An early 1st Millennium BCE “hill tribe” jar burial, Northern Thailand

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Research Article

Keywords:

Posted Date: August 13th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10450695/v1

Additional Declarations: No competing interests reported.

Abstract

An unusual jar burial of an adult male secreted in a deep shaft of a karst cave in the uplands of NW Thailand was associated with a cast copper-based artefact decorated with a finial in the form of a zebu-type bull (*Bos indicus*) which raised issues about its chronological age. To reduce uncertainties associated with radiocarbon dating of bone from carbonate rich environments a program of 14C AMS dating of apatite/collagen fractions from three bones was used to establish an early 1st millennium BCE age of the burial. Isotopic results suggest this individual was from a mixed agricultural and hunter-gatherer economy. Finds associated with the burial include a large handmade globular earthenware pot and the cast copper-based spatula. In size and treatment, the pot suggests a local origin but is a type common to lowland 1st millennium BCE agricultural communities in Thailand. The cast copper-based artefact is typologically closest to an elaborated form of lime spatula, an essential part of the paraphernalia for the ritual consumption of the addictive stimulant betel nut (*Areca catechu* and *Piper betle*). For this period and locale, this grave good, likely acquired through fledgling regional trickle trade networks, suggests a high prestige burial.

Introduction

Thailand has long been an archaeological focus in mainland Southeast Asia. Conflicting claims for early agricultural development, disparate dating regimes, and debates about metal working trajectories characterize the regional literature since the 1970s (e.g., Cyler Conrad, 2020; 1971; Roberts, Thornton, & Pigott, 2009; J. White, 2015)). Over the highly dynamic period of the last 4000 years, groups in Thailand increasingly participated in interregional networks of exchange of goods and ideas yet there is little agreement on when or how these impacted local trajectories of development (Eyre, 2010; Rispoli, Ciarla, & Pigott, 2013; J. C. White & Pigott, 1996). In part this reflects the limits of current archaeological data and dating and in part it reflects the dominance of debates surrounding a relatively small number of excavations focussed on early agricultural communities in lowland valleys. In this paper we describe an isolated burial secreted deep within a karst cave in the uplands of northwestern Thailand and establish an absolute date range for the male adult in the early 1st millennium BCE. This date range extends to associated grave goods allowing us to speculate on inferred practices for a new perspective on long-standing debates.

Background

The burial was found in Pang Mapha, the northern most administrative district of Mae Hong Son Province, Northern Thailand. Geographically, the district is intersected by steep and rugged karst ranges and valleys, currently occupied by agricultural communities of multiple ethnicities (e.g., Lahu, Karen, Lisu). The region has been a major archaeological province due to the preservation of a relatively high density of mortuary sites (Fig. 1). Three chronologically and culturally distinct phases of pre-modern mortuary practice have been identified across Pang Mapha: inhumations (late Pleistocene-mid Holocene), log coffins (~ 200BCE-1000 CE), and earthworks (~ 1400CE-modern).

Since the 1960s caves and rock shelters across the region have been targets of archaeological investigation. Pioneering excavations at three cave sites (Spirit, Banyan Valley, Steep Cliff) produced the first stratigraphically controlled evidence of a Hoabinhian domestic economy (Gorman, 1970, 1971). These sites continue to be as influential as they are controversial – e.g., the apparent contradiction of Hoabinhian hunter-gatherer sites with ceramics (C. Conrad, Higham, Eda, & Marwick, 2016; C. Conrad et al., 2022; Lampert et al., 2003). Several early Holocene (10-8K BCE) inhumation burials in Hoabinhian occupation levels have been excavated in the Ban Rai rock shelter and Tham Lod cave (R. Shoocongdej, 2006; R. Shoocongdej & Wattanapituksakul, 2020) that lacked grave goods (Hayes, Shoocongdej, Pureepatpong, Sangvichien, & Chintakanon, 2017; Suraprasit, Shoocongdej, Wattanapituksakul, Chintakanon, & Bocherens, 2024). From the late 1980s archaeological survey across Pang Mapha documented numerous well preserved above ground log coffins (Kiernan, Spies, & Dunkley, 1988) dated to ~ 200 BCE-1000 CE (Hotchkis et al., 1994). While the log coffins rarely preserve skeletal evidence *in situ*, associated grave goods include local types of earthenware vessels and small copper-based and iron artefacts such as bells. More recently circular earthworks, appear ~ mid-second millennium CE (P. Grave & Kealhofer, 1999; P. R. Grave, 1995): have also been documented across the region both in isolation and in cemetery clusters (Hoontrakul, 2022).

Bull Cave

This isolated karst cave, consisting of voids between breakdown blocks, holds a single burial located in a small chamber connected to a lateral gallery at the bottom of a near vertical ~ 14 meter deep entry shaft (Fig. 2a-c; supplemental figure). The burial consists of the disarticulated, postcranial remains of an adult male originally contained within a fragmentary globular earthenware handmade jar (diameter ~ 30cm) with a slightly flaring neck and rim and cord marked decoration. The pot burial held the disarticulated skeletal remains.

