

Book and Film Reviews

Review of *Ban Chiang, Northeast Thailand*, Volumes 2A, 2B, and 2C

Anke Hein

School of Archaeology, Oxford University, 1 South Parks Road, Oxford OX1 3TG, United Kingdom (anke.hein@arch.ox.ac.uk).
10 VIII 21

Background to the Study of the Metal Remains, volume 2A of *Ban Chiang, Northeast Thailand*. Edited by Joyce C. White and Elizabeth G. Hamilton. Philadelphia: University of Pennsylvania Museum of Archaeology and Anthropology, 2018.

Metals and Related Evidence from Ban Chiang, Ban Tong, Ban Phak Top, and Don Klang, volume 2B of *Ban Chiang, Northeast Thailand*. Edited by Joyce C. White and Elizabeth G. Hamilton. Philadelphia: University of Pennsylvania Museum of Archaeology and Anthropology, 2018.

The Metal Remains in Regional Context, volume 2C of *Ban Chiang, Northeast Thailand*. Edited by Joyce C. White and Elizabeth G. Hamilton. Philadelphia: University of Pennsylvania Museum of Archaeology and Anthropology, 2019.

This review is written for a general audience of archaeologists working outside Southeast Asia. It argues that the volumes in the Thai Archaeology Monograph Series, the archaeological evidence from Ban Chiang, and the archaeology of Thailand and Southeast Asia more broadly speaking are also of great interest to scholars working in other parts of the world. The three volumes reviewed here are furthermore of relevance to archaeometallurgists and anyone interested in the development, context, and transfer of technology on a local, regional, and supraregional level. The review attempts to look beyond the heated controversy on chronology, the acrimony of which tinges these and related publications in often unproductive ways. To contextualize the volumes, as a first step, the background of the research at Ban Chiang will be laid out, followed by a review of each of the three volumes and ending with general observations.

Background

Discovered in 1966, the site of Ban Chiang, northeast Thailand, was first noted for its fine red pottery, leading to further excavations in 1972. The site became a veritable sensation when early thermoluminescence dates (4420–3400 BC) taken for pottery associated with metal remains seemed to suggest that these were the earliest bronze objects in the world (Gorman and Charoenwongsa 1976; Muhly 1976). Similarly early dates had been suggested for metal finds from Non Nok Tha a little farther south,

sparking questions about previously held assumptions of a single origin and later diffusion of metal technology (Solheim 1968).

These finds drew worldwide attention and led to further excavations in a collaboration between the University Museum, Philadelphia, and the Thai Fine Arts Department, Phra Nakhon, Bangkok, Thailand, which opened two excavation pits altogether covering 130.8 m², as well as smaller test pits of 9–13 m² each at the nearby sites of Ban Tong, Ban Phak Top, and Don Klang. Radiocarbon dates taken from charcoal—a material now generally known to be problematic for dating—at Ban Chiang suggested slightly later, though still very early, dates of 3600 BC for the earliest bronze and 1600 BC for the earliest iron (Gorman and Charoenwongsa 1976).

When Chester Gorman, one of the two lead excavators of Ban Chiang, passed away in 1981, Joyce White, a PhD student of Gorman's, came to oversee the project documentation and finds. A first step toward making the material from the Ban Chiang excavations available and more broadly known was an exhibition titled *Ban Chiang: Discovery of a Lost Bronze Age* with an accompanying catalog of the same name (White 1982). Soon after, White (1986) finished her PhD dissertation on the chronology of Ban Chiang, proposing that the earliest graves dated to 2100 BC and the latest to AD 200 and that metalworking commenced around 2000 BC.

Thus, the long chronology was laid to rest, taking some of the heat out of the debates. Nevertheless, Ban Chiang remained of interest because of its remote location and lack of strong evidence for social hierarchy, casting doubt on long-held assumptions about the mechanisms of the link between technological and societal developments. In 1992, Ban Chiang became a UNESCO (2021) cultural heritage site, further highlighting its importance. In the meantime, however, excavations conducted at other sites in northeast Thailand and subsequent research resulted in Charles Higham, the lead excavator for many of these projects, suggesting even later dates for the emergence of metallurgy in the region (Higham and Amphan 1984). This led to a long-drawn-out debate between Higham and White that became increasingly acrimonious. White suggests dates around 2000 BC for the emergence of copper-based metal production and around 800 BC for the use of iron (e.g., White 2008, 2013, 2017; White and Hamilton 2014). In contrast, Higham argues for a clear presence of bronze at Ban Chiang only around 1000 BC and ironworking from the fifth century BC (e.g., Higham 1996, 2021; Higham and Cawte 2021; Higham, Douka, and Higham 2015; Higham and Higham 2009; Higham et al. 2011). They each question the reliability of the dates the other uses and the association of the dated material and the metal remains, disagreeing on which material can provide reliable dates (bone, shell, grains from chaff-tempered pottery).

One issue in discussions surrounding Ban Chiang has been that a comprehensive publication of all materials excavated

there in the 1970s has long been outstanding. The new Thai Archaeology Monograph Series is changing this, having commenced with a well-received volume on the human skeletal remains that presented one of the largest comprehensively analyzed groups of human remains in the region (Pietrusewsky and Douglas 2001). Volume 2 in the series, split into four subvolumes, 2A–2D, combines a detailed report on the metal remains from Ban Chiang, Ban Tong, Ban Phak Top, and Don Klang retrieved during the 1974–1975 excavations with a comprehensive archaeometric analysis and reinterpretation of the finds while at the same time discussing theories and methods of archaeometallurgy in general and the emergence and nature of metallurgy in northeast Thailand in particular. It is to be hoped that future volumes in this series will provide equally detailed reports on ceramics and other objects as well as mortuary and settlement data beyond skeletal evidence and metal finds. These later volumes will hopefully also be less mired in chronological debates—or at least provide a new view based on evidence other than the contested absolute dates published thus far.

Overview and General Remarks

Volume 2A provides an overview of the site and fieldwork, local geology, and theories, methods, and discussions in archaeometallurgy more generally and research on metalworking in prehistoric Southeast Asia more specifically. Volume 2B presents the empirical evidence from the four sites, including depositional context, description of artifact types, and technical analyses. Volume 2C discusses the regional economic context, covering material from northeast and central Thailand and Laos in particular but also placing the material in the broader context of global studies of early metallurgy. Volume 2D (White and Hamilton 2021) promises to provide catalogs for metals and related remains and the detailed results of scientific analyses, which will be crucial for anyone wishing to reevaluate all or parts of the data to investigate specific questions.

