Dongxiangzu Zizhixian Wenhuaguan (1984). Gansu Dongxiang Lijia yizhi fajue baogao [Report on the excavation at the Lingjia site in Dongxiang, Gansu]. *Kaoguxue Jikan, 4*, 111–160.

Glover, I. C. (1990). Ban Don Ta Phet: The 1984–5 excavation. In I. C. Glover & E. Glover (Eds.), *Southeast Asian archaeology 1986*. BAR International Series 561 (pp. 139–183). Oxford: British Archaeological Reports.

Glusker, D., & White, J. (1997). Comment. *Archaeometry, 39*, 259–260.

Good, I. (2010). When East met West: Interpretive problems in assessing Eurasian contact and exchange in antiquity. In A. V. G. Betts & F. Kidd (Eds.), *New directions in silk road archaeology: Proceedings of a workshop held at ICAANE V, Madrid, 2006.* Archäologische Mitteilungen aus Iran und Turan. Band 42, 2010 (pp.23–45). Berlin: Reimer.

Gorman, C. F., & Charoenwongsa, P. (1976). Ban Chiang: A mosaic of impressions from the first two years. *Expedition, 8*(4), 14–26.

Gu, J. X. (2003). Chuodun Yizhi Majiabang Wenhua Shiqi Shuidao Tian (The rice paddy land from Chuodun site of Majiabang Period). In G. Fengliang (Ed.), *Choudun Shan: Chuodun yizhi Lunwenji* [Chuodun Shan: collected papers on Chuodun site], Nanjing Bowuguan, *Dongnan Wenhua* special issue: 42–45.

Guangdong Sheng Wenwu Kaogu Yanjiusuo, & Zhuhai Shi Pingsha Wenhua Ke (1998). Zhuhai Pingsha Tangxiahuan yizhi fajue jianbao [Short report on the excavation at Tangxiahuan near Pingsha, Zhuhai city]. *Wenwu, 7*, 4–16.

Guangxi Zhuangzu Zizhiqu Wenwu Gongzuodui (2004). Guangxi xianQin yatong zang zongshu [A summary of the pre-Qin cave graveyards in Guangxi]. In Guangxi Zhuang Zizhiqu Bowuguan (Ed.), *Guangxi Kaogu Wenji-1* (pp. 192–212). Beijing: Wenwu Chubanshe.

Guangxi Zhuangzu Zizhiqu Wenwu Gongzuodui, Nanning Shi Wenwu Guanli Weiyuanhui, & Wuming Xian Wenwu Guanlisuo (1988). Guangxi Wuming Matou Yuanlongpo muzang fajue jianbao [Short report on the excavation of the Yuanlongpo graveyard in Matou, Wuming County, Guangxi]. *Wenwu, 12*, 1–13.

Guangxi Zhuangzu Zizhiqu Wenwu Gongzuodui, & Napo Xian Bowuguan (2003). Guangxi Napoxian Gantuoyan yizhi faxian jianbao [A brief report on the excavation at the Gantuoyan cave site in Napo County, Guangxi]. *Kaogu, 10*, 35–56.

Guizhou Sheng Bowuguan (1987). Guizhou Bijie Wayao yizhi fajue jianbao [A brief report on the excavation at Wayao site in Bijie, Guizhou]. *Kaogu, 7*, 303–310.

Ha Van Tan (1997). *Theo dau cac van hoa co [In pursuit of ancient cultures]*. Hanoi: Nha Xuat Ban Khoa Hoc Xa Hoi [Social Science publisher].

Hall, M. D. (1993). Aspects of pottery decoration. In C. F. W. Higham & R. Thorasat (Eds.), *The excavation at Khok Phanom Di. Volume III: The material culture* (pp. 239–274). London: Society of Antiquaries.

Han, R. B., & Ke, J. (1988). Jiangzhai di yiqi wenhua chutu huangtong zhipin de jianding baogao [Report on the identification of the brass artefacts discovered from the Jiangzhai Period 1 culture]. In B. Bowuguan et al. (Eds.), *Jiangzhai—Xinshiqi Shidai yizhi fajue* (pp. 548–554). Beijing: Wewu Chubanshe.

Hanks, B. K., Epimakhov, A. V., & Renfrew, A. C. (2007). Towards a refined chronology for the Bronze Age of the southern Urals, Russia. *Antiquity, 81*, 353–367.

Hayden, B. (2009). Funeral feasts: Why are they so important? *Cambridge Archaeology Journal, 19*(1), 29–52.

Hedges, R. E. M., Chen, T., & Housley, R. A. (1992). Results and methods in the radiocarbon dating of pottery. *Radiocarbon, 34*(3), 906–915.

Hedges, R. E. M., Pettitt, P. B., Bronk Ramsey, C., & Van Klinken, G. J. (1997). Radiocarbon dates from the Oxford AMS system: Archaeometry datelist 23. *Archaeometry, 39*, 247–262.

Higham, C. F. W. (1984). The Ban Chiang culture in wider perspective. *Proceedings of the British Academy, LXIX*, 229–261.

Higham, C. F. W. (1996). *The Bronze Age of Southeast Asia*. Cambridge: Cambridge University Press.