The original disposition of the skeleton and jar was disturbed and broken by subsequent rock fall. The likely antiquity of the burial and associated artefacts is indicated by both burial remains and rock fall partly cemented together by flowstone and supporting the growth of several stalagmites. A unique 20 cm long cast copper-based artefact was recovered directly under the jar and bone fragments that were extensively green-stained from long exposure to the associated copper-based artifact. This cast copper-based artefact has a solid, round sectioned shaft with a flattened squared off tip at one end and a finial at the other end in the form of a well-modelled humped and horned zebu type bull (*Bos indicus)* mounted on a four corned support plate (Fig. 3d). Functionally, its form and dimensions are consistent with a lime spoon/spatula (Montagne, 1983). The spatula is currently held at the Faculty of Archaeology, Silpakorn University, Bangkok.

The copper-based spatula has been damaged in two ways: a break midway along the shaft, and bent corners of the square support plate of the modelled bull. While shaft breakage could be expected from rock fall impact, this doesn't readily account for the damage to the four corners of the finial plate bent upwards to varying degrees, potentially "soft" damage as a result of heirlooming. On the other hand, the breakage and soft damage could have been intentional, to disable but not destroy the artefact's function, potentially providing insight into what could be a symbolically charged mortuary practice (Bedianashvili & Robinson, 2024)

This type of lime spatula is an essential part of the ritual paraphernalia for betel nut preparation. As part of preparation of the betel quid for chewing a spatula is used to scoop lime from a container and spread it onto betel leaves that are then wrapped around an areca nut that has been sliced or prepared. The addition of lime (calcium hydroxide) to the betel quid increases the absorption of arecoline and other alkaloids enhancing their stimulant effects (Castillo, 2022). We would note that the archaeological literature on this class of artefact is very slim (Castillo, 2022). Of the limited published comparanda, the closest in size and elaboration is a cast copper-based example from Indonesia (https://www.metmuseum.org/art/collection/search/58420) but this lacks firm provenance and has been assigned a broad 800 year estimated range from the mid-1st millennium BCE (500 BCE-300 CE).

The Bull Cave burial is without parallel in the region. It appears to represent a local mortuary tradition reserved for a high prestige individual. Both the mortuary practice (secondary jar burial) and the clandestine, difficult-to-access location of this burial in a deep shaft distinguishes it from other more accessible mortuary sites in Pang Mapha. Log coffins and circular earthworks are typically located in highly visible locations. The associated ceramic jar and cast copper-based spatula suggest the Bull Cave burial dates somewhere after the earliest appearance of metallurgy and Iron Age monumental log coffins (i.e., an ~5K period between 5 K BCE- ~>200 BCE).

The post cranial skeletal remains also distinguishes this jar burial from lowland Southeast Asian lowland practices of either Buddhist cremation (Indrawooth, 1997), or primary interment where the jar neck was intentionally removed to enable the insertion of a corpse (Lam, 2011). It also contrasts with adjacent lowland regions where a common mortuary practice was burial in family groups associated with houses in settled agricultural communities (J. C. White & Eyre, 2011). We would argue that the chronological integrity of the site is indicated by both its isolated placement evidently intended to protect the burial from casual visitation until rediscovery by a highly motivated caver, William Fanning in the 1980s. and its condition as rediscovered.

Methods

As part of a wider program of sample collection for radiocarbon dating by co-authors Grave and Barbetti, three large fragments of different bones were retrieved from the Bull Cave skeleton for dating (left calcaneus, right ulna, and left tibia) (Fig. 3a-c). The tibia had well-developed tendon attachments, and the ulna and calcaneus showed mild degenerative changes consistent with wear and tear/aging (Donlon, 1995). Comparison with a modern skeletal dataset from Hong Kong identifies the burial is that of a mature adult male of relatively small stature (< 165 cm).

Dating

Historically, radiocarbon dating of bone has presented significant challenges for measurement reliability due to the compound effects of diagenesis (environmental contamination, degradation and carbon-exchange (Hedges & Van Klinken, 1992)). Uncertainties associated with radiocarbon dating of bone from carbonate rich environments (e.g., Boaretto et al., 2009) are pronounced for the inorganic mineral component - bio-apatite. Radiocarbon results for bone mineral compared to collagen fractions can range from older, equivalent, to younger age ranges depending on environmental conditions. Karst systems with rapid water turnover can effect significant rejuvenation of bone apatite (Cherkinsky, Prasad, Pan, & Sheng, 2023), and can appear, somewhat counter-intuitively, younger than actual age (Zazzo, 2014). In contrast, the organic component of bone - collagen - while more perishable than the mineral component, is comparatively resistant to modern carbon cycling and provides 14C results relative to a bioapatite component more likely to accurately reflect actual age (Krueger, 1991). Contamination in collagen, in the form of inadequate pretreatment or microbial activity, can impact measurement accuracy but in the case of microbial contamination only for samples with ages that approach the range of two to three half-lives of 14C (i.e., ~ 10-15K years BP) (T. Higham, Jacobi, & Ramsey, 2006).

To evaluate, samples from each of the three bone fragments samples were fractionated into apatite/collagen pairs for dating by AMS. Of the three Bull Cave bone fragments, two (ulna (U), tibia (T)) with relatively compact cortical bone were visually identified as most promising for preservation of collagen. In contrast, the third (calcaneus (C)) showed extensive weathering damage with exposure of interior spongy trabecular bone and green staining from prolonged exposure to weathering products of the copper-based artefact.

Radiocarbon offsets caused by diagenetic alteration in karst settings are especially important when considered alongside calibration uncertainties, principally calibration plateaux. These primarily reflect nonlinear variation in ^{14}C production linked to changes in solar wind and sunspot activity in Earth's upper atmosphere (Heaton et al., 2021). The most notable example in the first millennium BCE, the so-called Hallstatt plateau (Brehm et al., 2025), spans approximately 400 years from 800 to 400 BCE., one of the longest and most archaeologically consequential radiocarbon calibration plateaux of the Holocene. Calibrated radiocarbon results within this interval carry a similarly wide margin of uncertainty, regardless of the precision of instrumental measurement.

