Community Diversity at Ban Lum Khao, Thailand: Isotopic Evidence from the Skeletons

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In this study we compare isotopes in human teeth with burial artifacts at a Bronze Age site in Thailand, to identify immigrants and delimit discrete social groups. One of the aims of the Origins of Angkor Archaeological Project is to assess seminal aspects of the social, cultural, and technological development in the Mun River valley of Northeast Thailand. Ranging from the Neolithic through the Bronze Age to the Iron Age, multiple archaeological sites and cemeteries of this valley document the development of human society from simple agrarian origins to a complex, hierarchical, and specialized society, culminating in the Angkor civilization.

One of these sites, Ban Lum Khao, settled during the late Neolithic, was used as a cemetery in the Bronze Age, after 1050 B.C. (T. Higham 2004). The cemetery, of which 110 graves were uncovered, appears to show all the indications of an undifferentiated, almost egalitarian community, rarely showing any significant differences in the goods included with female, male, or even child burials, whether it be pottery forms, pig bones, spindle whorls, shell beads, or bangles (Higham and O'Reilly 2004; O'Reilly 1999). There was also no significant differentiation based on location within the cemetery. The burials at Ban Lum Khao suggest an egalitarian community, although bearing in mind that archaeological burials may reflect people's personal idiosyncrasies as much as generalities of their society, that cemeteries might be subdivided by social class or status, and also that absence of evidence for inequality in burials does not mean it did not exist (e.g., Ames 2007; Ucko 1969).

The site of Ban Non Wat, about 20 km west of Ban Lum Khao, shows clear

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evidence of inequality during the initial two phases of the Bronze Age, when men, women, and infants interred during the tenth century B.C. were interred in very large graves with dozens of ceramic vessels, bronze implements and ornaments, as well as numerous items of shell and stone jewelry. A comparison between the form of the ceramic vessels from these two phases at Ban Non Wat and the earlier of the two phases of definite Bronze Age burials at Ban Lum Khao strongly suggests contemporaneity. Hence, within a short distance, one set of interments were outstandingly wealthy while their contemporaries were poor. This is a clear indication that egalitarianism, at least in mortuary treatment if not in social status, was not universal during this period in the Mun River valley. By the Iron Age, there was marked inequality in the Mun Valley, at the site of Noen-U-Loke (c. 300 B.C.–A.D. 600), near Ban Non Wat, where the 126 burials show multiple signs of inequality, including gold items, as well as expert craft specializations (bronze, iron, glass), and exotic ornaments (agate beads), and large qualities of domestic rice.

The evidence from Ban Lum Khao and Ban Non Wat reveals two contemporary groups of early Bronze Age burials, one very rich, the other relatively poor. This might reflect sampling bias, since the excavation at Ban Lum Khao was located on the periphery of the mound, whereas at Ban Non Wat it was in the center. Nevertheless, Ban Lum Khao might equally represent a society without the inequality, specialization, and competition that was present nearby and certainly during later periods. Whether Ban Lum Khao was exceptional or indicative, the site provides an excellent opportunity to look for the "seeds" of social complexity in the Mun Valley.

The Mun Valley lies in the seasonally arid portion of Thailand, dominated by scrub and woodland, with well-weathered alluvial and regolith soils (Boyd and McGrath 2001). The pollen sequence at Noen-U-Loke (Boyd and McGrath 2001), about 20 km from Ban Lum Khao, reflects an open landscape with rice present throughout the occupation period, from a managed landscape of rice cultivation and modified woodlands in its earliest phase, to an increase of woodland at the expense of rice in later phases (Boyd and McGrath 2001). The sequence at Ban Non Wat, just 1 km to the east of Noen-U-Loke is similar, except for a shift from wet to dry conditions that may reflect local alterations during the occupation of Ban Non Wat (Boyd and McGrath 2001).