Higham, C. F. W. (2002). Languages and farming dispersal: Austroasiatic languages and rice cultivation. In P. Bellwood & C. Renfrew (Eds.), *Examining the farming/language dispersal hypothesis* (pp. 223–232). Cambridge: McDonald Institute.

Higham, C. F. W. (2004). The opposed human figure at Khok Phanom Di. *Journal of the Siam Society, 92*, 15–36.

Higham, C. F. W. (2005a). East Asian agriculture and its impact. In C. Scarre (Ed.), *The human past: World prehistory and the development of human societies* (pp. 234–263). London: Thames & Hudson.

Higham, T. F. G. (2005b). Dating the occupation of Ban Lum Khao. In C. F. W. Higham & R. Thosarat (Eds.), *The origins of the civilization of Angkor. Volume I: The excavation of Ban Lum Khao* (pp. 5–8). Bangkok: Fine Arts Department of Thailand.

Higham, C. F. W. (2006). Crossing national boundaries: Southern China and Southeast Asia in prehistory. In E. A. Bacus, I. C. Glover, & V. C. Pigott (Eds.), *Uncovering Southeast Asia's past* (pp. 13–21). Singapore: National University of Singapore.

Higham, C. F. W. (2009). Recasting Thailand: New discoveries at Ban Non Wat. *Current World Archaeology, 31*, 38–41.

Higham, C. F. W. (2011a). Introduction. In C. F. W. Higham & A. Kijngam (Eds.), *The Excavation at Ban Non Wat: The Neolithic occupation* (pp. 1–9). Bangkok: Fine Arts Department of Thailand.

Higham, C. F. W. (2011b). The Bronze Age of Southeast Asia: New insight on social change from Ban Non Wat. *Cambridge Archaeological Journal, 21*(3), 365–389.

Higham, C. F. W., & Bannanurag, R. (1990). *The excavation at Khok Phanom Di. Volume I: The excavation, chronology and human burials*. London: Society of Antiquaries.

Higham, C. F. W., Kuzmin, Ya. V., & Burr, G. S. (2010). The AMS ^{14}C dating of Iron Age rice chaff ceramic temper from Ban Non Wat, Thailand: First results and its interpretation. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, 268*, 1022–1025.

Higham, C. F. W., & Higham, T. F. G. (2009). A new chronological framework for prehistoric Southeast Asia, based on a Bayesian model from Ban Non Wat. *Antiquity, 82*, 125–144.

Higham, C. F. W., Higham, T. F. G., & Kijngam, A. (2011). Cutting a Gordian knot. The Bronze Age of Southeast Asia: Origins, timing and impact. *Antiquity, 85*, 583–598.

Higham, T. F. G., Jacobi, R. M., & Bronk Ramsey, C. (2006). AMS radiocarbon dating of ancient bone using ultrafiltration. *Radiocarbon, 48*(2), 179–195.

Higham, C. F. W., & Kijngam, A. (Eds.) (1984). *Prehistoric excavations in northeast Thailand: Excavations at Ban Na Di, Ban Chiang Hian, Ban Muang Phruk, Ban Sangui, Non Noi and Ban Kho Noi*. BAR International Series 231 (pp. i–iii). Oxford: British Archaeological Reports.

Higham, C. F. W., & Kijngam, A. (2009). *The origins of the civilization of Angkor. Volume III: The Excavation of Ban Non Wat. Introduction*. Bangkok: Fine Arts Department of Thailand.

Higham, C. F. W., & Lu, T. L.-D. (1998). The origin and dispersal of rice cultivation. *Antiquity, 72*, 867–877.

Higham, C. F. W., & Thosarat, R. (1998). *The excavation of Nong Nor, a prehistoric site in central Thailand. University of Otago Studies in Prehistoric Anthropology No. 18*. Oxford: Oxbow Books.

Higham, C. F. W., & Thosarat, R. (2004). *The excavation of Khok Phanom Di. Volume VII: Summary and conclusions*. London: Society of Antiquaries.

Higham, C. F. W., & Thosarat, R. (Eds.). (2005). *The origins of the civilization of Angkor. Volume I: The excavation of Ban Lum Khao*. Bangkok: Fine Arts Department of Thailand.

Ho, C. M. (1984). *The pottery of Kok Charoen and its farther context*. Ph.D. dissertation, University of London.

Hoang, X. C. (2000). *Vinh Phuc. Thoi Tieu Su–So Su [Prehistory and Protohistory of the Vinh Phuc Province]*. Vinh Phuc: So Van Hoa Thong Tin–The Tao.

Hunan Sheng Wenwu Kaogu Yanjiusuo (1990). Hunan Lixian Pengtoushan Xinshiqi shidai caoqi yizhi fajue jianbao [Brief report on the excavation of the early Neolithic site at Pengtoushan in Lixian, Hunan]. *Wenwu, 8*, 17–29.

Hunan Sheng Wenwu Kaogu Yanjiusuo (1992). Hunan Shimen Zaoshi Shangdai yizhi [The Shang period site at Zaoshi, Shimen County, Hunan]. *Kaogu Xuebao, 2*, 185–219.