Sample Preparation

The bone samples were first physically cleaned to remove external surfaces. The cleaned samples were then cut into smaller pieces and washed in deionised water at ca.70°C in a sonic bath three times at ~ 40 minutes each. The samples were oven-dried at 60°C over two days. Each sample was split into two fractions of similar weight, one for bioapatite and the other for collagen extraction.

For the bioapatite fraction, dried bones were gently crushed to fine powder (< 200 μm). Powdered samples were treated with 50% acetic acid at room temperature for ~ 20 hours until all gas bubbles stopped, indicating that all secondary carbonate was removed. The samples were washed with deionised water several times to remove acetic acid then oven dried. For the other fraction, dried bones were crushed to coarse powder (~ 1 mm). Collagen extraction was carried out using a modified method of Longin (1971) and Brown et al. (1988). Bone powder was demineralized in 0.5M HCl at room temperature for ~ 1 hour until gas bubbles stopped evolving, then treated with 0.1M NaOH at room temperature for 20 minutes to remove humic acids contamination, reacted with 0.5M HCl at room temperature for 15 minutes. The samples were gelatinised in a pH3 HCl solution at 75˚C for 20 hours. The resulting solutions were filtered to remove insoluble residues then freeze dried.

The pre-treated bioapatite samples were reacted with 85% H_3PO_4 at 60˚C to release CO_2, while the extracted collagen samples were converted to CO_2 by combustion at 900˚C in the presence of pre-baked CuO (Hua et al., 2001). All the resulting CO_2 was then converted to graphite using the Zn/Fe method (Hua et al., 2001) for AMS radiocarbon analysis using the ANTARES Facility at the Australian Nuclear Science and Technology Organisation (ANSTO) (Fink et al., 2004).

The AMS ^{14}C results for the three bones are reported as collagen/apatite pairs totalling six conventional radiocarbon ages in years BP (Table 1). Age calibration was performed using 50/50 mixed calibration model for the tropics after Hogg et al (2020), with 50% IntCal20 (Reimer P. et al., 2020) and 50% SHCal20 and the OxCal program v.4.4 (Bronk Ramsey, 2021).

Results

Dating

Leaving aside outlying results for the calcaneus that are treated separately below, AMS results for the two best preserved T and U bone samples show a systematic offset between the organic collagen and mineral bio-apatite fractions (Table 1 top panel, Fig. 4). This offset is consistent with the findings of Cherkinsky et al.(2023), Zazzo (2014) and Krueger (1991) for diagenesis of bone apatite producing younger than actual age results due to carbon exchange with a ^{14}C-enriched (i.e., younger) carbon source, in this case the extensive coverage of flowstone indicative of rapid water turnover (Cherkinsky et al., 2023). At one end the collagen fractions produced the oldest, statistically inseparable results (2770 – 2710 BP). At the other the apatite fractions spanned a later, wider range (~ 2300 – 2200 BP). These results are also consistent with conclusions of Zazzo (2014), that for the Holocene the typical mean size of the offset between older collagen and deceptively younger apatite fractions for the same bone is in the order of ~ 300 years. The outlying results for the calcaneus suggest that its relatively poor condition has compromised the integrity of both fractions: 2360 BP for the collagen (i.e., ~ 300 years later than the collagen fractions from the better preserved U and T samples) and the youngest result (2100 BP) for the bone apatite.

External comparisons with isotopic datasets from regional archaeological cemetery populations further support the measurement reliability of the AMS results for the U and T collagen fractions (table 1 middle panel). Comparison of δ13C measurements for the Bull Cave U and T collagen samples with two cemetery population samples of lowland agriculturalists (i.e., 10 burials from an Iron Age cemetery in Cambodia (Ikehara-Quebral et al., 2017) and 14 burials from Non Nok Tha in Thailand (C. F. Higham, Higham, & Douka, 2014)) shows that the extent of variation - the reproducibility (reliability) of measurement - tightly brackets the U and T collagen results.

We conclude that pooled 14C results for the U and T collagen pair provides the most reliable age of the Bull Cave skeleton. It gives a relatively high-resolution calibrated age range for the burial in the early first millennium BCE (1 σ: 990 – 800 (100% confidence; Table 1 bottom panel). The remaining younger AMS results reflecting post-depositional diagenetic effects are also more directly impacted by the 800 – 400 BCE Hallstatt calibration plateau.

Isotopic dietary inferences

As noted, we compared mean isotopic δ13C results for the Bull Cave individual with results from two cemetery samples from Thailand and Cambodia (i.e., 10 burials from an Iron Age cemetery in Cambodia (Ikehara-Quebral et al., 2017) and 14 burials from Non Nok Tha in Thailand (C. F. Higham et al., 2014)) (Table 1, middle panel). The cemetery results for these two agricultural communities had a larger C3 - rice (19.4) dietary component. In contrast, the Bull Cave individual had lower δ13C (15.6) consistent with a mixed C3/C4 diet making use of an agro-ecosystem that incorporated foods from an intermediate mixed woodland (Kealhofer, 2002; Wattanapituksakul, Shoocongdej, & Conrad, 2022).