Skeletons from multiple sites in prehistoric Thailand from c. 2000 B.C. to c. 400 B.C. show a substantial increase in the rate of major long bone fracture from the Neolithic (0.3%) to the Bronze Age (3.0%), which may reflect a change in subsistence activities such as land clearance for the intensification of rice agriculture (Domett and Tayles 2006). Evidence for craniofacial fractures suggests possible interpersonal violence, including a few individuals from Ban Lum Khao (Domett 2004:131).

The aim of this article is to address the question of the structure of the society at Ban Lum Khao. We hypothesize that the egalitarian nature of the society reflects a kinship-based community. We test this by using isotopic evidence to see whether the individuals were all local or whether there were immigrants in the cemetery sample who might be expected to have contributed to a more diverse social structure.

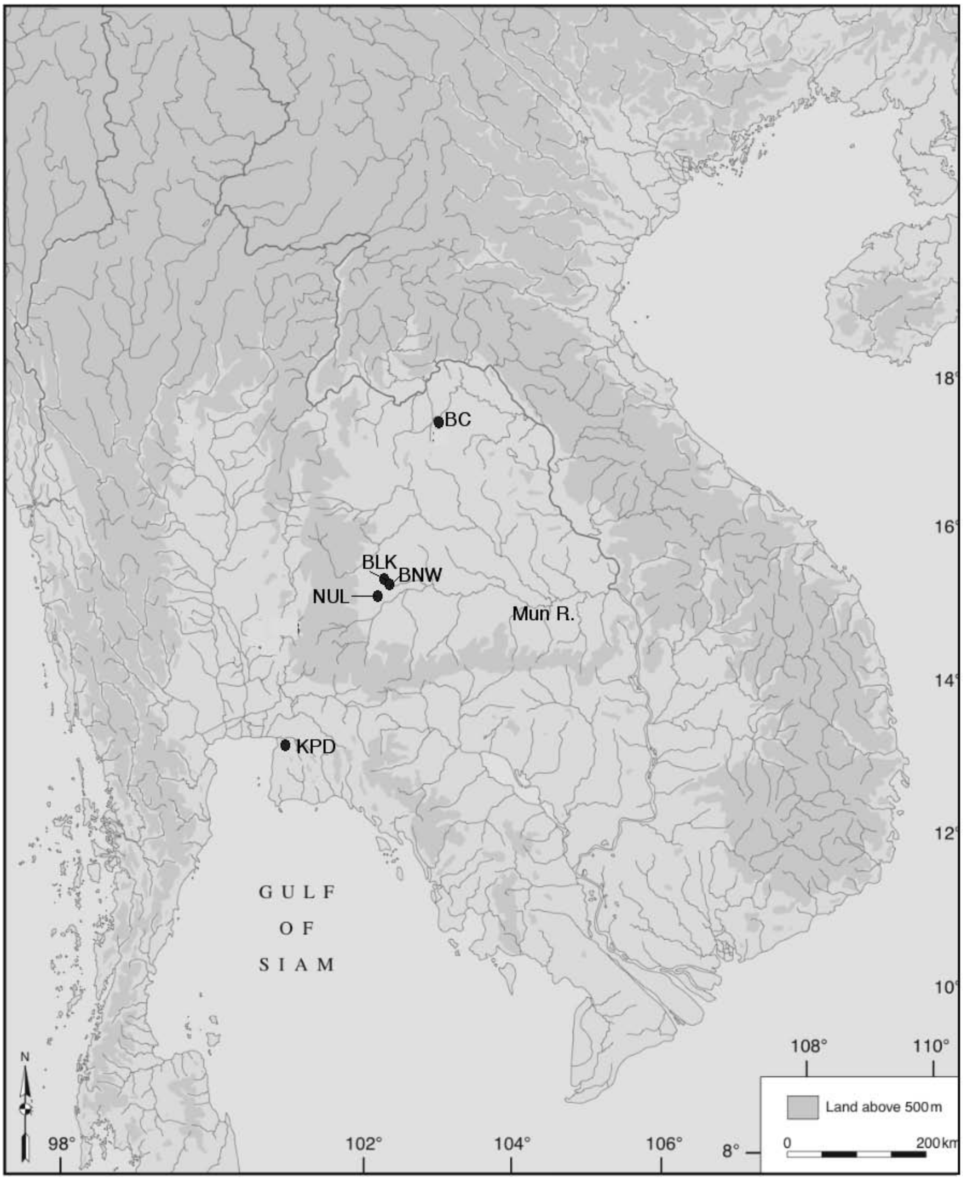

Fig. 1. Ban Lum Khao and other sites mentioned in text. Abbreviations: Ban Lum Khao, Ban Chiang, Ban Non Wat, Khok Phanom Di, Noen U-Loke.

BAN LUM KHAO

The site of Ban Lum Khao consists of thin occupation layers and a cemetery comprising three phases: late Neolithic/transitional Bronze (twelfth century B.C.), early Bronze Age, (tenth century B.C.) and late Bronze Age (seventh century B.C.). It lies at the junction of two small streams, about 3 km west of the site of

Ban Prasat (Monkhonkamnuanket 1992). Excavations in 1995–1996, now described in a monograph (Higham and Thosarat, Eds. 2004), uncovered an area of 15 by 10 m to a depth of 1.85 m, which was divided into three layers. At the top was an occupation layer incorporating a series of pits rich in organic remains, frequently modern, including fish, shellfish, mammalian bones, turtles, and much pottery. The second layer incorporated the three mortuary phases with some graves cut well into the natural substrate. Below this was layer 3, a late Neolithic occupation, with a dense shell midden, potsherds, and ash-filled hearths.