Jiang, L. P., & Li, L. (2005). The discovery of an 8000-year-old dugout canoe at Kuahuqiao in Lower Yangzi River, China. *Antiquity* 79. http://antiquity.ac.uk/projgall/liu/index.html.

Jiang, L. P., & Li, L. (2006). New evidence for the origins of sedentism and rice domestication in Lower Yangzi River, China. *Antiquity, 80*, 355–356.

Jiangxi Sheng Wenwu Kaogu Yanjiusuo, Jiangxi Sheng Bowuguan, & Xingan Xian Bowuguan (1997). *Xingan Shangdai Damu* [The large Shang tomb at Xin'gan]. Beijing: Wenwu Chubanshe.

Kohl, P. L. (2007). *The making of Bronze Age Eurasia*. Cambridge: Cambridge University Press.

Koryakova, L., & Epimakhov, A. V. (2009). *The Urals and Western Siberia in the Bronze and Iron Ages*. Cambridge: Cambridge University Press.

Kuzmin, Ya. V. (2002). The earliest centers of pottery origin in the Russian Far East and Siberia: Review of chronology for the oldest Neolithic cultures. *Documenta Praehistorica, 29*, 37–46.

Kuzmin, Ya. V., Hall, S., Tite, M. S., Bailey, R., O'Malley, J. M., & Medvedev, V. E. (2001). Radiocarbon and thermoluminescence dating of the pottery from the early Neolithic site of Gasya (Russian Far East): Initial results. *Quaternary Science Reviews, 20*, 945–948.

Lao, J. L. (2004). Zhujiang sanjiazhou yu Aobei diqu Shiqian taoqi de bijiao fenxi [A comparative analysis of the prehistoric ceramics in the Pearl River delta and the northern zone of the Bay]. *Dongnan Kaogu Yanjiu, 1*, 160–169.

Lefèvre-Pontalis, M. (1894). Note de M. Lefèvre-Pontalis. In M. Pavie (Ed.), *Mission Pavie: Explorations de l'Indo-Chine. Archéologie et histoire* (pp. 14–23). Paris: Ernest Leroux.

Leong, S. H. (1991). Jenderam Hilir and the mid-Holocene prehistory of the west coast plain of Peninsular Malaysia. *Bulletin of the Indo-Pacific Prehistory Association, 10*, 150–160.

Lertrit, S. (2004). Sab Champa revisited: Results of recent archeological field investigations. In V. Paz (Ed.), *Southeast Asian Archaeology. Wilhelm G. Solheim II Festschrift* (pp. 504–521). Quezon City: University of the Philippines Press.

Lertrit, S., Jumprom, P., & Klinpoklab, A. (2001). The archaeological excavation at Sab Champa: Results and speculations. *Muang Boran, 27*, 117–133. [in Thai].

Lévy, P. (1943). *Recherches préhistoriques dans la région de Mlu Prei*. Publications de l'École française d'Extrême Orient 30. Hanoi: Impr. d'Extrême-Orient.

Li, Y. (1995). Guangdong Qingtong Shidai caoqi yicun zhu wenti qianxi [A preliminary study on problems related to early Bronze Age finds in Guangdong]. In *Dongnanya Kaogu Lunwenji/Archaeology in Southeast Asia* (pp. 87–94). Hong Kong: University Museum and Art Gallery of the University of Hong Kong.

Li, Y. (2001). Guangdong caoqi Qingtong shidai yicun shulue [An outline of early Bronze Age remains in Guangdong]. *Kaogu, 3*, 57–65.

Li, F. (2009). Guizhou Anlong xinchu tongqi—jianlun Guizhou Xinan diqu de Qingtong wenhua [Bronze artefacts recently found in Anlong, Guizhou—a discussion on the Bronze culture in southwest Guizhou]. *Sichuan Wenwu, 9*, 62–69.

Li, M. R., Xie, P., & Zhang, D. Y. (2004). Shenzhen shi Wubeiling Shang shiqi muzang qun [The Shang period cemetery at Wubeiling in Shenzhen]. *Huanan Kaogu, 1*, 163–185.

Liang, Z. X. (1991). Dongao dao Nanshawan yizhi tiaocha [A survey investigation at Nanshawan site in Dong'ao island]. In Zhuhai Shi Bowuguan, Guangdong Sheng Wenwu Kaogu Yanjiusuo, & Guangdong Sheng Bowuguan (Eds.), *Zhuhai Kaogu Faxian yu Yanjiu* (pp. 80–83). Guangzhou: Guangdong Renmin Chubanshe.

Linduff, K. M. (2002). At the eastern edge: Metallurgy and adaptation in Gansu (PRC) in the 2nd millennium BC. In K. Jones-Bley & D. G. Zdanovich (Eds.), *Complex societies of central Eurasia from the 3rd to the 1st millennium BC: Regional specifics in light of global models*. Volume II (pp. 595–611), Journal of Indo-European Studies Monograph Series 45. Washington DC: Institute for the Study of Man.

Loofs-Wissowa, H. H. E. (1983). The development and spread of metallurgy in Southeast Asia: A review of the present evidence. *Journal of Southeast Asian Studies, 14*(1), 1–11. 26–31.

