KHOK PHANOM DI: NEW RADIOCARBON DATES AND THEIR IMPLICATIONS

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ABSTRACT

Khok Phanom Di is a Neolithic site located on the former estuary of the Bang Pakong River in Central Thailand. The initial dating of occupation was based on ten radiocarbon determinations from charcoal, that placed its foundation between about 2000 BC and the end of the seven-stage mortuary sequence five centuries later. Here we report on a new series of dates derived from human bone, shell and charcoal embedded in stratified structural remains. These suggest an earlier occupation than has previously been published with implications for identifying a coastal expansion of early rice farmers along the coast of Vietnam and the eastern shore of the Gulf of Siam.

INTRODUCTION

Khok Phanom Di was excavated over seven months in 1985. A cultural sequence seven meters deep was opened in the center of this five-hectare Neolithic mound, that was located on the estuary of the Bang Pakong River, a choke point commanding coastal and riverine exchange (Figure 1; Higham and Bannanurag 1990). From first settlement, the local clays were exploited for making ceramic vessels. Women were often interred with the anvils and stones used for shaping clay and burnishing pots before firing. Stone for adzes was imported, as were marine shells for fashioning a range of ornaments. The shape of the human crania matches that for other Neolithic settlements in Southeast Asia, and beyond to the Yangtze River region (Matsumura *et al*. 2019). Cultural deposits accumulated rapidly, due to the buildup of superimposed structures and middens that largely comprise bivalve shellfish. This has resulted in the dead being interred in tight clusters over their ancestors, creating seven mortuary stages and putative genealogies for about 17 generations. This has opened a window on some aspects of the social organization at the site, based on the changing mortuary rituals. Status, at times at an elite level, was expressed by the manner of interment, one notable woman potter, for example, being buried wearing clothing embellished with over 121,000 shell beads. The range of biological remains documents a diet that varied with the rise and fall of the sea level. During Mortuary Phases 3B and 4, dated to ca. 1800–1700 BC, the sea level fell and freshwater habitats formed, facilitating the local cultivation of rice. With the return of a higher sea level, the increased salinity of the brackish mangrove habitat would have made local rice cultivation marginal.

The retention of samples of cultural material in the archives at the University of Otago has encouraged an examination of structural remains, a topic not hitherto given the attention it deserves. Unexpectedly, these also provided an opportunity to return to the site's chronology that has for long been placed between ca. 2000–1500 BC.