Domestic animals at Ban Lum Khao include pigs, cattle, and dogs. Wild water buffalo and deer were likely hunted, and fish and shellfish collected. Wet sieving and flotation during the excavation recovered the remains of freshwater fish, frogs, turtles, birds, and small mammals. The fish from early contexts are significantly larger than their modern counterparts (Thosarat 2004). Larger bones from layer 3 include the wild water buffalo, many middle-sized deer that probably come from *Cervus eldi*, some large pig bones and a few bones from the domestic dog (Higham 2004). Both wild water buffalo and deer bones became rare in layer 2, while domestic-sized cattle and pigs proliferate.

The Burials

Excavations at Ban Lum Khao (BLK) in 1995–1996 uncovered the burials of 110 individuals, including males, females, children, and infants laid out in what may have been rows, typical of the Bronze Age in central and northeastern Thailand. The adults were interred with the preferred orientation of the head to the southeast (Fig. 2). Virtually all the infant jar burials were found beyond the head of an adult.

The burials have been subdivided into three mortuary phases (MP) based on location, depth, orientation, superposition, and grave goods (Higham and Thosarat 2004:23). Most adult burials contained pottery, and over 400 complete pottery vessels were recovered from the burials, including footed jars identical to those recovered from Ban Prasat, with cord-marked, red-slipped, and burnished bodies, broadly flaring at the top (O'Reilly 2004). O'Reilly (1999, 2004) categorized the pottery into 15 forms, based on overall vessel shape and key attributes. Of particular interest (as discussed below) are pottery forms 1 and 1A. Form 1A, probably a serving vessel, is a small red-slipped open bowl with a pedestal base. Form 1, possibly a simplification of Form 1A, is the same bowl but without the pedestal, among the simplest pottery from the site. Form 1A is found among males, females, and children, whereas Form 1 was found predominantly with females ($n = 7$) with only one occurrence among males (Higham and O'Reilly 2004). Another important pottery type for this study is the Form 5 group (5A–5E), consisting of pots with an ellipsoid body and conical neck, probably cooking pots. Form 5A, introduced in MP 2, is the most common and was distributed among females, males and children around the cemetery (Higham and O'Reilly 2004). Late burials feature a range of forms, in which the upper part of the body of the pot is cylindrical in form, rather than everted (O'Reilly 2004). Some of the pottery and its decoration may recall that from the cemetery of Non Nok Tha (Higham 2002).