Maglioni, R. (1975). *Archaeological discovery in Eastern Kwangtung*. Journal Monograph II. Hong Kong: Hong Kong Archaeological Society.

Maleipan, V. (1979). The excavation at Sab Champa. In R. B. Smith & W. Watson (Eds.), *Early South East Asia* (pp. 337–341). Oxford: Oxford University Press.

Manning, K., Pelling, R., Higham, T. F. G., Schwenninger, J.-L. & Fuller, D. Q. (2011). 4500-year old domesticated pearl millet (*Pennisetum glaucum*) from the Tilemsi Valley, Mali: New insights into an alternative cereal domestication pathway in Africa. *Journal of Archaeological Science, 38*, 312–322.

Masanari, N. (2005). Settlement patterns on the Red River plain from the late prehistoric period to the 10th century AD. *Bulletin of the Indo-Pacific Prehistory Association, 25*, 99–107.

Masanari, N., & Nguyen, K. D. (2002). Excavation of An Son: A Neolithic mound site in the middle reach of the Vam Co Dong River, Southern Vietnam. *Bulletin of the Indo-Pacific Prehistory Association, 22*, 101–109.

Massie, M. (1894). Note de M. Massie. In A. Pavie (Ed.), *Mission Pavie: Explorations de l'Indo-Chine. Archéologie et histoire* (pp. 7–13). Paris: Ernest Leroux.

Meacham, W. (1993). Sha Po Tsuen. *Journal of the Hong Kong Archaeological Society, 13*, 33–54.

Mei, J. (2003). Cultural interaction between China and Central Asia during the Bronze Age. *Proceedings of the British Academy, 121*, 1–39.

Mei, J. (2004). Metallurgy in Bronze Age Xinjiang and its cultural context. In K. M. Linduff (Ed.), *Metallurgy in ancient eastern Eurasia from the Urals to the Yellow River*. Chinese Studies 31 (pp. 173–188). Lewiston: Edwin Mellen.

Mulholland, S. C., & Prior, C. (1993). AMS radiocarbon dating of phytoliths. In D. M. Pearsall & D. R. Piperno (Eds.), *Current research in phytolith analysis: Applications in archaeology and paleoecology*. MASCA Research Papers in Science and Archaeology 10 (pp. 21–23). Philadelphia: The University Museum.

Natapintu, S. (1988). Current Research on ancient copper-base metallurgy in Thailand. In P. Charoenwongsa & B. Bronson (Eds.), *Prehistoric studies: The Stone and Metal Ages in Thailand* (pp. 107–124). Bangkok: Thai Antiquity Working Group.

Natapintu, S. (1997). Current archaeological research in central Thailand. In R. Ciarla & F. Rispoli (Eds.), *Southeast Asian archaeology 1992*. Serie Orientale Roma 77 (pp. 45–56). Rome: Istituto Italiano per l'Africa e l'Oriente (IsIAO).

Noulet, J. B. (1879). *L'Âge de la pierre polie et du bronze au Cambodge d'après les découvertes de M.J. Moura*. Archives du Musée d'Histoire naturelle de Toulouse 1. Toulouse: Privat.

O'Reilly, D. J. W. (2004). Social aspects of the cemetery. In C. F. W. Higham & R. Thosarat (Eds.), *The origins of the civilization of Angkor. Volume I: The excavation of Ban Lum Khao* (pp. 301–324). Bangkok: Fine Arts Department of Thailand.

Onsuwan, C. (2000). *Excavation of Ban Mai Chaimongkol, Nakhon Sawan Province, Central Thailand: A study of site stratigraphy, chronology and its implications for the prehistory of central Thailand*. MA thesis, Department of Anthropology, University of Pennsylvania.

Onsuwan Eyre, C. (2006). *Prehistoric and proto-historic communities in the eastern upper Chao Phraya River valley Thailand: Analysis of site chronology, settlement pattern and land use*. Ph.D. dissertation, University of Pennsylvania.

Parzinger, H., & Boroffka, N. G. O. (2003). *Das Zinn der Bronzezeit in Mittelasien.* Archäologie in Iran und Turan. Mainz: P. von Zabern.

Pavie, A. (1894). *Mission Pavie: Explorations de l'Indo-Chine.* Archéologie et histoire (pp. 7–13). Paris: Ernest Leroux.

Pei, A. P. (1998). Notes on new advancements and revelations in the agricultural archaeology of early rice domestication in the Dongting Lake region. *Antiquity, 72*, 878–885.

Peng, K. F. (1987). *Zhongguo Nanfang Gudai Yinwentao* [Ancient stamped pottery of Southern China]. Beijing: Wenwu Chubanshe.

Peng, M. H. (2005). *Wucheng Wenhua* [The Wucheng culture]. Beijing: Wenwu Chubanshe.

Pietrusewksy, M., & Douglas, M. T. (2002). *Ban Chiang: A prehistoric village site in northeast Thailand. Volume I: The human remains*. Philadelphia: Museum of Archaeology and Anthropology.

Pigott, V. C., & Ciarla, R. (2007). On the origins of metallurgy in prehistoric Southeast Asia: The view from Thailand. In S. La Niece, D. Hook, & P. Craddock (Eds.), *Metals and mines.* Studies in Archaeometallurgy (pp. 76–88). London: British Museum.