Discussion

Above, we presented the analytic rationale for dismissing four of the six AMS determinations from calculation of the age of the burial. This left two collagen results as the best measure of the actual age of the Bull Cave adult male burial that in combination gave it a relatively high-resolution pre-Hallstatt plateau range in the first 200 years of the 1st millennium BCE calibrated. Here we discuss the cultural significance of the burial in relation to status, inferred ritual practice (betel nut use), amongst the earliest evidence of the operation of long-distance exchange extending into the uplands, and the material culture economy of the early to mid-1st millennium BCE.

Material culture

Ceramic

In form, decoration, and timing, the Bull Cave jar represents a widely reproduced ceramic type common to contemporary lowland agriculturalists. These early agricultural communities included some groups who spread from either southern China or Vietnam around ca. 2500 BCE. These groups may have also introduced the practice of betel nut consumption (e.g., Bellwood, 2005). By 1250 – 750 BCE, Metal Age settlements in central Thailand such as Ban Non Wat were also producing jars comparable in form and decoration to the Bull Cave vessel (i.e., handmade earthenware globular jars with fine cord marked body and raised necks (Rispoli et al., 2013; Rispolli, 2022)). However, the challenge of transporting a relatively large and fragile vessel of the type placed in Bull Cave suggests a nearby agricultural community produced the vessel (and the deceased).

Cast copper-based spatula

The scope of long distance exchange in littoral Southeast Asian societies has long been recognised (Glover, 1989). Evidence for the commencement of metal production in the region appears in the late 2nd millennium BCE based on the central Thai copper mining sites in the Khao Wong Prachan Valley (Pigott & Ciarla, 2007). An early 1st millennium BCE date for the Bull Cave spatula is consistent with the regional emergence of copper-based casting technology represented in the Bronze Age 1–3 levels (1050 – 800 BCE) at the central Thai sites of Ban Non Wat and adjacent Ban Lum Khao (C. Higham, 2024). However, compared to the relative simplicity of the cast copper-based artifacts recovered from these sites and periods, the fine modelling evident in the Bull Cave spatula suggests an origin well beyond this zone. At this early stage, long-distance movement of small copper-based artifacts could also have been fuelled by their relative rarity and likely would have had high local prestige value (Barretto-Tesoro, 2003; C. Higham, 2024). Comparable arguments by Carter and Dussubieux (2016) have been made for beads as small, readily transported, high value items disseminated even into relatively remote parts of mainland Southeast Asia. However, the Bull Cave artefact presages by up to five hundred years (Tauber, 1973, p. 111) the later long-distance and logistically more challenging movement of larger bronzes (e.g., Dong Son Heger type 1 drums, Ongbah cave, Kanchanaburi province).

Bos indicus: Recent genetic studies of *Bos sp.* bone from archaeological sites in Thailand reveal that only *B. taurus* was present at this time (Ban Chang, Ban Non Wat, Sri Thep and Ban Dung: 3500 – 1700 BP calibrated). The earliest representations of *B. indicus* in Thailand cover a potential range of dates from 4000 – 1300 BP (Wangkumhang et al., 2015), but the earliest dates are poorly constrained.

Based on genetic data, Siripan and colleagues (2019) suggest that *B. indicus* introduction into Thailand occurred relatively late in the 1st millennium CE before completely replacing *B, taurus*. The Bull Cave representation therefore provides one of the earliest and best dated pieces of evidence for the knowledge, if not the actual presence, of *B. indicus* in Thailand. If, as seems most likely, the Bull Cave spatula is an object of long-distance exchange then its finial is most likely a reflection of fauna in the region of manufacture which, in the absence of provenance could range from South India to island Southeast Asia. The current dominance of *B. indicus* varieties in Thailand suggests that potentially earlier interactions with South Asia, during the early 1st mill BCE, occurred before the introduction and transition to the later dominance of hump backed cattle.

Betel nut use

Betel nut (a fruit of the palm *Areca catechu L.*) consumption is a widespread phenomenon from South to East Asia with a long history. While common, it is also associated with social gatherings and rituals, and betel material culture is often used to mark elite consumption (Raman & Umar, 2024). Most recently Moonkham et al. (2025) reported betel nut residues on teeth from burials dated to ca. 4000 BP at Nong

Ratchawat. Prior to this, no site from Thailand had provided conclusive evidence for betel chewing before the common era (Zumbroich, 2007/8, p. 110).

In the Pang Mapha region, botanical remains of betel nut and betel vine (*Piper betle L.*) were recovered from early Holocene 9-7.5 K contexts in Spirit Cave (Fig. 1, site 11). These were the basis for claims of betel use at this time (Glover, 1979, pp. 11–17; Gorman, 1971, pp. 570–572; Yen, 1977). However, such claims are undermined by doubts about the accuracy of archaeobotanical identification (Fairbairn & Swadling, 2005, p. 381), and its very early outlying chronology (Zumbroich, 2007/8, p. 97). We would add that both occur naturally in the region so their presence in an archaeological context alone is not sufficient to infer betel nut consumption. These botanical remains would be strengthened by evidence of consumption such as remains of preparation paraphernalia (e.g., betel nut cutter, lime pot, lime spatula) and/or dental staining (Barretto-Tesoro, 2003; Oxenham, Locher, Lan Cuong, & Kim Thuy, 2002) although see Pietrusewsky and Douglas (2002, p. 76).