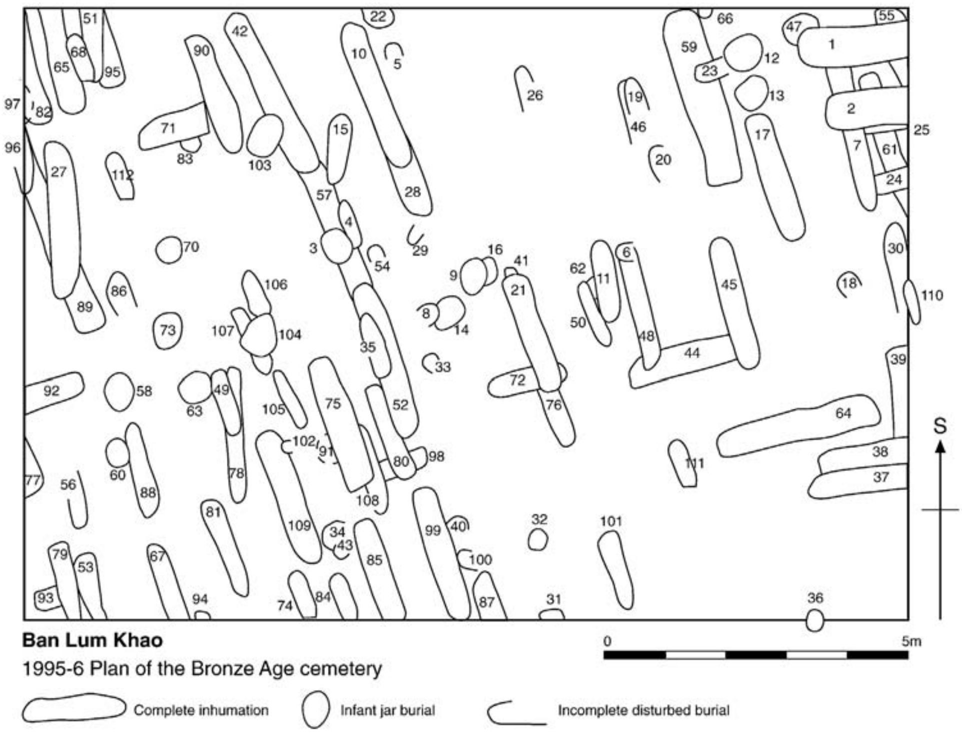

Fig. 2. The Ban Lum Khao cemetery.

Grave offerings also included bangles of marine shell (*trochus* and *conus*) and marble (Chang 2004). Other items included stone adzes, cord-marked cylinders of rice-tempered clay, pellet-bow pellets, fragments of clay bovid figurines, shell disc beads, freshwater bivalve shellfish, pig, and fish bones, sandstone abraders and bone implements that resemble the so-called "shuttles" from Khok Phanom Di. Although no bronze artifacts were found with any of the 110 burials, certain graves from MP 2 contained the remains of crucibles, molds, and corroded fragments of bronze. Overall, the shell and stone ornaments, clay bivalve mold casting technology and the clay figurines fit within the traditions of other Bronze Age sites on the Khorat Plateau and in central Thailand.

In terms of burial goods and apparent wealth of individuals, Ban Lum Khao essentially lacks marked differentiation, and there was no identifiable group significantly wealthier than another (Higham et al. 2004). There are no spatial patterns with pottery forms or other artifact forms among the burials, and no significant wealth differences according to age, stature, or putative cemetery row (Higham and O'Reilly 2004). The grave goods do not show any definitive signs of a division of labor, as utilitarian items such as abraders, spindle whorls, and anvils were found with men, women, and children alike.