All volumes are edited and in large part written by Joyce C. White and Elizabeth G. Hamilton, the latter an archaeometallurgist who has been working on Southeast Asian metals since 1999. Individual chapters have been contributed or co-written by James Muhly (foreword, vol. 2A), Samuel K. Nash (chap. 4, vol. 2B), William W. Vernon (chap. 5, vol. 2B), Vincent C. Piggott (chap. 2, vol. 2C), and T. O. Pryce (chap. 3, vol. 2C), all of them experts in archaeometallurgy with long research experience in Southeast Asia. All volumes have references and a helpful index that is separated by volume, and volumes 2A and 2B have a glossary of technical and nontechnical terms. For the more technical volume, 2B, the glossary is highly useful, especially for anyone not well versed in metallurgy. For 2A, the selection of terms also includes words that are surprising, such as adoption, bangles, bells, artifacts, comparanda, constraints, essentialize, and valuables. It is not quite clear how they were chosen, and their inclusion seems unnecessary, as the meaning of some is obvious and others are discussed in detail in the text. Location-specific terms such as incised and impressed (i&i) pot-

tery, however, which archaeometallurgists working in other areas might not be familiar with, are not listed. It is also not clear why two of the three volumes, rather than just the most technical one or all of them, have a glossary. If there is a reprint of the volumes, confining the glossary to technical terms and having it either only in 2B or in all volumes would be advisable. What should also be added is a list of abbreviations and cross-references for site, layer, context, and item references, such as BCES 385B/1115, to name a random example impossible to understand for the uninitiated. Hopefully, volume 2D will provide such a concordance. Here, the open-access online project database can be of help, though it is not clearly referenced in the present volumes. It contains micrographs, photographs, images, and context information on slag as well as on metals, crucibles, and molds, together with literature references, and there used to be a downloadable database that does not seem to work anymore (<http://db.iseaarchaeology.org/metals-database/>; accessed April 25, 2021). Presumably, all this information will be contained in volume 2D, hopefully accompanied by electronic files.

The references provided in all volumes are highly useful as a starting point for anyone wanting to learn about methods and theories in archaeometallurgy in general and discussions on early metallurgy both worldwide and in Southeast Asia more specifically. They fall a bit short in the inclusion of publications in languages other than English or French. For archaeometallurgy, there is plenty of German-language literature that could have been mentioned. What are likewise missing are references to literature in local languages. While there is not a lot published in Thai, Khmer, or Lao, there are quite a number of publications in Vietnamese and Chinese that would have been important to consult for volume 2C when discussing the material in its regional context. Including publications in such a broad range of languages probably goes beyond what a series focused on metallurgy can possibly cover, but these lacunae indicate that there is room for further research that also considers material from neighboring regions.

In terms of presentation, the volumes are highly pleasing, with a nice layout rendering the text easily readable, and they are carefully copyedited, with high-quality drawings, nice micrographs, and high-quality color and black-and-white photographs, as well as useful overview tables and a careful selection of graphs clarifying and illustrating specific points and data. The maps are likewise commendable, black-and-white, with varying levels of geomorphological detail and carefully chosen details on site locations, modern political boundaries, and the like, depending on what type of information is needed for the discussion at hand in a specific chapter or section. All in all, this is a wonderfully high standard of publication to be emulated.

Volume 2A: Background to the Study of the Metal Remains

This volume is authored by White and Hamilton, with a foreword by Muhly. Chapter 1, written by White, provides a

broad overview of the archaeology of prehistoric metallurgy with a special focus on Southeast Asia, highlighting the importance of Ban Chiang in this debate. This is a greatly useful overview of general developments and important points of discussion in the emergence, development, and context of metal production around the world, drawing on a vast range of literature. Main issues highlighted are chronology, technological transmission, social context of the development and adoption of metallurgy, and the impact that the advent of metal production and its expansion had on intra- and interregional social, political, and economic dynamics. The latter issues especially are of great interest to archaeometallurgists around the world, and this overview will be especially useful to people new to the field but also to more seasoned scholars. Of broader interest is also White's critique of the Three Age System and underlying assumptions concerning human and societal developments. In this story, finds from Southeast Asia and other parts of the world outside Europe and the Near East highlight still pervasive ideas around cultural evolutionism, as White convincingly shows. White's solution of replacing the capitalized terms of Stone, Bronze, and Iron Age with pre-metal, bronze period, and iron period could be misinterpreted as a mere relabeling exercise. This would be to miss the point, however, since these terms constantly remind the reader of the underlying theoretical issues and debates. Building on this, chapter 2, also written by White, summarizes the history of the excavation at the four sites in question and their stratigraphy and dating and provides a working chronology, distinguishing among the lower Early Period (2100–1500 BC), upper Early Period (1500–900 BC), Middle Period (900–300 BC), and Late Period (300 BC–AD 200).

Chapters 3–6 are written by White and Hamilton, White taking the lead for chapters 3–5 and Hamilton being the first author for chapter 6. Chapter 3 further develops some of the topics raised in chapter 1, especially the socioeconomic context of early metallurgy, explicitly moving beyond the issue of origins. This chapter describes a “conventional paradigm” of research on early metallurgy, while the following chapter, chapter 4, develops a “new archaeometallurgy paradigm.” Like chapter 1, chapter 3 provides a great overview of previous and current debates with a large number of references useful for anyone wanting to delve further into the matter. It does oversimplify by talking about a century of research with considerable diversity in views as being under one conventional paradigm, pitted against the new paradigm that they are following in their research. Here and even more so in chapter 1, many ideas that the authors take issue with are laid at Higham's door, slipping into an acrimonious tone that makes reading these sections uncomfortable and detracts from an otherwise brilliantly written collection.

This undertone vanishes in chapter 4, introducing the new or maybe “not-so-new” paradigm based on scholarship that the authors refer to as the “anthropology of technology,” which dates back to Gosselain, Lemonier, Pfaffenberger, and Schiffer. This chapter is a pleasure to read, providing a well-founded

and highly persuasive introduction to the foundational literature on the approach the authors are following. They focus on sociotechnical systems, which they describe as the intersection between technological systems (the material world, comprising, e.g., subsistence, metallurgical, and ceramics) and interpersonal systems (the social work, including political, religious, and societal domains). Overall, they propose an approach that “shifts away from grand narratives of change and towards investigation of process and mechanisms of innovation and adoption along with the details of change society by society” (2A:114). This approach allows for research even where absolute dates are not available or contested, as is the case here. On the basis of this outlook, the authors propose a focus on the evidence for metal technologies at the four sites under study, first identifying all relevant artifacts; then reconstructing the life history evidence of their production, usage, and deposition; looking at assemblages; providing technical studies of the artifacts and a contextual assessment of the data; and then making comparisons with other assemblages to discuss “technological tradition, regional patterning, transmission processes and sources, role in political economy, etc.” (2A:115).