Pigott, V. C., & Weisgerber, G. (1998). Mining archaeology in geological context: The prehistoric copper mining complex at Phu Lon, Nong Khai Province, northeast Thailand. In T. Rehren, A. Hauptmann, & J. D. Muhly (Eds.), *Metallurgica antiqua: In honor of Hans-Bert Bachmann and Robert Maddin*. Der Anschnitt 8 (pp. 135–162). Bochum: Deutsches-Bergbau Museum.

Pigott, V. C., Weiss, A. D., & Natapintu, S. (1997). The archaeology of copper production: Excavations in the Khao Wong Prachan Valley, Central Thailand. In R. Ciarla & F. Rispoli (Eds.), *Southeast Asian archaeology 1992*. Serie Orientale Roma 77 (pp. 119–158). Rome: Istituto Italiano per l'Africa e l'Oriente (IsIAO).

Pisnupong, P. (1993). The industrial stone technology. In C. F. W. Higham & R. Thosarat (Eds.), *The excavation of Khok Phanom Di.* Volume III (part 1): *The material culture*. Research Report 50 (pp. 45–104). London: Society of Antiquaries.

Pryce, T. O. (2011). Technical analysis of Bronze Age Ban Non Wat copper-base artefacts. In C. F. W. Higham & A. Kijngam (Eds.), *The origins of the civilization of Angkor. Volume V: The Bronze Age* (pp. 489–498). Bangkok: Fine Arts Department of Thailand (in press).

Pryce, T. O., Martinón-Torres, M., Pigott, V. C., & Rehren, T. (2010a). Prehistoric copper production and technological reproduction in the Khao Wong Prachan Valley of central Thailand. *Archaeological and Anthropological Sciences, 2*, 237–264.

Pryce, T. O., Pollard, M., Martinón-Torres, M., Pigott, V. C., & Pernicka, E. (2010b). Southeast Asia's first isotopically-defined prehistoric copper production system: When did extractive metallurgy begin in the Khao Wong Prachan Valley of central Thailand? *Archaeometry, 53*, 146–163.

Reimer, P. J., Baillie, M. G. L., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., et al. (2009). Intcal09 and Marine09 radiocarbon age calibration curves, 0–50, 000 years cal BP. *Radiocarbon, 51*(4), 1111–1150.

Ren, M. E., Yang, R. Z., & Bao, H. S. (1985). *An outline of China's physical geography*. Beijing: Foreign Languages Press.

Rice, P. M. (1987). *Pottery analysis: A sourcebook*. Chicago/London: University of Chicago Press.

Rispoli, F. (1997). Late third/early second millennium BC pottery traditions in central Thailand: Some preliminary observations in a wider perspective. In R. Ciarla & F. Rispoli (Eds.), *Southeast Asian archaeology 1992*. Serie Orientale Roma 77 (pp. 59–97). Rome: Istituto Italiano per l'Africa e l'Oriente (IsIAO).

Rispoli, F. (2004). Looking for the root of Neolithization in Southeast Asia. *Paper presented at the 10th international conference of the European Association of Southeast Asian Archaeologists*. British Museum, London, September 13–17.

Rispoli, F. (2007). The incised and impressed pottery style of mainland Southeast Asia: Following the path of Neolithization. *East and West, 57*, 235–304.

Rispoli, F. (2009). Incised and impressed pottery style as a chronological boundary in mainland Southeast Asia. *Paper presented at the 19th Indo-Pacific Prehistory Association Congress*, Hanoi, November 29th–December 5th.

Rispoli, F., Ciarla, R., & Pigott, V. C. (2009). Towards a working chronology for Central Thailand: Revising the sequence for the Khao Wong Prachan Valley and the Greater Lopburi region. *Paper presented at the 19th Indo-Pacific Prehistory Association Congress*, Hanoi, November 29th–December 5th.

Rispoli, F., Ciarla, R., & Pigott, V. C. (2010). Revising the prehistoric cultural sequence for the Greater Lopburi Region, Central Thailand: An update. *Paper presented at the 13th international conference of the European Association of Southeast Asian Archaeologists*, Berlin, September 27th–October 2nd.

Rispoli, F., Ciarla, R., & Pigott, V. C. (2011). Establishing the prehistoric cultural sequence for the Lopburi Region, Central Thailand (in prep).

Roberts, B. W., Thornton, C. P., & Pigott, V. C. (2009). Development of metallurgy in Eurasia. *Antiquity, 83*, 1012–1022.

Santos, G. M., Alexandre, A., Coe, H. H. G., Reyerson, P. E., Southon, J. R., & De Carvalho, C. N. (2009). The phytolith ^{14}C puzzle: A tale of background determinations and accuracy tests. *Radiocarbon, 52*(1), 113–128.

Sanxingdui Bowuguan (2005). *Sanxingdui: Gu Shu wangguo de shenmi mianju* [Sanxingdui: The mysterious masks of the ancient Shu kingdom]. Beijing: Wuzhou Zhuanbo Chubanshe.