If in fact the spatula was used as suggested, its association with the Bull Cave burial may offer material evidence for an initial date for betelnut consumption. It also raises several critical issues related to this practice including reassessing the remoteness of this region of mainland Southeast Asia in relation to the timing and geographic penetration of betel nut consumption. Current evidence is insufficient to distinguish the specific direction of interaction. The spatula may also represent an exchanged high-status object, without having been used for betel nut consumption. The lack of a skull and direct evidence of chewing leaves the question open.

Whether or not it was used locally, the spatula points to a much larger scale and earlier expansion of interaction spheres into upland mainland Southeast Asia than previously understood. The implications of the Bull Cave burial for social organization of the upland group responsible for the interment are twofold. The first is the significance of this burial in terms of its unusual nature. Care in burial site selection and placement also suggests recognition of an elevated or special social position. This is reinforced by the inclusion of an unusual, symbolically-charged grave good (not only the symbolism of the finial decorated with a mature bull but potentially also the more general social significance of betel nut chewing). Additionally, the stark difference between Bull Cave mortuary practices and those of the lowlands points to a very different social milieu for upland groups (J. C. White & Eyre, 2011).

Conclusion

The early 1st millennium BCE contents of the Bull Cave burial have direct implications for our understanding of a critical period of transformation in mainland Southeast Asia. The handmade earthenware vessel points to a likely local origin in a nearby settlement in an adjacent valley. The isotopic data suggests the subsistence economy of this community was that of a mixed set of subsistence strategies. The inclusion of the cast copper-based spatula in the burial suggests complex social organisation recognizing an unusual or high-status individual, and potentially placing the practice of betel nut consumption in the early 1st millennium BCE in the western mainland of Southeast Asia (consistent with lowland evidence).

In terms of the expansion of agriculture in this upland region, environmental proxies from Lake Phayao in northern Thailand provide microfossil evidence for upland erosion associated with clearing hillslopes for agriculture from the first half of the 1st millennium CE (Penny & Kealhofer, 2005). The Bull Cave isotopic evidence is consistent with upland agricultural communities in the interior of the northern highlands clearance of small patches for cultivation or management at least a thousand years earlier. Such small-scale, patchy clearing is difficult to identify in lowland regional environmental proxies. The Bull Cave results expand our understanding of patterns of agricultural adoption and suggest more targeted re-evaluation of other occupation sites in the region would be fruitful.

The hump-backed bull (*Bos indicus)* representation on the finial of the copper-based spatula potentially links this region to long distance networks, whether trickle trade or more coordinated, originating in south Asia, also evident in the later Iron Age carnelian bead trade (Carter & Dussubieux, 2016).

In sum, the Bull Cave burial represents a singular window into the operation of early to mid-1st millennium BCE social organization in a region that was both relatively remote geographically but that also appears to have developed extra-regional connections. An early to mid-1st millennium BCE data for the Bull Cave spatula represents a firm chronological data range. Our interpretation of it as evidence for betel nut consumption is necessarily speculative, but nonetheless sits conformably between the 2000 BCE evidence for betel nut consumption at Nong Ratchawat and the evidence from middle of the first millennium BCE in the Mekong Valley and coastal Vietnam (Zumbroich 2007/8: 110).

Declarations

Funding Declaration

This work was supported by the Australian Research Council (# DP0344782).

Author Contribution

PG LK and JS undertook overall construction of the manuscript, QH undertook description of sample preparation and AMS dating. PG and LK undertook final revisions.

Acknowledgement

Mike Barbetti, deceased 2019, provided support for the radiocarbon component of this paper. We wish to thank the National Research Council of Thailand for having granted permission for our research in the province. Sampling for this work was conducted in the early 1990’s under a National Research Council of Thailand permit and the Australian Institute of Nuclear Science and Engineering. We thank Gerhardt

Hauptman, Simeon Krompart, and Dwight Livingston of the 2026 Expedition to Thailand for mapping and cartography of Bull Cave. We also gratefully acknowledge Vince Pigott for commenting on an earlier draft of this paper.

Data Availability

All data supporting the findings of this study are available within the paper and its Supplementary Information.Mike Barbetti, deceased 2019, provided support for the radiocarbon component of this paper.

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Table

Table 1 is available in the Supplementary Files section.