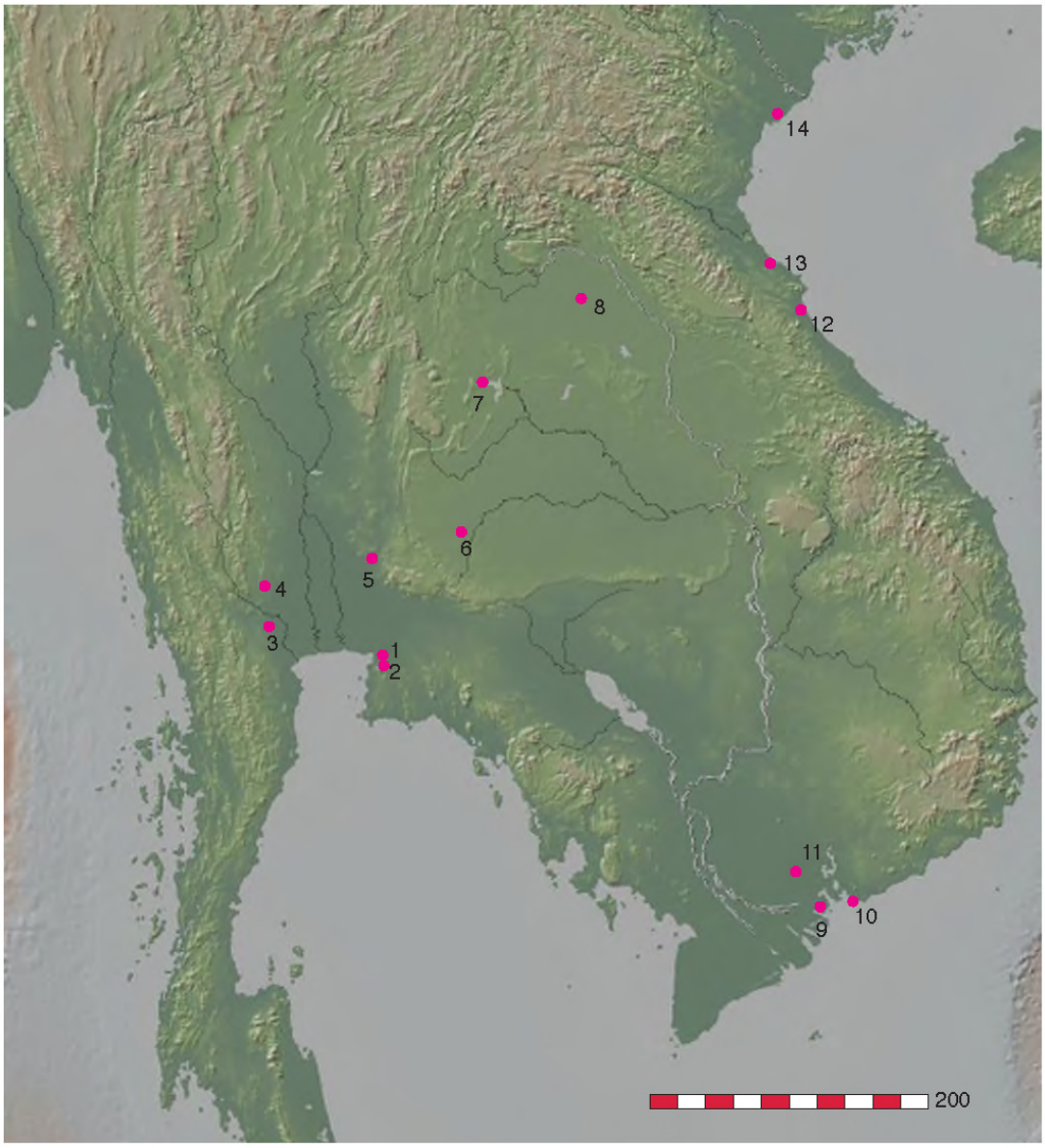

Figure 1. Map showing the location of the sites mentioned in the text. 1. Khok Phanom Di, 2. Nong Nor, 3. Ban Kao, 4. Nong Ratchabat, 5. Non Pa Wai, 6. Ban Non Wat, 7. Non Nok Tha, 8. Ban Chiang, 9. Rach Nui, 10. Go Ca Soi and Go Cay, 11. An Son, Loc Giang, 12. Bau Tro, 13. Thach Lac, 14. Man Bac. Map by C.F.W. Higham, employing GeoMapApp (www.geomapapp.org), CC by Ryan et al. *(2009).*

STRUCTURAL MATERIAL

During the excavations, numerous postholes were identified, some with the remains of wood still in place. We also excavated a rectangular room with a clay floor, and clay wall foundations that incorporated postholes for the wooden studs (Figure 2). Three graves were cut through this floor. Our archived samples, on close examination, included fragments of wattle and daub structural remains (Figure 3). A framework of wooden posts and rails was manufactured, and then covered in clay. This was in turn covered on the exterior with a second coat of clay, the surface of which was

smoothed and painted red. This practice, together with the discovery of clay floors, recalls the successive house floors identified at several Neolithic settlements in southern Vietnam. One of these, An Son in the Vam Co Dong river valley, has been dated to 2200–1500 BC. Superimposed floors at Rach Nui, where the Vam Co Dong and Dong Nai rivers meet, were associated with a site that like Khok Phanom Di, was a pottery manufacturing locale (Piper and Oxenham 2014; Sarjeant 2014). Similar floors have been traced at Go Ca Soi and Go Cay Me (Piper *et al*. 2022) and Loc Giang, where they were made of lime plaster manufactured from burnt shells (Grono *et al*. 2022). This has encouraged a reappraisal of the substrate below the room mentioned at Khok Phanom Di. Our early report described it as being situated on a raised platform comprising horizontal layers of fill. We now have to include the alternative that as in the Dong Nai sites, it was not so much a raised platform but rather an accumulation of successive house floors (Figure 4).