There were some subtler differences, however, that suggest social and/or age-related differences within the community. In MP 2, the early Bronze Age phase, there were slightly more artifacts per burial (6.1 vs. 4.4) among adult females than adult males, with the "richest" four adult MP2 burials (Burials 21, 42, 52, 85) being those of females aged 20–35 years (Higham and O'Reilly 2004: fig. 12:26). Copper, bivalve molds and adzes were all found more often with children than with adult men or women, abraders more often with adult women, where they appeared along with adzes.

The Skeletons

Among the 110 individuals, 61 contained articulated or partly articulated skeletons, 35 were disturbed or scattered, and 14 contained infant jar burials (Domett 2004). Domett (2001; 2004) identified 51 children (<15 years old) and 59 adults, which is approximately the ratio expected for a cemetery sample representative of the population. The female survival rate, between 20 and 29 years of age, is only half that of males, which suggests both a fairly low fertility and a high risk of death during childbirth among BLK females (Domett 2004). The relative lack of older females as compared with older males (Table 1) is one of several notable differences between the sexes. Domett (2004) finds that BLK males had a more extreme variation in stature, a greater prevalence of osteoarthritis, osteophytosis, and traumatic bone fractures. While this partly reflects the higher number of older males in the sample, the difference is enough to suggest that males engaged in more rigorous and weight-bearing activities than females. This could be associated with gender-based differences in diet, as females have a significantly greater prevalence of caries (Table 2). Hence one possibility is that males engaged in hunting and females had a more starch-based diet (Domett 2004). Domett (2004)

Table 1. Adult age structure for Ban Lum Khao, as determined by Domett and Tayles (2006:225)

AGE (YEARS)	FEMALES	%	MALES	%
15–19	2	6	3	11
20–29	17	53	7	26
30–39	7	22	9	33
40–49+	4	13	7	26
unknown	2	6	1	4
Total	32	100	27	100

Note: Having already been split by age and sex, for sampling reasons these data were not further split into mortuary phases, as this would produce groups too small for useful analysis.

Table 2. Pathologies identified by Domett (2004) among the Ban Lum Khao skeletal sample

BAN LUM KHAO	OSTEOARTHRITIS	OSTEOPHYTOSIS	ADVANCED DENTAL ATTRITION	DENTAL CARIES
Females	15.4%	24.0%	6.3%	8.5%
Males	54.5%	43.8%	18.8%	1.9%

suggests that these differences in pathologies, if partly genetic, could reflect a matrilocal or patrilocal marriage pattern, by which one sex would comprise the majority of immigrants to the community from other populations.

METHODS

To characterize variation in human geographic origins and diets, we analyzed isotopes of strontium, carbon, and oxygen in samples of tooth enamel. We sampled 27 adults, including 15 females and 12 males (Table 3), and the condition of the material was excellent (cf. Domett 2004). Sampled skeletons were chosen