Chapter 5 develops this theoretical outlook further, focusing on the economic context of metal production and consumption, again based on a broad range of literature from anthropology, archaeology, material sciences, and other disciplines. They discuss four main areas: (1) issues surrounding craft production, specialization, and economic control of production processes; (2) consumer demands, including concepts of valuables and prestige goods; (3) trade and exchange, including style and commodity movement, provenance sourcing, and mechanisms of exchange; and (4) economics, wealth, and regional exchange systems, what they call “middle-range societies.” They argue convincingly against assumptions that early metal production was governed by considerations of efficiency, a ruling elite, or market forces of supply and demand in the modern sense. For Southeast Asia and northeast Thailand in particular, they suggest the presence of middle-range societies, which were not states but had complex social structures with considerable local variability yet were integrated into complex networks of exchange. Metal production, so they argue, was conducted by independent part-time specialists, and their products were made not with efficiency in mind but to provide objects of ritual or social significance, be they to signify identity or to be used in exchange. Foreshadowing volume 2C, they explain that their study aims are to “elucidate the role of metals in multiscalar exchange networks of prehistoric Thailand by examining the place of metals in social, economic, and political networks” (2A:135).

Chapter 6 provides an excellent overview of the geography of northeast Thailand: present-day landforms, plate tectonics, ore formation, and metallogenesis in mainland Southeast Asia. The nature and location of each of the different types of metal resources (copper, tin, lead antimony, iron, arsenic) are discussed, and several maps show their modern distribution

in relation to metallogenic belts. Usefully, these maps also show geomorphology and highlight the location of Ban Chiang and known metal extraction sites (figs. 6.4, 6.5). As the authors point out, the picture is far from complete, as these maps do not reflect small sources that may have been exhausted in the past or overlooked or disregarded by modern geologists. The fact that the lead isotope signatures of artifacts from Ban Chiang and Don Klang do not match those from known extraction sites confirms the suspicion that much is yet to be learned about the locations of prehistoric ore extraction sites in Southeast Asia. Still, there are plenty of sources for copper, lead, iron, and tin available throughout Southeast Asia, which would have made it easy to obtain the necessary raw materials without long-distance elite-controlled networks, as the authors argue.

Chapter 7, written by Hamilton, connects back to the methodology discussions in chapters 3–5 while also drawing on the information on raw materials provided in chapter 6. Chapter 7 also provides the foundation for the metal analyses in volume 2B. It starts with an overview of the archaeological evidence left by the various steps in the production process of copper-based metallurgy (table 7.1). These are then introduced in detail on the basis of anthropological, experimental, and archaeometallurgical research, starting with copper extraction (prospecting, mining, beneficiation, roasting, charcoal preparation, and smelting), then moving to finished objects (refining the copper, alloying, casting, and working), and finally discussing special alloys. The same is then done for bloomery iron smelting (table 7.2). Here, additional ethnographic evidence on labor organization, ritual, and gender is briefly summarized. Throughout the chapter, Hamilton draws on research from around the globe but also emphasizes material from Southeast Asia. Overall, this chapter provides an excellent overview of the steps in metal production processes and their material correlates that might be observable archaeologically, connecting them to socioeconomic structures where possible and laying the ground for the study of the material at hand in volume 2B.

Volume 2B: Metals and Related Evidence

Large parts of this volume are written by Hamilton, with some chapters written by or coauthored with White and others coauthored with Samuel K. Nash and William W. Vernon. Rather than presenting only a few choice artifacts, this volume provides an analysis of the entire assemblage of 639 metal objects and related items from prehistoric contexts and 110 objects from historic contexts at the four sites.

Chapter 1 is a brief introduction by White laying out the plan of the volume. Chapter 2, by Hamilton, explains the methods used in analyzing the artifacts, starting by describing the collection, conservation, databases and recording, and methods for metallurgical analysis (optical metallography; compositional analysis, including particle-induced X-ray emission, X-ray fluorescence, scanning electron microscopy, and optical emission

spectroscopy; and microhardness). Hamilton emphasizes that previous studies were based on a small and unbalanced selection of samples, so she chose a broad range of items, conducting metallographic analysis of more than 170 artifacts and elemental analysis of more than 50 items, making every effort “to select samples of sound metal from a full range of artifacts, strata, and sites” from an unusually “complete, well-documented, and relatively uncorroded collection of the products of a prehistoric metalworking technological system” (2B:3). This, she stresses, is necessary because “a technological system cannot be reconstructed, even tentatively, from limited and unrepresentative samples of materials” (2B:16). To eliminate individual and technical differences, Hamilton and Nash analyzed all samples themselves, even previously analyzed samples.

Chapter 3, likewise written by Hamilton, presents a typological analysis of the artifacts. While she acknowledges that these must be integrated with material culture made of other kinds of materials, she argues that it is justifiable to study the metal objects in isolation because “the very presence of metal alloy artifacts at any prehistoric site, as well as the artifacts used in their manufacture, implies much about the technological knowledge and inter- and intra-site social cooperation” (2B:18–19). While this might be true, metal items are relatively rare within the assemblages of all sites in the region. I would therefore argue that it is difficult, even impossible, to come to a clear understanding of the nature of the sites and the socioeconomic makeup of the communities inhabiting them and buried there on the basis of a study of metal artifacts alone. Still, analyzing all materials separately by material category first, especially when taking a *chaîne opératoire* approach as done here, is advisable, though they should be viewed together with the other material evidence in the end to provide a more complete picture. The items in question are mostly ornaments, especially bangles in a variety of shapes and a small number of rattle-type bells, as well as a few tools (adzes or axes, blades, points [small points, spearpoints, socketed points, unclassified points]) and fragmentary items of unclear function (wires and rods, flat pieces, amorphous artifacts). These are all described and illustrated with high-quality drawings. The numbering of the artifacts is a bit confusing, as it does not indicate raw material or retrieval context beyond the abbreviated site name. Here, a concordance, which may be provided in volume 2D, would be useful. The artifact counts by class and metal as well as their distribution by period and other numerical information are provided in convenient tables.

Then follows an explanation of the terminology used in defining the bangle types, which are presented in an overview table of parent types A–O and subtypes 0–3, plus a category labeled “unknown” (table 3.4). Some of the types can be correlated to an earlier typology by Nigel Chang (2001). These were initially based on a 12-style typology of ornaments of shell, stone, and bone found at the coastal site of Khok Phanom Di developed by Pilditch (1993). Chang (2004) adapted this for ornaments made from various materials recovered from Nong Nor, resulting in 21 basic styles, and expanded it to 29 bangle

styles to incorporate items from Ban Lum Khao. As the items discussed here are all made of metal and thus have a different range of shapes, Hamilton developed a new typology. The whole range applies only to copper-based metal artifacts, which have mostly been cast in the lost wax process, allowing for a wider range of forms, while the iron bangles are more limited in their shapes (2B:46). In terms of chronology, it is pointed out that—with the exception of the bells, which appear only in the Late Period—all artifact classes are consistently present over time, and even the introduction of iron did not lead to major changes in bangle morphology. This suggests that the metal object types and subtypes cannot be used for establishing a precise (and much-needed) relative chronological framework. For this purpose, ceramics might be more suitable, though these naturally do not have much mention in these metal-focused volumes.