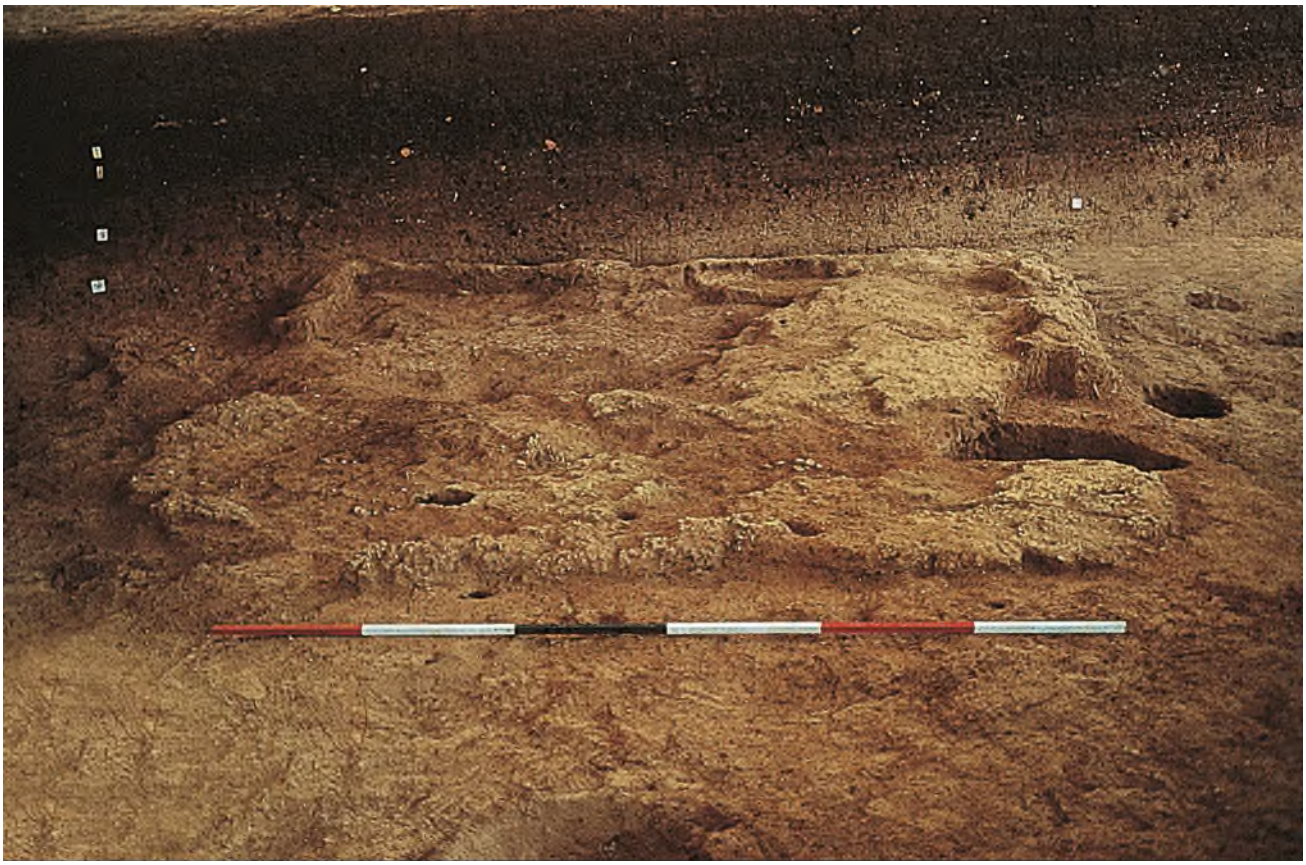

Figure 2. The chamber with clay floor and wall foundations at Khok Phanom Di. Photograph by C.F.W. Higham.

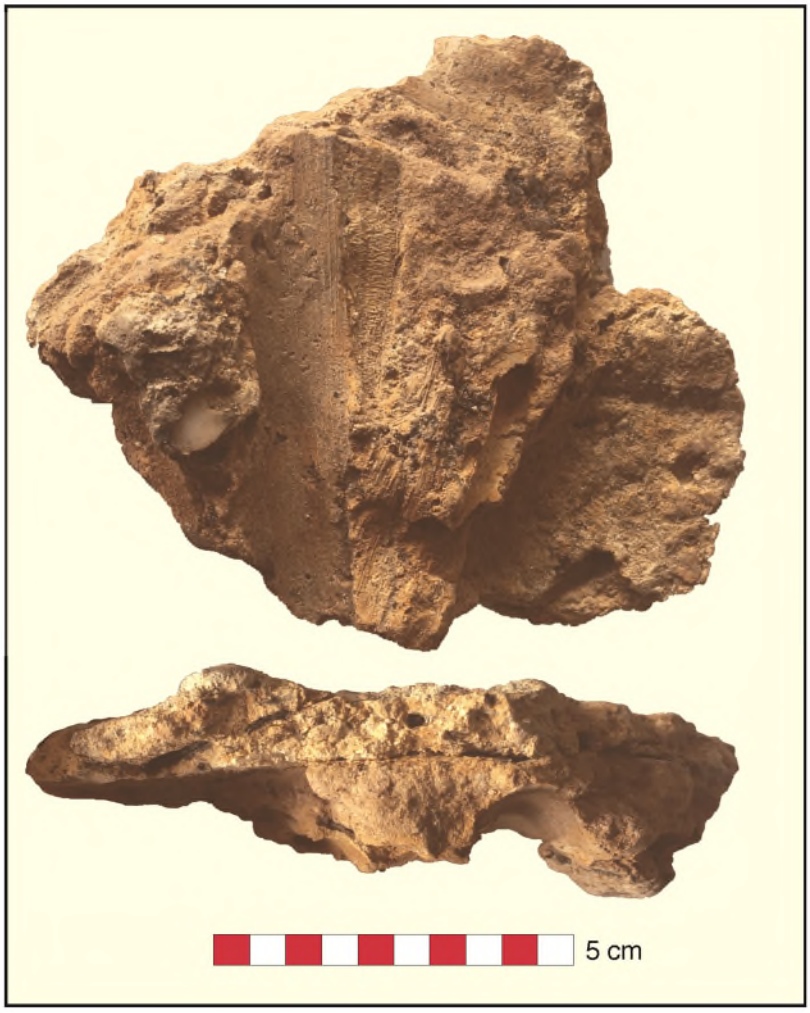

Figure 3. Wattle and daub structural remains from Khok Phanom Di. Photograph by C.F.W. Higham.