Figures

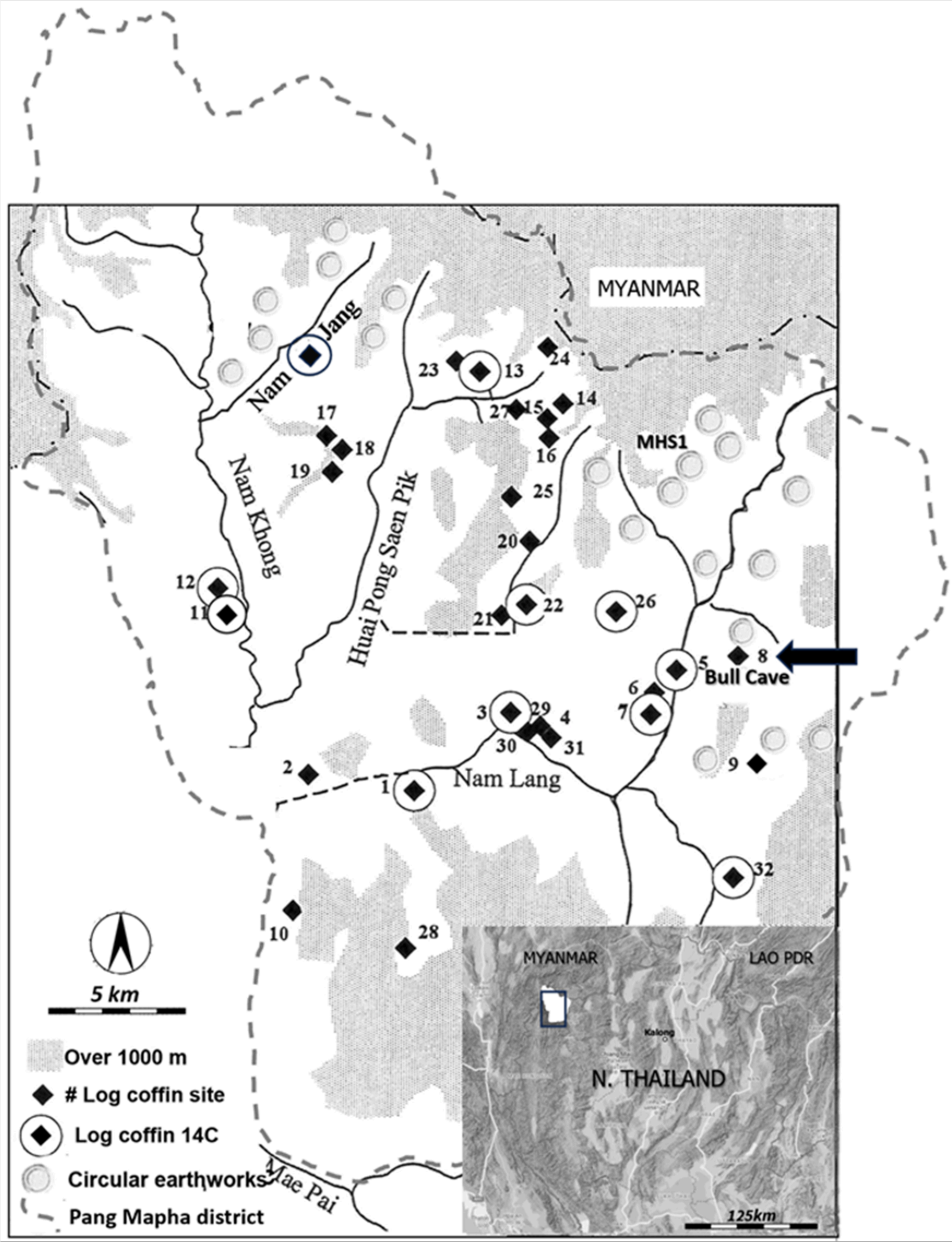

Figure 1

Map of Pang Mapha district, Mae Hong Son province ~30-40 km area showing location Bull Cave (arrow). The distribution of log coffins and circular earthworks are noted. Sites dated by AMS indicated (Buajan et al., 2020; Kiernan et al., 1988). Locations of additional earthworks based on (Hoontrakul, 2022). Inset shows study area (white) in broader geographic context.