Chapter 4, written by Hamilton and Nash, describes the results of their detailed technical analyses. The chapter starts with an introduction to metallography, providing a clear description of the techniques used and their potential and limitations, written in a way that is also understandable to non-experts without being overly simplistic. The chapter aims to offer “a convincing case for the usefulness of detailed laboratory analysis of both mortuary and non-mortuary data” (2B:102), which it does beautifully. It is to be read together with chapter 5 in the same volume, which provides the results of the analyses of the crucibles, and chapter 3 in volume 2C, which discusses the lead isotope results, as they develop “a clear picture of the characteristics, both technical and social, of this technological system in northern northeast Thailand” and present “a baseline contribution, setting the framework and model for further comparative analytical work” (2B:102). Chapter 4 provides a technical analysis by class, site, and period and compositional analyses identifying 67 objects of 2%–19% tin bronze, 53 bronze or copper items, 4 impure copper objects, 2 tin bronzes with arsenic, 9 leaded artifacts, and 29 high-tin bronzes. It then discusses fabrication evidence by class and metallurgical structure and finally summarizes the results of hardness tests. The chapter then turns to variability in fabrication separated by locales and finally summarizes the results from the point of view of changes over time. As even the earliest bronze items show evidence of a full grasp of the technique, the authors suggest that the technology, including raw material extraction, alloying with tin and lead, casting, working, and annealing, was introduced from the outside fully formed. The alloy recipes were not tailored to specific artifact types, there was not any indicator that object performance was considered when choosing alloys, and there was no evidence for the deliberate hardening of cast bronzes or forged iron, even in the case of tools and weapons. Iron was introduced in the Middle Period, and some high-tin bronzes appeared in the Late Period, but otherwise most objects were made of binary bronze with little change over time, and there was little reworking after casting. In terms of production organization, the authors suggest that the techniques used could easily have been practiced by part-time specialists without the

involvement of an organizing elite or a large number of people, thus confirming White and Pigott’s (1996) suggestion that metal production in prehistoric northeast Thailand was based “on intracommunity specialization that took place in a relatively egalitarian and mostly peaceful society” (2B:102), as the lack of large-scale production of effective metal weapons suggests.

Chapter 5, written by Vernon, White, and Hamilton, describes what insights into the technological process can be gained from clay crucibles, molds, and slag. Two complete crucibles and 102 crucible fragments, the vast majority of them from Ban Chiang, were analyzed morphometrically, by analysis of composition, use wear, and residues. They were tempered with rice chaff, grog, quartz sand, slag, organic temper, or a mixture of two of the above, similar to crucibles found at other sites in northeast Thailand and wider Southeast Asia. This leads the authors to argue for the existence of a sophisticated crucible technology centered at Ban Chiang. There are only six molds or partial molds made of sandstone or clay, but it is unclear what was cast in them. Agreeing with Higham’s assessment that the bangles were mostly made by lost wax casting, the authors point out that the molds would have been small and fragmented, so the fragments could have been mistaken for potsherds and thus underreported (2B:119).

In terms of evidence for iron production, half of the 21 pieces of slag (the only evidence for iron production discernible) were found at Don Klang, but only 12.7% of the metal assemblage there was of iron (vs. 25.3% at Ban Chiang). The large number of slag pieces and a slag pile on the site surface all point to Don Klang having had lots of iron smelting and smithing, as the authors emphasize (2B:119–120). No hearths were found, and it was instead suggested that the crucibles were heated internally while embedded into the ground. On the basis of the lack of evidence for ore processing, the authors suggest that the smelting of ores took place elsewhere but that refining was done at Ban Chiang. The crucibles point only at the casting of small metal items, and it is not certain whether all copper-based items were made by crucibles present at the sites in question. Interestingly, different sites seem to have specialized in different ranges of artifacts, even though metal production was relatively small in scale. Like the object shapes, the crucible morphology and technology are quite homogeneous throughout time, with people “melting ingots of copper, tin, and bronze, and casting the copper-base metals into artifacts in bi-valve molds of stone and lost wax molds of ceramics” and also smithing iron from the Middle Period onward (2B:124). It remains unclear whether each village had its own metalworkers or whether there was a group of itinerant metalworkers moving among villages. This will require further research, as the authors point out.

Chapter 6, written by Hamilton and White, investigates the depositional context under a life history framework, emphasizing that materials found in domestic contexts are just as important as those found in graves. They start from metals as grave goods, discussing the placement and treatment of metal

items with detailed plans and photos for each case as well as tables connecting age, sex, period, phase, and grave goods. While most tables and the text focus on the metal objects, the grave plans and table 6.8 also include information on nonmetal burial goods, which will be of importance to more comprehensive analyses of burial customs and overall material culture assemblages that are hopefully to come in future volumes. It is noteworthy that a high percentage of subadults received metal artifacts and that women seem to have received slightly fewer metal items than men, though the number of cases is quite low, meaning that further research, such as an evaluation of overall mortuary assemblages, not just metal items, is needed. Chronologically speaking, metal items appear in all periods, with bangles being the dominant metal grave good, and in later periods iron items, both bangles and other items, are added. Throughout, subadults and men receive a larger proportion of metal items. Furthermore, metal items tend to cluster in graves, but there is no repetition of objects in the same grave or repetition of the same sets between graves, suggesting that each suite is unique to the individual in question (2B:151). There are no metal production tools in any of the graves analyzed here, though they appear at other sites in northern and central Thailand, suggesting local and regional differences. In a next step, the authors discuss “burial-associated metals,” that is, items found near burials, reviewing each in turn to assess whether they were from the grave fill, from settlement layers or other features, or from disturbed graves. Then they turn to “feature metals” (i.e., metal items from nonburial contexts), which were much more numerous than those found in graves. Naturally, feature metals were largely fragmented, mostly metal lumps left over from production activities and bangle fragments. Overall, they conclude that only 15.3% of the metal artifacts came from burials, while the majority were found in the general soil matrix, pointing to frequent metal production activities and a fairly abundant presence of metal in daily life.