Figure 4. The raised platform at Khok Phanom Di, or is it made up of successive house floors? Photograph by C.F.W. Higham.

CHRONOLOGY

The archived structural remains incorporated flecks of charcoal and rice chaff. Although with charcoal, there is always the issue of inbuilt age, there is a strong likelihood that the charcoal in this case comes from recently cut branches employed in the wattle and daub buildings. By dating this charcoal, it has been possible to obtain a new series of AMS radiocarbon dates from *in situ* structures. Most of these come from the lower contexts in layer 10, towards the base of the occupation, with one from layer 9 and one from layer 8. We have also dated four samples of human bone from Mortuary Phases 2 and 5, and 15 samples of shell ornaments. In Table 1 those with OxA-X- prefixes denote lower than ideal collagen yields from the dated bones. Determinations from marine shell have been corrected for the reservoir effect. We used a ΔR correction of -174±70 years (Southon *et al*. 2002) to account for the local offset in the marine reservoir effect in tandem with the MARINE20 calibration curve (Heaton *et al*. 2020). There is a degree of uncertainty in this value, since it is based on a single estimate from the south of the Gulf of Siam near Ko Ang Trang (Southon *et al*. 2002). There can be variability in reservoir offsets, both spatially and temporally. This needs to be tested and expanded in future. Terrestrial samples were calibrated and modeled using the INTCAL20 curve (Reimer *et al*. 2020) and the OxCal4.4 software package (Bronk Ramsey 2009a). We applied an Outlier detection approach after Bronk Ramsey (2009b), using the general outlier model. Together with the original charcoal samples, 35 radiocarbon samples have been incorporated in the model (Table 1). The Bayesian model CQL code is provided in the Supplementary Information.

Recent radiocarbon determinations from coastal Vietnamese Neolithic sites and inland settlements on the Khorat Plateau of Northeast Thailand have begun to reveal a consistently earlier date for the former. A possible occupation phase at Thach Lac dated as early as 2800–2700 BC might represent very early penetration by settlement with a northern origin, followed by the Neolithic Bau Tro occupation dated to 2480–2000 BC (Piper *et al*. 2022). Further south, at An Son, initial settlement has been placed at ca. 2200 BC (Bellwood *et al*. 2011). There are common features that link these Vietnamese sites with Khok Phanom Di. Occupation of coastal mangrove habitats, while providing immediate movement by boat, did not encourage rice cultivation due to the salinity of the surface water. Indeed, at the coastal settlement of Rach Nui, despite a Neolithic material culture, there is no evidence for rice cultivation (Oxenham *et al*. 2015). Therefore there was much exploitation of the abundant fish, shellfish, crabs and other marine resources. The burial rituals at Man Bac and An Son involved extended inhumation with mortuary offerings. The cranial shape was East Asian with close parallels with ancestral populations in the Yangtze region, and hints of introgression with Australo-Papuan hunter-gatherers, seen in particular at Man Bac (Matsumura *et al*. 2019). Artifacts present common features: the incised and impressed decoration on pottery vessels, polished stone adzes, bone fishhooks and ceramic anvils. Settlements were permanently occupied, and now we have identical methods of constructing dwellings.

The Bayesian model is shown in Figure 5; see also the Outlier probability results in the Supplementary Information. There were two major outliers, one of charcoal (OxA-40923) and one of shell (OxA-29129). These were downweighted in the model by the value of the posterior outlier value (100% and 80% respectively). There were three other determinations with outlier values of ~25–35%, which were similarly downweighted. Overall, given the uncertainties in the ΔR values and the possibility of some inbuilt age, the model is considered fairly robust and there is a good level of agreement generally between the shell, charcoal and bone determinations. Taken together, it requires a modification of the chronology for Khok Phanom Di. The initial settlement is now placed before 2240–1960 BC (at 95.4% probability) (this being the start boundary estimate for MP1), possibly slightly earlier given the lack of any radiocarbon dates

for the basal layer 11. Mortuary Phase 5, which comprises the outstandingly wealthy burials 14, 15 and 42, begins from 1840–1700 BC. The burials of MP7 and final occupation of layers 2–3 are not dated, but most probably take the occupation of the site down to at least 1500–1600 BC. This chronology fits with that emerging for coastal Neolithic Vietnam, and suggests a progressive migratory move south along the coastline of Southeast Asia during the second half of the third millennium BC.