Schofield, W. (1975). An archaeological site at Shek Pik. In W. Meacham (Ed.), *An archaeological site at Shek Pik*. Journal Monograph I. Hong Kong: Hong Kong Archaeological Society.

Shao, W. P. (2002). The formation of civilization: The interaction sphere of the Longshan period. In K. C. Chang & P. F. Xu (edited and with an introduction by S. Allan), *The formation of Chinese civilization: An archaeological perspective* (pp. 85–123). New Haven: Yale University Press.

Shelach, G. (2009). *Prehistoric societies on the northern frontiers of China: Archaeological perspectives on identity formation and economic change during the first millennium BC*. Approaches to Anthropological Archaeology Series. London: Equinox.

Shelach, G. (2011). I fenomeni di interazione interregionale tra la tarda Età Neolitica e la prima Età del Bronzo. In R. Ciarla & M. Scarpari (Eds.), *La Cina*. Volume I. Torino: Einaudi (in press).

Shi, J. S. (2003). *Changjiang liuhuo qingtong qi yanjiu* [Researches into the bronzes of the Yangtze valley]. Beijing: Wenwu Chubanshe.

Shijiahe Kaogudui (2003). *Tianmen Shijiahe Kaogu Fajue Baogao Zhi Er—Dengjiawan* [Second report on the excavations at Shiajiahe in Tianmen: Dengjiawan site]. Beijing: Wenwu Chubanshe.

Sichuan Sheng Wenwu Guanli Weiyuanhui, Sichuan Sheng Wenwu Kaogu Yanjiusuo, & Wushan Xian Wenhuaguan (1998a). Wushan Jingnei Changjiang/Daninghe Liuhuo Gu Yizhi Tiaocha Jianbao [Brief report of the survey of ancient sites in the valley of the Yangtze–Daning rivers in Wushan region]. In Sichuan Sheng Wenwu Kaogu Yanjiusuo (Ed.), *Sichuan Kaogu Baogaoji* (pp. 1–10). Beijing: Wenwu Chubanshe.

Sichuan Sheng Wenwu Kaogu Yanjiusuo Sanxingdui Gongzuodui, & Guanhan Shi Wenwu Guanlisuo (1998b). Sanxingdui Yizhi Zhenwu Cangbaobao Jisi Keng tiaocha jianbao [A short report on the survey of the sacrificial pit at Cangbaobao in Zhenwu village, Sanxingdui site]. In Sichuan Sheng Wenwu Kaogu Yanjiusuo (Ed.), *Sichuan Kaogu Baogaoji* (pp. 78–90). Beijing: Wenwu Chubanshe.

Siripanish, S. (1985). *An analytical study on pottery from the excavation at Ban Tha Kae*, Muang District, Lopburi Province, M.A. thesis, Silpakorn University [in Thai].

Solheim, W. G., II. (1968). Early bronze in northeastern Thailand. *Current Anthropology, 9*(1), 59–62.

Solheim, W. G., II. (1972). An earlier agricultural revolution. *Scientific American CCVI, 4*, 34–41.

Solheim, W. G., II. (1980). Early pottery in northern Thailand and conjectures on its relationship. In H. H. E. Loofs-Wissowa (Ed.), *The diffusion of material culture: 28th International Congress of Orientalists, proceedings of seminar E* (pp. 35–52). Canberra: Social Science Research Institute, University of Honolulu.

Solheim, W. G., II. (1983). The development and spread of metallurgy in Southeast Asia: Another reply to Loofs-Wissowa. *Journal of Southeast Asian Studies, 14*(1), 18–25.

Sørensen, P., & Hatting, T. (1967). *Archaeological investigations in Thailand: The archaeological materials from the burials*. Copenhagen: Munksgard.

Stuiver, M., & Polach, H. A. (1977). Discussion: Reporting of ^{14}C Data. *Radiocarbon, 19*, 355–363.

Sun, H. (1992). Shilun Guanhan Sanxingdui yizhi de fenqi [On the periodization of the Sanxingdui site in Guanhan]. *Nanfang Minzu Kaogu, 5*, 10–24.

Sun, S. Y. (2003). Dengjiawan yizhi tongkuangzha jianyan baogao [Report on the testings on copper slags from Dengjiawan site]. In Shijiahe Kaogudui (Ed.), *Tianmen Shijiahe Kaogu fajue baogao zhi er—Dengjiawan* (p. 303). Beijing: Wenwu Chubanshe.

Tan F. (2006). Guangxi xianQin Shiqi de Qingtong Jian [The bronze daggers of pre-Qin period in Guangxi]. In Guangxi Zhuang Zizhiqu Bowuguan (Ed.), *Guangxi Kaogu Wenji-2* (pp. 474–493). Beijing: Wenwu Chubanshe.

Tang, L. H. (2003). Chuodun Yizhi de Yuanshi Daozuo Yicun [The primitive rice remains from Chuodun site]. In G. Fengliang (Ed.), *Choudun Shan: Chuodun yizhi Lunwenji* [Chuodun Shan: Collected papers on Chuodun site]. Nanjing Bowuguan, Dongnan Wenhua special issue: 46–49.