In chapter 7, White and Hamilton again emphasize the importance of analyzing nonmortuary metal finds in detail and in a contextual manner with a life histories approach. They focus on the earliest copper-based and iron metal finds at the four sites, considering possible disturbances and relocation, especially of small metal fragments, by bioturbation, monsoonal rains, or other kinds of intrusions. Such considerations are crucial for the chronology debate. Though this a touchy issue, as especially volume 2A has shown, in this chapter the matter is discussed fairly neutrally, with the evidence clearly laid out on the basis of local stratigraphy and relative local chronology rather than absolute dates. This makes the chapter particularly useful for all future research on the matter, regardless of what future discussions on absolute dates may bring. Although there might be some issues with individual fragments having been dislocated, they firmly establish that there is evidence for metalworking and consumption before the appearance of metal items in burials and together with iron pottery. They name an amorphous fragment from a hearth in Level 4 in the Ban Chiang lower Early Period context, which is contemporaneous with lower Early Period II

burials, as the earliest copper-based item found to date. For iron, the earliest find came from below grave 31 of lower Early Period III and IV at Ban Chiang, where iron is more common than at the other sites. Interestingly, while copper-based metal items continue to be rare in all contexts, with a notable increase only in upper Early Period nonmortuary contexts at Ban Chiang and Ban Tong, the continued presence of fragments in all layers throughout all sites suggests that “metal was not so precious that it was meticulously recovered for recycling” (2B:199), indicating that metal may not have been seen as crucially important, rare, difficult to access, highly coveted, or under the control of a handful of people. Nevertheless, on the basis of the abundance of iron fragments at Ban Chiang, the authors suggest that there “may have been differential access to metal on a site-by-site basis,” while the considerable variation in emphasis on the use of metals “could relate to local consumer choices and behaviors” (2B:201). All in all, this volume, with its detailed description and analysis of the available evidence for metalworking and consumption across the four sites, discussed with a *chaîne opératoire* and life histories approach within a local relative-chronological framework and with great attention to context and technological details, provides a great basis for comparative research with other sites in the region and beyond.

Volume 2C: Regional Context

This volume places the material presented and analyzed in volume 2B into a broader regional context, with a focus on socioeconomic matters. For a general overview, the volume provides an administrative map showing the main sites in question and the provinces of Thailand and Laos and a nice foldout table showing a working relative chronology of selected prehistoric sites from northeast and central Thailand developed by White on the basis of ceramic styles and a few other material features seen as chronologically or regionally distinctive. The latter is part of chapter 4 but applies to the entire volume.

Chapter 1, by White, is a general introduction and short summary of the individual chapters. Chapter 2, written by Vincent C. Pigott, provides an overview of known mining and smelting sites in northeast Thailand (the Phu Lon Copper Mining Complex), central Thailand (the Lopburi region, including Non Pa Wai, Nil Kham Haeng, Non Mak La, Khao Sai On, Khok Din, and Noen Din), and central Laos (Sepon, including Khanong A2 and Tenghkam South D). The accounts are detailed, providing ore body maps, geomorphological maps, ore body stratigraphies, radiocarbon dates, descriptions and photos of the material evidence, and research results concerning production processes. It becomes clear that the evidence from central Thailand is especially abundant, with some massive sites of substantial time depths with plenty of archaeological evidence. The largest known mines that operated in prehistoric times are those at Phu Lon, near Lopburi, and at Sepon, though others were probably in existence. Crucible smelting was the

main extraction technology observed at all sites. Bivalve molds made of stone (mostly in northeast Thailand) or clay were used to make socketed implements. The author points out a number of distinct techniques that connect some production sites but not others and argues for the existence of an exchange network, with raw copper from the Khao Wong Prachan Valley in central Thailand reaching Ban Non Wat and other sites in northeast Thailand, which added alloys and cast final products. Indeed, it seems that the sites in central Thailand mostly provided raw copper, while alloying and casting were done elsewhere. Pigott largely agrees with Pryce et al. (2010) that the adoption of metallurgy here may have been selective, with copper chosen rather than the tin bronze prevalent in northeast Thailand. Connecting the issue to broader discussions in Asian archaeology, Pigott explains that the presence of tin bronze there has been used to argue for a transmission of the technology from the outside, possibly from the Eurasian steppe (see, e.g., Ciarla 2007; Higham 1996; White 1988). Pigott also reviews some of the debates on and evidence for the use of a mold plug for creating cast sockets having been transmitted from north to south, though overall, he points out that more fieldwork and laboratory analyses are needed to investigate the routes followed and people involved. In conclusion, Pigott suggests that the substantial copper extraction in central Thailand may have helped meet consumer demands for copper-based metal items in surrounding areas during the first millennium BC, though the exact details, dimensions, and routes of production, exchange, and consumption are to be explored further.

Chapter 3, written by T. O. Pryce, reports on lead isotope analyses conducted on 20 items from Ban Chiang and Don Klong that provide information on the details of the networks linking metal producers and consumers. The chapter highlights the importance of making data widely available, as was done via the Ban Chiang Project online database, to allow for comparison with other regional assemblages. So far, these comparisons have been based on typology, microstructures, and elemental composition; however, lead isotope signatures can additionally help identify the origin of metal raw material and help reconstruct exchange networks. The study identifies five alloy groups (bronze, leaded bronze, leaded high-tin bronze, leaded copper, and high-tin bronze), with isotope data suggesting primary production or secondary recycling. Five items from Ban Chiang and two from Don Klong may have been produced with copper from Sepon, central Laos, while the others “fall within the core Mainland Southeast Asian copper-base metal consumption field” (2C:62), though further research is needed to investigate more precise provenience and potential preferences for using material from specific sources for specific object types or at specific production or consumption sites. So far, the evidence suggests that “consumer villages were getting copper, lead, and presumably tin from more than one producer population/network” (2C:62). Pryce ends by emphasizing the importance of a copper-based metal exchange database for prehistoric Southeast Asia (including information on typology, technology, chronology, and geochemistry, including lead isotope

data), which is currently under construction, as this allows for research on exchange networks of raw materials and products.

Chapter 4, written by Hamilton and White, compiles archaeometallurgical evidence from prehistoric northeast and central Thailand previously published in a wide range of publications in sometimes obscure places. This chapter, especially its great summary tables, including one on prehistoric metallurgical evidence in northeast and central Thailand (table 4.1), one on archaeometallurgical research in Thailand (table 4.2, including references to the publications in question), and a concordance for regional temporal units in relation to the Ban Chiang periodization (table 4.3, though the absolute dates are contested and are appropriately labeled “working time range”), promises to be exceedingly useful for all future research on the topic. The text is detailed and clear, starting from a regional relative chronology; introducing the first metal-consuming sites in northern northeast Thailand, then those in southern northeast Thailand, and finally those in central Thailand; and laying out all the archaeometallurgical evidence from 34 sites in addition to the eight sites covered in chapter 2 and the four sites at the core of the four-part volume 2. This forms the basis for the following chapter.