Table 1: Radiocarbon determinations from Khok Phanom Di.

Laboratory	Context	Radiocarbon Age BP	Mortuary Phase	Source
OxA-28124	Burial 8	3429±29	MP6	shell
ANU-5482	Layer 6:6	3310±128	MP5	charcoal
OxA-X-2524-23	Burial 14	3482±28	MP5	bone
OxA-29135	Burial 15	3768±30	MP5	shell
OxA-29136	Burial 43	3594±29	MP5	shell
OxA-29137	Burial 16	3749±30	MP5	shell
OxA-29138	Burial 14	3708±29	MP5	shell
OxA-40926	Layer 8:8	3678±21	MP5	charcoal
ANU-5483	Layer 8:2	3430±80	MP4	charcoal
ANU-5484	Layer 10:6	3280±140	MP3	charcoal
ANU-5485	Layer 10:10	3410±110	MP3	charcoal
OxA-29128	Burial 73	3552±29	MP3	shell
OxA-29129	Burial 72	3967±29	MP3	shell
OxA-29173	Burial 90	3779±28	MP3	shell
OxA-40923	Layer 10:11	3725±20	MP3	charcoal
ANU-5486	Layer 10:15	3610±90	MP2	charcoal
ANU-5487	Layer 10:19	3490±110	MP2	charcoal
OxA-X-2524-24	Burial 143	3574±26	MP2	bone
OxA-X-2524-25	Burial 121	3643±29	MP2	bone
OxA-X-2524-26	Burial 96	3678±28	MP2	bone
OxA-29126	Burial 140	3625±29	MP2	shell
OxA-29127	Burial 140	3655±29	MP2	shell
OxA-29130	Burial 132	3917±29	MP2	shell
OxA-29131	Burial 113	3985±29	MP2	shell
OxA-29132	Burial 101	3917±29	MP2	shell
OxA-29133	Burial 99	3789±30	MP2	shell
OxA-29134	Burial 91	3744±29	MP2	shell
OxA-29172	Burial 120	3736±29	MP2	shell
OxA-40925	Layer 10:19	3741±21	MP2	charcoal
OxA-40924	Layer 10:20	3733±21	MP1	charcoal
ANU-5489	Layer 10:21	3420±90	MP1	charcoal
ANU-5488	Layer 10:22	3580±100	MP1	charcoal
ANU-5491	Layer 10:24	3530±80	MP1	charcoal
ANU-5492	Layer 10:25	3480±110	MP1	charcoal
ANU-5490	Layer 10:25	3730±100	MP1	charcoal