Tang, Z. X., & Li, F. H. (1991). Qiao dao Yapowan, Nanmangwan yizhi tiaocha [Survey investigation at Yapowan and Nanmangwan sites in Qi'ao island]. In Zhuhai Shi Bowuguan, Guangdong Sheng Wenwu Kaogu Yanjiusuo, Guangdong Sheng Bowuguan (Eds.), *Zhuhai Kaogu Faxian yu Yanjiu* (pp. 57–69). Guangzhou: Guangdong Renmin Chubanshe.

Tayles, N. G. (1999). *The excavation of Khok Phanom Di. Volume V: The people*. London: Society of Antiquaries.

Thompson, G. B. (1996). *The excavation of Khok Phanom Di. Volume IV: The biological remains. Part II*. London: Society of Antiquaries.

Thorp, R. (2006). *China in the early Bronze Age: Shang civilization*. Philadelphia: University of Pennsylvania Press.

Veraprasert, M. S. (1982). *Etude archéologique sur le site de Sab Champa*. M.A. thesis, Université de la Sorbonne Nouvelle, Paris.

Vincent, B. A. (2003). *The excavation of Khok Phanom Di. Vol. VI: The pottery*. London: Society of Antiquaries.

Wang, D. D. (1985). Yunnan Jianchuan Haimenkou zaoqi qingtong yanjiu [A study of the early bronzes from Haimenkou,Yunnan]. In Zhongguo Kaogu Xuehui (Ed.), *Zhongguo Kaoguxuehui di sici nianhui lunwenji* [Essays for the 4th Annual Meeting of the Chinese Archaeological Association] (pp. 244–251.). Beijing: Wenwu Chubanshe.

Wang, Y., & Sun, H. (1999). Baoduncun Wenhua de chubu renshi [A preliminary study of the Baodun culture]. *Kaogu, 8*, 60–73.

Wei J. (2006). Guangxi XianQin Kaogu Shuping [A survey of the pre-Qin archaeology in Guangxi]. In Guangxi Zhuangzu Zizhiqu Bowuguan (Ed.), *Guangxi Kaogu Wenji-2* (pp. 48–59). Beijing: Wenwu Chubanshe.

White, J. C. (1982). *Ban Chiang: Discovery of a lost Bronze Age*. Philadelphia: University Museum.

White, J. C. (1986). *A revision of the chronology of Ban Chiang and its implications for the prehistory of northeast Thailand*. Ph.D. thesis, University of Pennsylvania.

White, J. C. (1988). Early East Asian metallurgy: The southern tradition. In R. Maddin (Ed.), *The beginning of the use of metals and alloys: Papers from the second international conference on the beginning of the use of metals and alloys*, Zhengzhou, China, 21–26 October 1986 (pp. 175–181). Cambridge, MA: MIT Press.

White, J. C. (1997). A brief note on new dates for the Ban Chiang cultural tradition. *Bulletin of the Indo-Pacific Prehistory Association, 16*, 103–106.

White, J. C. (2008). Dating early bronze at Ban Chiang, Thailand. In J.-P. Pautreau, A.-S. Coupey, V. Zeitoun, & E. Rambault (Eds.), *From Homo erectus to the living traditions* (pp. 91–110). Bougon: European Association of Southeast Asian Archaeologists.

White, J. C., & Hamilton, E. (2009). The transmission of early Bronze Age technology to Thailand: New perspectives. *Journal of World Prehistory, 22*, 357–397.

Xizang Zizhiqu Wenwu Guanli Weiyuanhui, & Sichuan Daxue Lishixi (1985). *Changdu Karuo* [The archaeological site of Karuo in Changdu]. Beijing: Wewu Chubanshe.

Xu, H. B. (1984). A general discussion on the Bronze Age of Guangdong. In Guangdong Provincial Museum and the Art Gallery of the Chinese University of Hong Kong (Eds.), *Guangdong chutu xianQin Wenwu* [Archaeological Finds from pre-Qin Sites in Guangdong] (pp. 64–85). Hong Kong: Art Gallery of the Chinese University of Hong Kong.

Yan, W. M. (1984). Lun Zhongguo de tongshi bingyong shidai [On the Chalcolithic Age of China]. *Shiqian Yanjiu, 1*, 36–44.

Yang, Y. L. (1997). Shenzhen ji linjing diqu xian Qin qingtongqi zhuzao jishu de kaocha [A study of pre-Qin bronze casting techniques in Shenzhen and surrounding region]. *Kaogu, 6*, 77–96.

Yunnan Sheng Bowuguan (1977). Yuanmou Dadunzi Xinshiqi shidai yizhi [The Neolithic Site at Dadunzi in Yuanmou County, Yunnan Province]. *Kaogu Xuebao, 1*, 43–72.

Yunnan Sheng Bowuguan (1995). Yunnan Jianchuan Haimenkou Qingtongqi shidai zaoqi yizhi [The Bronze Age site of Haimenkou in Jianchuan county]. *Kaogu, 9*, 775–787.

Yunnan Sheng Wenwu Kaogu Yanjiusuo, Dali shi Bowuguan, Dali shi Wenwu Guanlisuo, & Dali zhou Wenwu Guanlisuo (2009). Yunnan Dali shi Haidong Yinsuodao yizhi fajue jianbao [Preliminary Report on the Excavation of the Yinsuodao Site at Haidong in Dali City, Yunnan]. *Kaogu, 8*, 23–41.