Chapter 5, written by White and Hamilton, describes what can be gleaned about metal production and consumption in prehistoric northeastern and central Thailand starting with early metal technological systems, then turns to iron, and finally discusses the social contexts of metallurgy. The authors take the *chaîne opératoire* approach established in volume 2A and also applied in parts of volume 2B, discussing mining, ore processing, crucible smelting, installations, further processing, alloying, and various casting techniques and discussing changes over time (especially in alloying) and regional variation and networks. The emerging picture suggests broadly shared general technological systems practiced largely on a household level combined with considerable diversity in the details of metallurgical practices, echoing the diversity of object shapes (metal, ceramic, and other materials) and burial practices. For instance, the authors argue that crucible technology was common throughout northeast and parts of central Thailand, but the composition and sources of the copper base metal differed among sites, suggesting the existence of distinct but spatially overlapping communities of practice. Consumption patterns were also variable, but at none of the sites did copper and bronze objects seem to be markers of high status or wealth, and there is no evidence for elite control over or the centralized organization of production or distribution. Networks of exchange of raw materials and final products alike were variable as well and shifted over time, likewise indicating a decentralized system not controlled by any specific group. In terms of networks, the authors mention lead isotope studies as well as technological transfer. Lead isotope studies as conducted by Pryce, so they emphasize, have the potential to trace specific exchange networks for raw materials and finished products. In terms of technological transfer, Khao Sam Kaeo, for instance, which was previously thought to have received its copper from

one location, seems to have received its ores from a variety of sources, making them into artifacts in a variety of styles from South Asia, Vietnam, and western Han China (2C:142–143; see also Murillo-Barosso et al. 2010; Pryce et al. 2014). These long-distance connections are not discussed further, though, which leaves many questions for future research.

The sections on iron are short and of limited depth, but the evidence is relatively limited to begin with. On the whole, there seems to be much continuity between bronze and iron in terms of production and consumption. The chapter discusses so-called founder's burials (i.e., graves containing metal production tools and thus interpreted as holding the remains of metalworkers) and consumer burials. It suggests that there were no clear rules as to who got metal objects and what kind they got, while metalworkers (if people buried with metalworking tools were indeed thus specialized) were buried next to people with no such special knowledge or occupation. It is noteworthy, however, that to date only Non Nok Tha shows evidence for both men and women having been buried with metalworking tools. This potential difference in the construction of gender identities in different communities deserves further research in future studies. In conclusion, the authors emphasize the community-driven nature of metal production and consumption, which needs to be taken into consideration when considering routes and mechanisms of technological transmission, a matter that still requires further research.

In the final chapter, chapter 6, White discusses metals in prehistoric Thailand in their social contexts, starting from the possible connection between the proximity of suitable ores and the emergence of early metallurgy, then turning to socioeconomic aspects of metal production, then turning to mechanisms of the transmission and adoption of metal technology, and ending with suggestions for future work in the region as well as the contribution of Southeast Asia to archaeometallurgy in general. She points out that in contrast to the "Bronze Age arms race" observed for prehistoric Europe, in Southeast Asia the adoption of bronze does not seem to have led to an increase in violence or the emergence of a dominant elite. Here, White argues that the abundance of ores stimulated the emergence of relatively peaceful and stable agrarian societies with community-centric networks of exchange of technological knowledge, ores, and final products, rather than social and political elites controlling everything in a top-down manner. White emphasizes the variability in production and consumption patterns that responds to differences in consumer demands in largely localized production activities that supply small implements and personal ornaments for individual use, although they may also have been exchanged or given as gifts to "foster social and political debts and alliances" (2C:167). As this evidence does not fit with a prestige good exchange model, she suggests turning to Shennan's regional exchange system model, which is based on the principle that some communities specialized in certain things to exchange them for other commodities that were produced by other communities, "fostering a regional economic specialization undertaken by nearby autonomous communities" (2C:169), in

this case in a peaceful manner with no particular demand for metal weapons. The evidence does indeed point to the presence of heterarchical networks independent of centralized or hierarchical controls, networks that were probably established before the advent of metallurgy, as White says, agreeing with Higham (2014:129).

There is also evidence for more far-flung networks, but these receive little attention here. The present study does not provide new insights into these long-distance contacts, the routes of the earliest transmission of metallurgy into Southeast Asia, or later technological innovations. White summarizes the debate, pointing again at evidence that she sees as contradicting the shorter chronology proposed by Higham, but she contends that more archaeometallurgical research in southern and southwest China—and further chronometric data—is needed to move the (transmission of copper-based and iron metallurgy into Southeast Asia) debate forward. She furthermore suggests that "detailed evidence for the chaînes opératoires needs to be traced over space and time to reconstruct networks of practitioner communities" (2C:170). Such detailed studies on practices—as presented in these volumes—indeed promise to help explain mechanisms of transmission, adoption, and changes over time as well as their embeddedness in local sociopolitical structures and practices and their connection with various networks of exchange. Such studies may also help put to rest debates on chronology if accompanied by studies on other aspects of material culture and social structures and practices and research on relative and absolute dating using various methods and techniques. White emphasizes that in all, this is a broad range of samples, and consideration of full archaeological assemblages, rather than a "limited study of a handful of selected metal grave goods" (2C:171), is needed, but it needs to be embedded into clearly stated and well-thought-out frameworks.

Next, White turns to an explicit and extended critique of "the Higham metal age model," which she sees as "based on essentialist lines of reasoning," leading to "misinterpretation of social phenomena" based on "conflation, data normalization, reified boundaries, and profound oversimplification" (2C:172). In particular, she criticizes the focus on elites and the suggestion of dramatic social changes, caused partially by the separate treatment of graves as cemetery sites rather than as "residential burials in intimate proximity to daily life activities" (2C:173). Furthermore, she comes back to the argument made in volume 2A that the chronology proposed by Higham "artificially shortens Thailand's bronze period by several centuries and its iron period by two to three centuries" (2C:176). White admits that Higham (2014) does discuss "transegalitarian ideas" in some of his more recent publications but still sees his framework as essentially flawed. The way forward that she proposes is to focus on regional case studies that consider their full sociocultural, economic, and technological contexts to explain technological change over time. White suggests that this will require more fieldwork, studies of full assemblages, thorough technical analysis, detailed publications of full assemblages and typologies, more lead isotope work, and "improved conceptual tools"

(2C:177). She sees Chernykh's (1980) concept of metallurgical provinces ("a system of kindred metallurgical and metalworking foci on centers, limited in space and time" [320]; recently also applied to Southeast Asia, which he calls the Indo-Chinese metallurgical province; see Chernykh 2014:1008, fig. 6) as particularly useful for integrating economic and technological systems with geographic information to provide a more holistic picture of past technologies. This concept has—quite rightfully, I would say—been criticized as too metal-centric and prone to emphasizing hierarchies (e.g., Courcier 2014; Roberts 2014), which especially in the case of Southeast Asia would not be suitable. White sees this as less important but emphasizes the focus on practitioner networks transcending local cultures, as they needed to face raw material needs and technological choices as well as limitations. She points out that there is now evidence for certain focus areas of metalwork, such as mining or smelting versus other areas, with evidence for consumption rather than production, so there is something to be said for a spatial approach taking into account geology and geography as well as technological, economic, and social aspects to see how they all hang together in a specific region. Still, it remains questionable whether it is helpful to draw specific boundaries around such a supposed "province" or whether it is even advisable to focus on metallurgy alone. The latter focus implies that metal was the main *movens* according to the idea that "metals make the world go round" (Pare 2000), thus overemphasizing the importance of metallurgy in a region where metal items do not seem to have been of great importance in terms of status, social organization, or broader economic structures or processes. This will require further discussion.