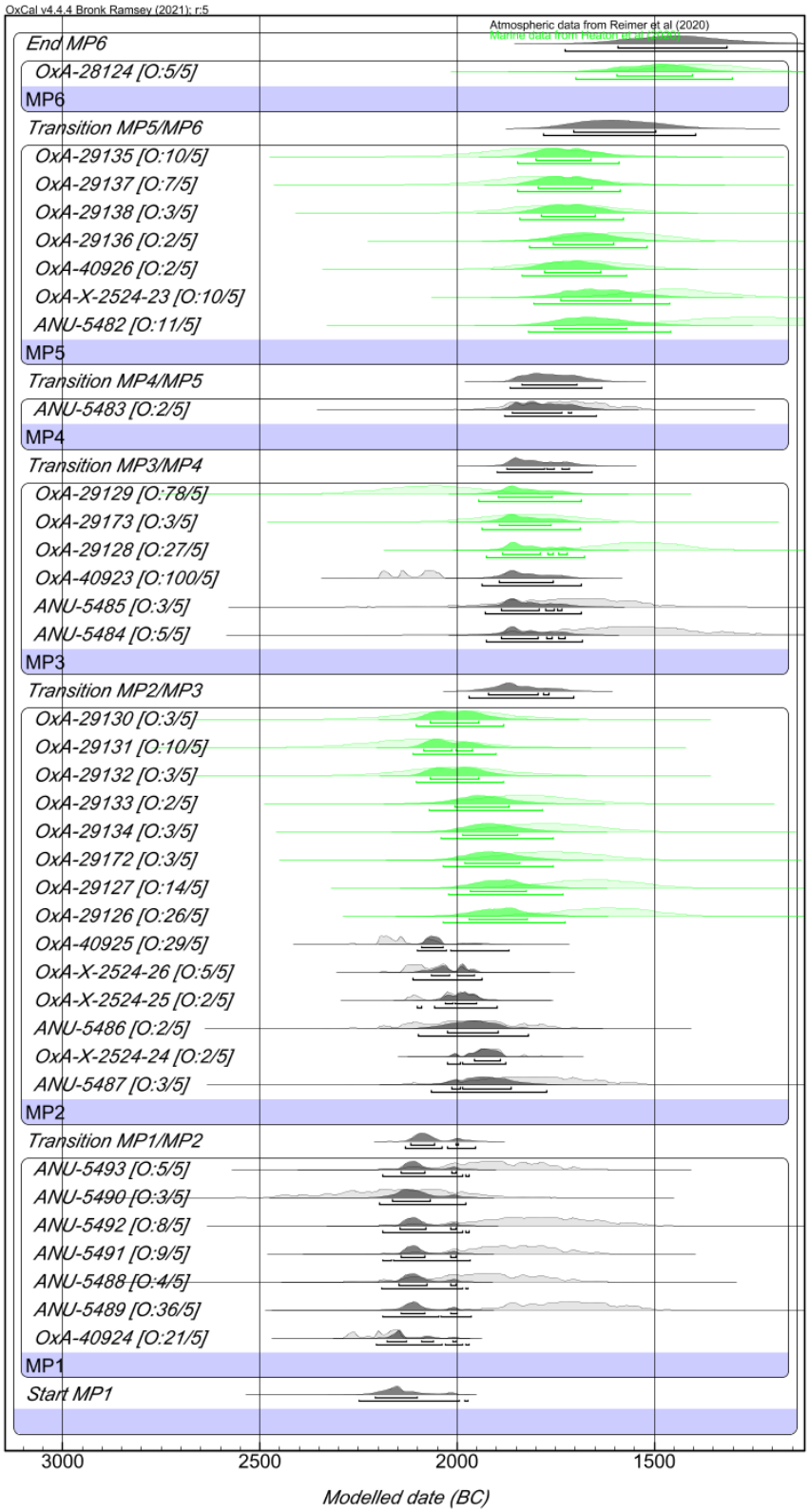

Figure 5. Bayesian model of the chronology of Khok Phanom Di. Green dates are from shell, corrected for the local marine reservoir effect (see text). The figure was produced using OxCal 4.4 (Bronk Ramsey 2009a) and the INTCAL20 (Reimer et al. *2020) and MARINE20 curves (Heaton* et al. *2020). Figures in brackets after the date codes represent the posterior:prior outlier values (see Supplementary Information). Illustration by T.F.G. Higham.*

Nong Nor is another key site in the discussion of the wider cultural sequence of SE Asia. Excavated over three seasons in 1990–2, this site lies about 10 km to the south of Khok Phanom Di, and during its first occupation phase, it was located on the shore of a marine embayment (Higham and Thosarat 1998). This cultural context is dominated by a thick shell midden, with the sandy shore bivalve *Meretrix lusoria* accounting for over 90% of the identified shellfish. The occupants also fished and hunted marine mammals. There was no evidence for domestic animals or rice. The pottery vessels, fishhooks, stone adzes and bone tools are closely matched in the basal layer at Khok Phanom Di. One burial was encountered, a woman in a seated, flexed position under four pottery vessels, in association with a burnishing stone. This posture for the dead is characteristic of the indigenous hunter-gatherers, but the inclusion of pottery vessels is very much a feature of the immigrant rice farmers.

In earlier syntheses, Nong Nor has been described as a coastal hunter-gatherer settlement of short duration (Higham and Thosarat 1998). Now, the revised and earlier date for the early occupation of Khok Phanom Di, albeit not from the initial occupation, brings the two sites closer together in time (Table 2, Figure 6). Indeed, there is a degree of overlap. The similarity in material culture between early Khok Phanom Di and Nong Nor now require the latter site to be seen, like Rach Nui, as a coastal Neolithic settlement with no evidence for domestic rice.

Table 2: Radiocarbon determinations from Nong Nor.

Laboratory	Radiocarbon Age BP	Calibrated Age BC 95.4% probability	Context in site
Wk-2025	3670±180	2572–1548	A2 hearth
Wk-2026	3810±150	2674–1982	A2 hearth
Wk-2027	3890±180	2882–1902	X1 surface of natural
Wk-2028	3930±90	2842–2141	A1 layer 2
Wk-2029	3980±90	2864–2205	A2 layer 2
Wk-2847	3780±60	2454–2031	A6 layer 2:1