Yunnan Sheng Wenwu Kaogu Yanjiusuo, Dali Zhou Wenwu Guanlisuo, & Jianchuan Xian Wenwu Guanlisuo (2009a). Yunnan Jianchuan xian Haimenkou yizhi [The Haimenkou site in Jianchuan county, Yunnan]. *Kaogu, 7*, 18–23.

Yunnan sheng Wenwu Kaogu Yanjiusuo, Dali Zhou Wenwu Guanlisuo, & Jianchuan Xian Wenwu Guanlisuo (2009b). Yunnan Jianchuan xian Haimenkou yizhi di sanci fajue [Third excavation season at Haimenkou site in Jianchuan county, Yunnan]. *Kaogu, 8*, 3–22.

Yunnan Sheng Wenwu Kaogu Yanjiusuo, Dali zhou Wenwu Guanlisuo, & Yongping xian Wenwu Guanlisuo (2002). Yunnan Yongping Xinguang yizhi fajue baogao [A report of the excavations at Xinguang site in Yongping, Yunnan]. *Kaogu Xuebao, 2*, 203–234.

Yunnan Sheng Wenwu Kaogu Yanjiusuo, Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo Yunnan Gongzuodui, Chengdu Shi Wenwu Kaogu Yanjiusuo, Chuxiong Zhou Bowuguan, & Yongren Xian Wenhuaguan (2003). Yunnan Yongren Caiyuanzi, Mopandi yizhi 2001 nian fajue baogao [Report of 2001 excavation season at Caiyuanzi and Mopandi sites in Yongren, Yunnan]. Wenhuaguan International Series. *Kaogu Xuebao, 2*, 263–923.

Zhang, Z. (2000a). Yunnan Midu Hejiashan chutu gudai shi taofan he qingtong qi [Ancient bronze artefacts and stone/ceramic moulds excavated at Hejiashan in Midu, Yunnan]. *Wenwu, 11*, 39–49.

Zhang, Z. T. (2000b). *Xianggan Kaogu Lunji* (Essays on the archaeology of Hong Kong). Beijing, Wenwu Chubanshe.

Zhang, Z. T. (2000c). Xianggang diqu Qingtongqi shidai kaogu ji youguan wenti de shentao [The Bronze Age archaeology in Hong Kong and some related problems]. In Z. T. Zhang (Ed.), *Xianggan Kaogu Lunji* (pp. 102–118). Beijing, Wenwu Chubanshe.

Zhang, C. P. (2004a). Lun Yinxu shiqi Nanfang de zun he lei [On the *zun* and *lei* of Yinxu phase found in the South]. *Kaoguxue Jikan, 15*, 116–128.

Zhang, J. G. (2004b). Nanfang diqu chutu Shang-Zhou shiqi yingtao zun tanchu [A preliminary investigation on the Shang-Zhou period stoneware *zun* found in South China]. *Huanan Kaogu, 1*, 74–88.

Zhang, Z. P. (2005). The Yangshao period: Prosperity and the transformation of prehistoric society. In K. C. Chang & P. F. Xu (edited and with an introduction by S. Allan), *The formation of Chinese civilization: An archaeological perspective* (pp. 43–83). New Haven: Yale University Press.

Zhang, C., & Hung, H. C. (2007). The Neolithic of southern China: Origin, development and dispersal. *Asian Perspectives, 47*, 299–329.

Zhang, C., & Hung, H. C. (2010). The emergence of agriculture in southern China. *Antiquity, 84*, 11–25.

Zhejiang Sheng Wenwu Kaogu Yanjiusuo, & Xiaoshan Bowuguan (2004). *Kuahuqiao* (The site of Kuahuqiao). Puyangjiang liuhuo kaogu baogao zhi yi [Archaeological report of Puyang River valley I]. Beijing: Wenwu chubanshe.

Zheng, Q. M. (1993). Chilajiao tongfu shifan chutan [Preliminary investigation of the stone moulds for bronze axe from Chilajiao/Chek Lap Kok]. *Journal of the Hong Kong Archaeological Society, 13*, 120–122.

Zhongguo Shehui Kexueyuan Kaogu Yanjusuo (1991). Zhongguo Kaoguxue zhong Tanshisi niandai shuju 1965–1991 [Radiocarbon Dates in Chinese Archaeology 1965–1991]. Beijing: Wenwu Chubanshe.

Zhonguo Shehui Kexueyuan Kaogu Yanjiusuo Sichuan Gongzuodui, & Sichuan Guangyuan shi Wenwu Guanlisuo (1991). Sichuan Guangyuan shi Zhangjiapo Xinshiqi shidai yizhi de tiaocha yu shijue [Survey and trial excavation at the Neolithic site of Zhangjiapo in Guangyuan city, Sichuan]. *Kaogu, 9*, 774–780.

Zhu, F. H. (1995). *Gudai Zhongguo Qingtongqi* [Bronze artefacts of ancient China]. Tianjin: Nankai University Press.