Further research and debate on intraregional technological traditions are also needed. Here, White discusses what she sees as two distinct subtraditions, one using unalloyed copper (Lopburi area), the other tin bronze (northeast Thailand and Laos). Here again she points to the need for further elemental and lead isotope studies of a larger number of samples to explain what might be called the flow of metals, both newly mined ores and worked materials all the way to finished products and remelted items. This is also connected with debates on economic networks and more generally around communities of practice. The material from Thailand seems to indicate that here technology had an integrative function (as pointed out by White, following Pfaffenberger [2001]) rather than leading to social, political, or regional hierarchization, a phenomenon that may not be unique to Southeast Asia but is sufficiently different from Europe and western Asia, where development was traditionally seen as "the norm." In conclusion, White emphasizes that the material from Southeast Asia "demonstrates that the avenues for adopting metallurgy had no single path" (2C:183), thus challenging many long-held assumptions on the interplay between technological and sociopolitical development as well as cultural evolutionism-based models of social complexity more broadly. Indeed, technology-focused research like that presented in these volumes can provide broader insights into social structures

and cultural processes as well as their embeddedness in local geographies.

Conclusion

All in all, the soon-to-be four-part publication provides detailed documentation and multifaceted analysis of the evidence for metal production at the sites of Ban Chiang, Ban Tong, Ban Phak Top, and Don Klang, as well as some suggestions on the regional context. Many of the series' chapters, however, go far beyond what is needed to introduce the material or the analytical results, reviewing theories, suggesting new approaches and different points of view, and discussing principles and issues of archaeological research on technology more broadly. The volumes are thus of interest to a broader readership beyond scholars working in Southeast Asia or on early metallurgy in particular. They also show how even limited excavation areas and a single class of materials represented by a relatively small number of artifacts can provide deep insights into the actions of the people who produced and used them and even into patterns of human behavior more generally speaking. Indeed, they show clearly that the material from Southeast Asia can help question and make us rethink long-held assumptions about the connections between technological and societal developments as well as their embeddedness in local and regional geographies (including raw material availability).

Throughout the volumes, the authors point out many topics for further research, the most significant being research into the long-distance contact and interaction beyond Thailand and Laos. It does come as a bit of a surprise that the volume on the regional context does not go beyond those regions, though that would probably require an additional volume, if not an entire set of volumes. Furthermore, the authors emphasize their aim to go beyond origin stories and instead focus on local developments that can be discussed even in the absence of widely accepted absolute dates. This proves to be highly productive for the core of the present volumes after the somewhat off-putting tone of the chronology discussions in chapters 1–3 in volume 2A. Interestingly, while volume 2A lists contributing to the ongoing debate between White and Higham as one of the main aims of this set of volumes, in 2C the main aims are stated as providing the excavated and analytical evidence on metal production at the four sites, placing the data in a regional context, and presenting current theoretical perspectives to place the data in their social, economic, and political contexts (2C:155), aims that are clearly met and can be—and are—discussed without any of the acrimony dominating the chronology debates. Indeed, in volume 2C in particular, it becomes clear that White and Higham agree on many questions regarding socioeconomic issues and even long-distance contacts and their connections with early metallurgy. A further aim that the volumes meet beautifully is highlighting the importance of Southeast Asia for global archaeology and providing "a foundation upon which many future studies of the archaeometallurgy of Southeast Asia and many future Ph.D. dissertations can

build” (2A:XXIII). One particular topic that requires further work is connections with neighboring regions. There are a number of recent publications—some with reference to the volumes discussed here (e.g., Higham 2021; Yao et al. 2020)—that explore the connections between Southeast Asia and southern China, especially in regard to copper-based technologies but also taking into account evidence for rice and millet farming, which has received much attention in recent years. Such research continues to be hampered by the lack of secure relative and absolute dates for many of the relevant sites, which prevents definite conclusions on the timing and direction of exchange. Indeed, for many sites, including the sites presented in the volumes discussed here, complete excavation reports and studies on other types of evidence—such as pottery, which may provide an independent source of evidence for resolving issues of chronology—are still outstanding. The latter issue is hopefully going to be addressed soon in future volumes in the Thai Archaeology Monograph Series.