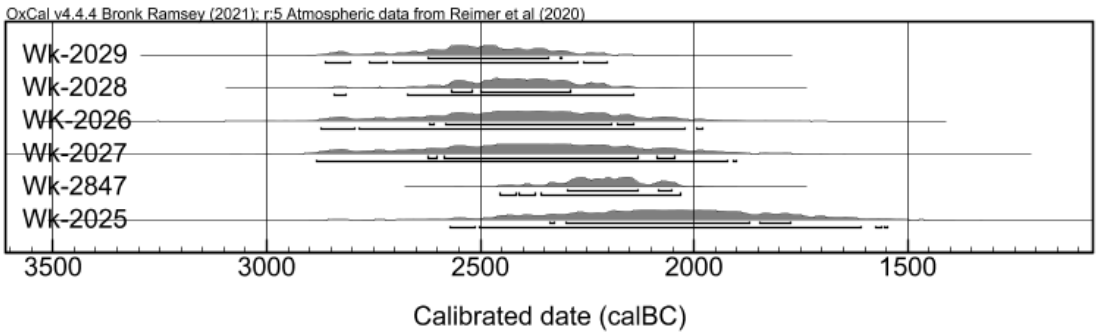

Figure 6. The calibrated radiocarbon determinations for Nong Nor. Illustration by T.F.G. Higham.

CONCLUSIONS

New data from several sources now firmly identify the ultimate origins of Southeast Asian rice and millet farming communities in the Yangtze and Yellow river regions to the north. The analysis of cranial morphology, for example, relates the inhabitants of Khok Phanom Di with those of the Majiabang culture site of Weidun, located between the lower Yangtze and Lake Taihu and dated between 5000–3500 BC (Matsumura *et al*. 2019). Ancient DNA is similarly relating early Southeast Asian rice farmers with northern sources (Lipson *et al*. 2018; McColl *et al*. 2018). There are similarities too, in the material culture and burial practices (Rispoli 2007).

It is not, therefore, surprising to find common cultural features and similar dates for the Neolithic sites of coastal central and southern Vietnam and the two sites that were located on the shore of the Gulf of Siam. However, while bringing their knowledge of rice farming, the maintenance of domestic pigs and dogs, material culture, mortuary rituals and domestic building practices, they also encountered environments that made the cultivation of rice marginal. They therefore became more reliant on exploiting the rich marine environment in which fish and shellfish contributed significantly to the diet. It is considered likely that rice was imported through exchange with their contemporary communities located inland. Certainly, there were multiple exchange networks that linked estuarine sites like Khok Phanom Di with the interior. If, as now seems likely, Nong Nor was indeed a near contemporary of early Khok Phanom Di, it might be that there was a settlement pattern that incorporated a central permanently occupied place and sites for seasonal exploitation of marine resources. Rice was cultivated locally only when there was brief fall in the sea level during Mortuary Phases 3B and 4 at Khok Phanom Di, seen in the presence of granite hoes and harvesting knives (T. Higham 1993). During that period, domestic rice was identified in the digestive tract of one female and the feces of a man (Thompson 1996). The presence of the beetle *Oryzaphilus*, that is known to invade rice stores, and mouse hairs in human feces from burial 67 during that period, further evidences the cultivation and storage of rice (Harris 1991; Moore 1991).

The date for this wave of settlement along the coast of Vietnam and Thailand within the second half of the third millennium BC is matched by new dates for the inland sites of Non Pa Wai and Nong Ratchabat (T. Higham *et al*. 2020; Doungsakul n.d.). However, the pottery vessels from the latter group of sites on the western margins of the Bangkok Plain are quite different from those at Non Pa Wai or Khok Phanom Di, and suggest a different route of penetration probably via the Salween River, as suggested by Sørensen after his excavation of Ban Kao (Sørensen 1972). The initial occupation of the Khorat Plateau, judging from the new chronologies for Ban Non Wat, Non Nok Tha and Ban Chiang, appears to have been at least 500 years later than on the coast. Increasingly too, there is evidence for admixture between the first farmers and the indigenous Australo-Papuan hunter-gatherers.