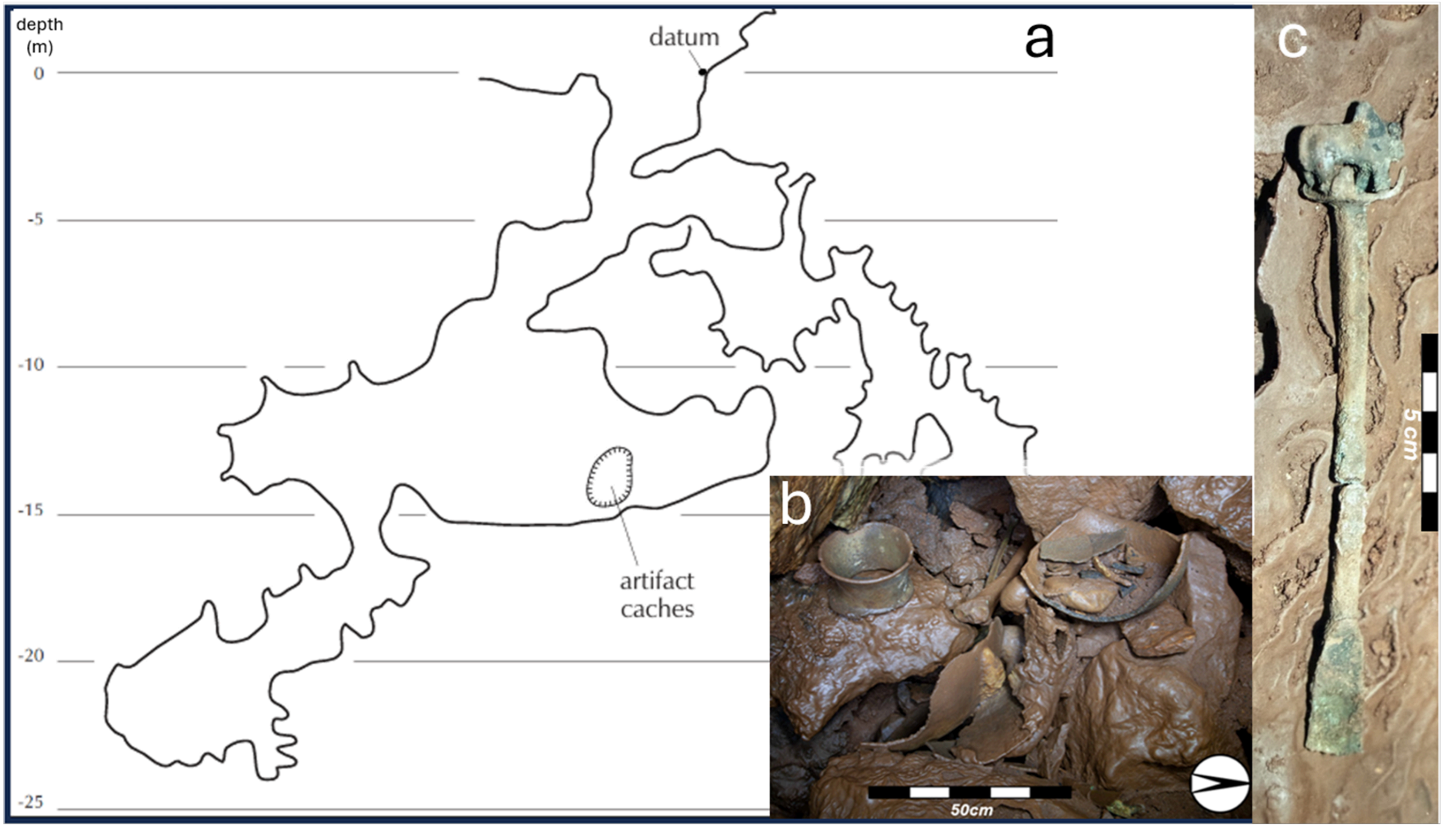

Figure 2

Bull Cave jar burial: (a) west facing profile view showing shaft access to main lower chamber and location of entrance to artefact cache in side chamber, (b) photograph of burial composed of disarticulated and fragmentary human bone (note proximal end of human tibia and fibula between jar neck at left and jar body right) and cord marked handmade globular earthenware jar with high neck co-mingled with rock fall and partly covered by flowstone; and (c) cast copper-based bull spatula (illustrated in fig 3) with finial in the form of a hump backed, horned bovid (*Bos Indicus*) condition at time of recovery. Cartography (a) courtesy of Dwight Livingston 2026, photography (b and c) by co-author Spies.