References Cited

- Chang, Nigel J. 2001. Personal ornaments in Thai pre-history: Nong Nor, Ban Lum Khao and Noen-U-Loke. PhD thesis, University of Otago, Dunedin, New Zealand.
- . 2004. The personal ornaments. In *The excavation of Ban Lum Khao*, vol. 1 of *The origins of the civilization of Angkor*. C. Higham and R. Thosarat, eds. Bangkok: Fine Arts Department of Thailand.
- Chernykh, E. N. 1980. Metallurgical provinces of the 5th–2nd millennia in eastern Europe in relation to the process of Indo-Europeanization. *Journal of Indo-European Studies* 8:317–336.
- . 2014. Metallurgical provinces of Eurasia in the Early Metal Age: problems of interrelation. *Iron and Steel Institute of Japan International* 54(5):1002–1009.
- Ciarla, Roberto. 2007. Rethinking Yuanlongpo: the case for technological links between the Lingnan (PRC) and Central Thailand in the Bronze Age. *East and West* 57(1/4):305–328.
- Courcier, Antoine. 2014. Ancient metallurgy in the Caucasus from the sixth to the third millennium BCE. In *Archaeometallurgy in global perspective: methods and syntheses*. Benjamin W. Roberts and Christopher P. Thornton, eds. Pp. 579–664. New York: Springer.
- Gorman, Chester, and Pisit Charoenwongsa. 1976. Ban Chiang: a mosaic of impressions from the first two years. *Expedition* 8(4):14–26.
- Higham, Charles F. W. 1996. *The Bronze Age of Southeast Asia*. Cambridge World Archaeology. Cambridge: Cambridge University Press.
- . 2014. *Early mainland Southeast Asia: from first humans to Angkor*. Bangkok: River.
- . 2021. The later prehistory of Southeast Asia and southern China: the impact of exchange, farming and metallurgy. *Asian Archaeology* 4:63–93.
- Higham, Charles F. W., and Kijngam Ampham, eds. 1984. *Prehistoric investigations in northeast Thailand: excavations at Ban Na Di, Non Kao Noi, Ban Muang Phruk, Ban Chiang Hian, Non Noi, Ban Kho Noi, and site surveys in the Upper Songkhram and Middle Chi Valleys*. BAR International Series. Oxford: British Archaeological Reports.
- Higham, Charles F. W., and H. Cawte. 2021. Bronze metallurgy in Southeast Asia with particular reference to northeast Thailand. *Journal of World Prehistory* 34(1):1–46.
- Higham, Charles F. W., Katerina Douka, and Thomas F. G. Higham. 2015. A new chronology for the Bronze Age of northeastern Thailand and its implications for Southeast Asian prehistory. *PLoS ONE* 10(9):e0142511.
- Higham, Charles F. W., and Thomas F. G. Higham. 2009. A new chronological framework for prehistoric Southeast Asia, based on a Bayesian model from Ban Non Wat. *Antiquity* 83(319):125–144.
- Higham, Charles F. W., Thomas F. G. Higham, Roberto Ciarla, Aikaterini Douka, Kijngam Ampham, and Fiorella Rispoli. 2011. The origins of the Bronze Age of Southeast Asia. *Journal of World Prehistory* 24:227–274.
- Muhly, James David. 1976. *Copper and tin: the distribution of mineral resources and the nature of the metals trade in the Bronze Age*. New Haven: Connecticut Academy of Arts and Sciences.
- Murillo-Barroso, Mercedes, T. O. Pryce, Bérénice Bellina, and Marcos Martín-Torres. 2010. Khao Sam Kaeo: an archaeometallurgical crossroads for trans-Asiatic technological traditions. *Journal of Archaeological Science* 37(7):1761–1772.
- Pare, C. F. E., ed. 2000. *Metals make the world go round: the supply and circulation of metals in Bronze Age Europe: proceedings of a conference held at the University of Birmingham in June 1997*. Oxford: Oxbow.
- Pfaffenberger, Bryan. 2001. Symbols do not create meaning—activities do: or, why symbolic anthropology needs the anthropology of technology. In *Anthropological perspectives on technology*. M. B. Schiffer, ed. Pp. 77–86. Albuquerque: University of New Mexico Press.
- Pietrusewsky, Michael, and Michele T. Douglas. 2001. *The human skeletal remains*, vol. 1 of *Ban Chiang, a prehistoric village site in northeast Thailand*. Philadelphia: University of Pennsylvania Museum of Archaeology and Anthropology.
- Pilditch, J. S. 1993. The personal ornament. In *The material culture*, pt. 1, vol. 3 of *The excavation of Khok Phanom Di: a prehistoric site in central Thailand*. Charles F. W. Higham and Rachanie Thosarat, eds. Pp. 119–176. London: Oxbow.
- Pryce, T. O., Sandrine Baron, Bérénice H. M. Bellina, Peter S. Bellwood, Nigel Chang, Pranab Chattopadhyay, Eusebio Dizon, et al. 2014. More questions than answers: the Southeast Asian Lead Isotope Project 2009–2012. *Journal of Archaeological Science* 42(1):273–294.
- Pryce, T. O., V. C. Pigott, M. Martín-Torres, and T. Rehren. 2010. Prehistoric copper production and technological reproduction in the Khao Wong Prachan Valley of Central Thailand. *Archaeological and Anthropological Sciences* 2(4):237–264.
- Roberts, Benjamin W. 2014. Production networks and consumer choice in the earliest metal of western Europe. In *Archaeometallurgy in global perspective: methods and syntheses*. Benjamin W. Roberts and Christopher P. Thornton, eds. Pp. 423–446. New York: Springer.
- Solheim, Wilhelm G. 1968. Early bronze in northeastern Thailand. *Current Anthropology* 9(1):59–62.
- UNESCO. 2021. Ban Chiang archaeological site. <https://whc.unesco.org/en/list/575/> (accessed April 24, 2021).
- White, Joyce C. 1982. *Ban Chiang: discovery of a lost Bronze Age: an exhibition organized by the University Museum, University of Pennsylvania, the Smithsonian Institution, Traveling Exhibition Service, [and] the National Museums Division, Department of Fine Arts, Thailand*. Philadelphia: University of Pennsylvania Press.
- . 1986. A revision of the chronology of Ban Chiang and its implications for the prehistory of northeast Thailand. PhD dissertation, University of Pennsylvania, Philadelphia.
- . 1988. Early East Asian metallurgy: the southern tradition. In *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*. R. M. Ehrenreich, C. I. Crumley, and J. E. Levy, eds. Pp. 175–181. Arlington, VA: American Anthropological Association.
- . 2008. Dating early bronze at Ban Chiang, Thailand. In *From Homo erectus to the living traditions: choice of papers from the 11th International Conference of the European Association of Southeast Asian Archaeologists, 25th–29th September 2006*. J.-P. Pautreau, A.-S. Coupey, V. Zeitoun, and E. Rambault, eds. Pp. 91–104. Chiang Mai: European Association of Southeast Asian Archaeologists.
- . 2013. Ban Non Wat: new light on the metal ages of Southeast Asia. *Antiquity* 87(337):1230–1232.
- . 2017. Changing paradigms in Southeast Asian archaeology. *Journal of Indo-Pacific Archaeology* 41:66–77.
- White, Joyce C., and Elizabeth G. Hamilton. 2014. The transmission of early bronze technology to Thailand: new perspectives. In *Archaeometallurgy in global perspective: methods and syntheses*. Benjamin W. Roberts and Christopher P. Thornton, eds. Pp. 805–882. New York: Springer.
- , eds. 2021. *Catalogs for metals and related remains from Ban Chiang, Ban Tong, Ban Phak Top, and Don Klang*, vol. 2D of *Ban Chiang, northeast*

- Thailand*. Thai Archaeology Monograph Series. Philadelphia: University of Pennsylvania Museum of Archaeology and Anthropology.
- White, Joyce, and Vincent C. Pigott. 1996. From community craft to regional specialization: intensification of copper production in pre-state Thailand. In *Craft specialization and social evolution: in memory of V. Gordon Childe*. B. Wailes, ed. Pp. 151–175. Philadelphia: University Museum of Archaeology and Anthropology.
- Yao, Alice, Valentin Darré, Jiang Zhilong, Wengcheong Lam, and Yang Wei. 2020. Bridging the time gap in the Bronze Age of Southeast Asia and southwest China. *Archaeological Research in Asia* 22:100189.