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SUPPLEMENTARY INFORMATION

1. CQL Code for the KPD Bayesian model

```
// Delta_R values updated for Marine20
 Plot()
 {
  Outlier_Model("General",T(5),U(0,4),"t");
  Curve("IntCal20","intcal20.14c");
  Curve("Marine20","Marine20.14c");
  Delta_R("LocalMarine",-174,70);
  Sequence()
  {
   Boundary("Start MP1");
   Phase("MP1")
   {
    Curve("=IntCal20");
    R_Date("OxA-40924", 3773, 21)
    {
     Outlier("General", 0.05);
    };
    R_Date("ANU-5489", 3420, 90)
    {
     Outlier("General", 0.05);
    };
    R_Date("ANU-5488", 3580, 100)
    {
     Outlier("General", 0.05);
    };
    R_Date("ANU-5491", 3530, 80)
    {
     Outlier("General", 0.05);
    };
    R_Date("ANU-5492", 3480, 110)
    {
     Outlier("General", 0.05);
    };
    R_Date("ANU-5490", 3730, 100)
    {
     Outlier("General", 0.05);
    };
    R_Date("ANU-5493", 3560, 80)
    {
     Outlier("General", 0.05);
    };
   };
   Boundary("Transition MP1/MP2");
   Phase("MP2")
   {
    Curve("=IntCal20");
    R_Date("ANU-5487", 3490, 110)
    {
     Outlier("General", 0.05);
    };
    R_Date("OxA-X-2524-24", 3574, 26)
    {
     Outlier("General", 0.05);
    };
    R_Date("ANU-5486", 3610, 90)
    {
     Outlier("General", 0.05);
    };
    R_Date("OxA-X-2524-25", 3643, 29)
    {
     Outlier("General", 0.05);
    };
    R_Date("OxA-X-2524-26", 3678, 28)
    {
     Outlier("General", 0.05);
    };
    R_Date("OxA-40925", 3742, 21)
    {
     Outlier("General", 0.05);
    };
    Curve("=Marine20");
    Delta_R("=LocalMarine");
    R_Date("OxA-29126 ", 3625, 29)
    {
     Outlier("General", 0.05);
    };
    R_Date("OxA-29127 ", 3655, 29)
    {
     Outlier("General", 0.05);
    };
    R_Date("OxA-29172 ", 3736, 29)
    {
     Outlier("General", 0.05);
    };
    R_Date("OxA-29134", 3744, 29)
    {
     Outlier("General", 0.05);
    };
    R_Date(" OxA-29133", 3789, 30)
    {
     Outlier("General", 0.05);
    };
    R_Date("OxA-29132", 3917, 29)
    {
```

```
 Outlier("General", 0.05);
 };
 R_Date("OxA-29131", 3985, 29)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-29130", 3917, 29)
 {
 Outlier("General", 0.05);
 };
};
Boundary("Transition MP2/MP3");
Phase("MP3")
{
 Curve("=IntCal20");
 R_Date("ANU-5484", 3280, 140)
 {
 Outlier("General", 0.05);
 };
 R_Date("ANU-5485", 3410, 110)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-40923", 3725, 20)
 {
 Outlier("General", 0.05);
 };
 Curve("=Marine20");
 Delta_R("=LocalMarine");
 R_Date("OxA-29128", 3552, 29)
 {
 Outlier("General", 0.05);
 };
 R_Date(" OxA-29173", 3779, 28)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-29129", 3967, 29)
 {
 Outlier("General", 0.05);
 };
};
Boundary("Transition MP3/MP4");
Phase("MP4")
{
 Curve("=IntCal20");
 R_Date("ANU-5483", 3430, 80)
 {
 Outlier("General", 0.05);
 };
};
Boundary("Transition MP4/MP5");
Phase("MP5")
{
 R_Date("ANU-5482", 3310, 128)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-X-2524-23", 3482, 28)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-40926", 3678, 21)
 {
 Outlier("General", 0.05);
 };
 Curve("=Marine20");
 Delta_R("=LocalMarine");
 R_Date(" OxA-29136", 3594, 29)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-29138", 3708, 29)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-29137", 3749, 30)
 {
 Outlier("General", 0.05);
 };
 R_Date("OxA-29135", 3768, 30)
 {
 Outlier("General", 0.05);
 };
 };
 Boundary("End MP5");
 Interval("Length of occupation");
 };
};
```

2. Outlier probability results

Element	Prior	Posterior	Model	Type
OxA-40924	5	24	General	t
ANU-5489	5	36	General	t
ANU-5488	5	4	General	t
ANU-5491	5	8	General	t
ANU-5492	5	8	General	t
ANU-5490	5	3	General	t
ANU-5493	5	5	General	t
ANU-5487	5	3	General	t
OxA-X-2524-24	5	2	General	t
ANU-5486	5	2	General	t
OxA-X-2524-25	5	2	General	t
OxA-X-2524-26	5	5	General	t
OxA-40925	5	30	General	t
OxA-29126	5	24	General	t
OxA-29127	5	13	General	t
OxA-29172	5	3	General	t
OxA-29134	5	3	General	t
OxA-29133	5	2	General	t
OxA-29132	5	4	General	t
OxA-29131	5	12	General	t
OxA-29130	5	4	General	t
ANU-5484	5	5	General	t
ANU-5485	5	3	General	t
OxA-40923	5	100	General	t
OxA-29128	5	24	General	t
OxA-29173	5	3	General	t
OxA-29129	5	80	General	t
ANU-5483	5	2	General	t
ANU-5482	5	14	General	t
OxA-X-2524-23	5	20	General	t
OxA-40926	5	2	General	t
OxA-29136	5	2	General	t
OxA-29138	5	3	General	t
OxA-29137	5	5	General	t
OxA-29135	5	8	General	t