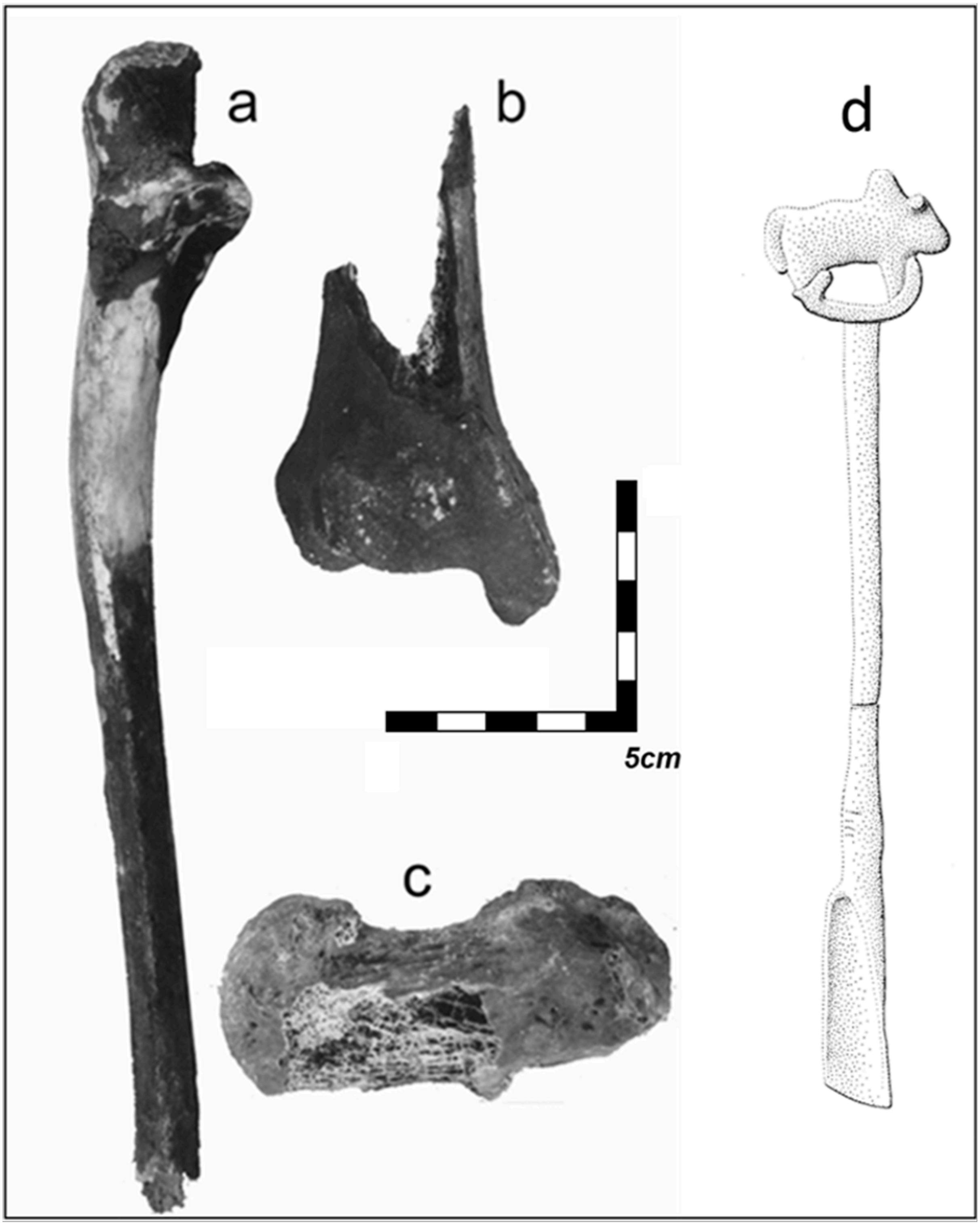

Figure 3

Bull Cave jar burial. Skeletal elements recovered for AMS dating (a: right ulna; b: left tibia distal end; c: left calcaneus; note dark discolored areas remnants of calcareous flow stone). d: rendering of associated cast copper based spatula with finial in the form of a hump backed, horned bovid (*Bos Indicus*).

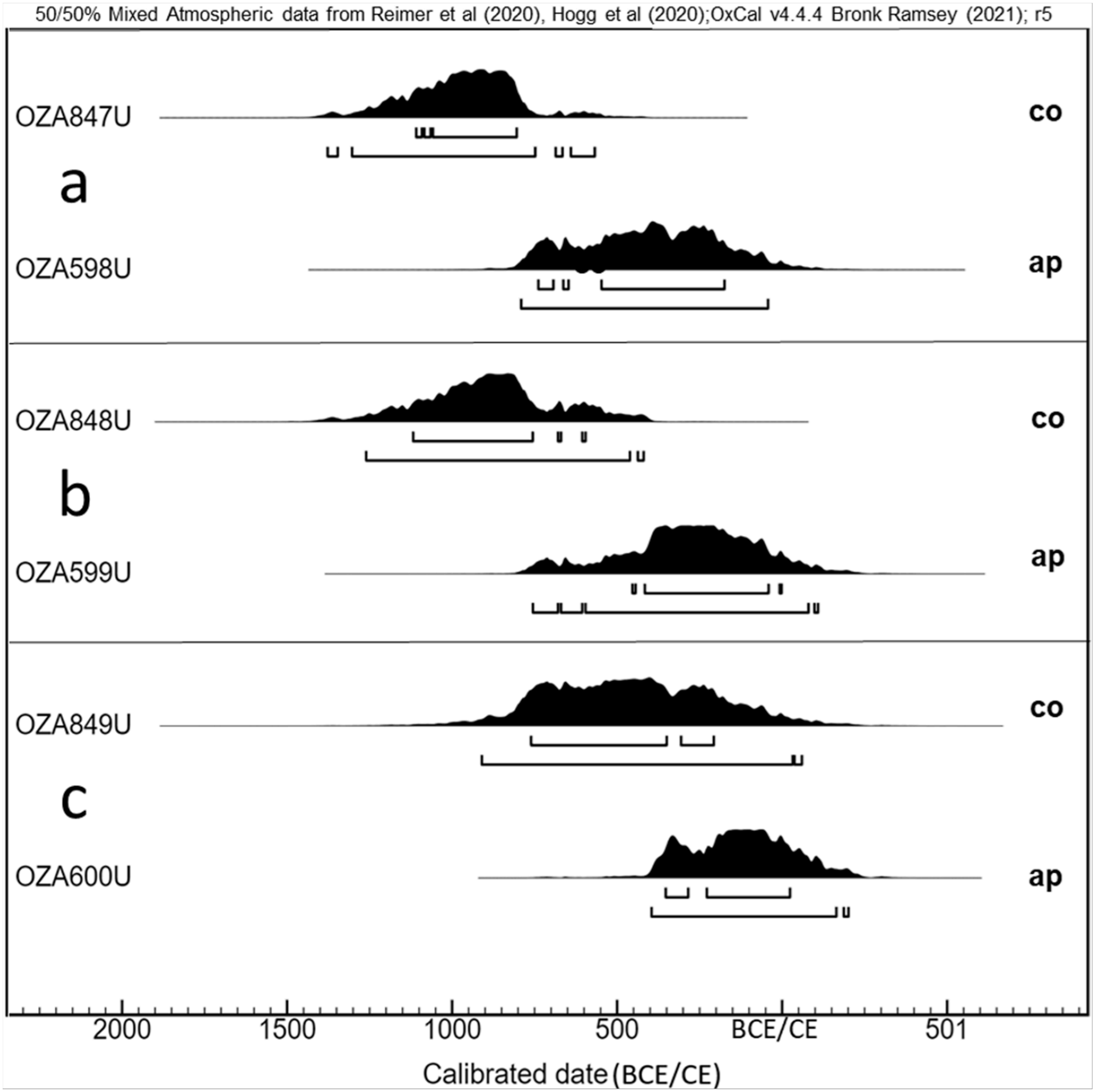

Figure 4

Calibrated AMS ranges (50/50 mixed calibration model after Hogg et al (2020)) for the co(llagen) and ap(atite) fractions of the three bone samples (a: ulna; b: tibia: c: calcaneus). Note all apatite AMS ranges are systematically younger than the collagen fractions consistent with post-depositional diagenetic contamination from more recent carbon (Zazzo and Saliège 2011). The two collagen results from the ulna and tibia samples are statistically inseparable. This, coupled with their equally highly constrained

$\delta 13C$‰ range of variation comparable to larger regional cemetery samples supports pooling the results for this pair of samples for a date range of 990-800 BCE (see Table 1).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplemental1.pdf
- BCtable1.xlsx