TABLE 3. ISOTOPE VALUES IN ENAMEL FROM BLK HUMAN SKELETONS

BLK BURIAL	TOOTH	MP	SEX	AGE	^{87}Sr/^{88}Sr	δ^{13}C	δ^{18}O	POTTERY TYPES	OTHER ITEMS
64	37	1	F	40–44	0.71129	−14.3	24.5	6, 10(7), 12(3)	Ba, SB
30	17	1	M	30–34	0.70974	−13.6	25.0	1A, 6, 10, 12(2)	786 SB, PB
44	26	1	M	30–39	0.70685	−14.3	24.6	10(3)	Bi, A
71	16	1	M	20–29	0.70984	−13.7	26.0	(cat. 822)	TS
17	26	2	F	20–24	0.70988	−14.1	26.1	1, 1A, 5A	CBa, BS
19	47	2	F	20–24	0.70917	−14.0	24.2	1A(2), 5A, 6, 10, 12	Ba
21	16	2	F	30–39	0.70990	−13.9	25.9	1, 1A, 8(2)	MBa, PB
34	46	2	F	30–39	0.70964	−14.6	24.5	5A(5), 5E	Adze
42	36	2	F	20–29	0.70988	−13.6	25.7	1, 1A, 2, 5E, 6(3), 8A(2)	MBa
46	16	2	F	20–24	0.70991	−14.3	26.5	none	AB
52	36	2	F	20–24	0.70974	−14.2	25.4	5A(2), 6, 10	2595 SB, 4MB, AB
53	17	2	F	40+	0.70975	−14.4	26.0	6(3)	–
75	16	2	F	40+	0.70963	−14.3	24.3	5A, 6(2)	AB, CP
77	36	2	F	25–29	0.70999	−14.1	24.9	1, 1A, 6, 8A	SBa
79	16	2	F	20–29	0.70981	−14.0	24.4	1, 5A, 5B, 6	Bi
28	38	2	M	35–39	0.70964	−14.2	26.0	6, cat. 530	Bi, O, DT
48	27	2	M	40+	0.70975	−14.0	27.1	5A, 5E(5), 6	BN, 48 SB
65	48	2	M	40+	0.70977	−13.3	25.5	5A	–
67	16	2	M	25–29	0.70967	−14.3	25.1	1A, 5A, 5E(3)	MBa, O
82	37	2	M	20	0.70969	−13.6	27.5	1, 1A, 5E(2), 11	MBa
89	46	2	M	35–39	0.70975	−15.1	24.8	none	13 SBa, Bi, 150 SB
94	26	2	M	30–39	0.70980	−13.1	24.6	??	–
109	36	2	M	20–29	0.70994	−14.0	24.7	5A, 5E(3)	PB
39	37	3	F	25–29	0.70967	−13.4	27.5	1(3), 7(3)	PB, CA, T, CP
49	28	3	F	20–24	0.70948	−14.1	27.1	9, 15	PB, CA
51	16	3	F	20–24	0.70967	−13.7	24.5	none	–

Notes: Typical uncertainties (based on repeat analyses from selected teeth) are $\pm$ 0.00002 for ^{87}Sr/^{88}Sr, $\pm$ 0.2 for δ^{13}C, and $\pm$0.5 for δ^{18}O. Abbreviations for other burial items: antler, A; bangle, Ba; bead necklace, BN; bivalve, Bi; burnishing stone, BS; clay anvil, CA; clay bangle, CBa; clay pellet, CP; copper alloy object, CA; dog tooth, DT; fish bones, FB; marble bangle, MBa; ochre, O; pig bone, PB; shell bead, SB; shell bangle, SBa; spindle whorl, S; shell disc beads, SDB; stone abrader, AB; turtle shell, T.

according to availability of a molar for analysis, presence of an antimere, and a sex estimation.

Strontium isotope signatures ($^{87}Sr/^{86}Sr$) are conveyed from eroded earth materials through soils and the food chain and into human tooth enamel (see Bentley 2006, and references therein). The technique is based on the fact that strontium isotope signatures ($^{87}Sr/^{86}Sr$) in tooth enamel derives from the biologically available strontium of the region, which at least partly reflects the geologic material where the diet was obtained during childhood (when the enamel was forming). Given the local variability in soils, rocks, and plants (e.g., Bentley 2006; Capo et al. 1998; Sillen et al. 1998), the best way to "map" the prehistoric, biologically available $^{87}Sr/^{86}Sr$ values is to sample it directly, in the tooth enamel of local animals from archaeological sites around the study area (Bentley 2006; Bentley and Knipper 2005). Local animals do a wonderful job of averaging the $^{87}Sr/^{86}Sr$ in their feeding area (Burton et al. 1999).

Mapping the biologically available isotope signatures is a long-term project involving strontium- and oxygen-isotope analysis of hundreds of archaeological faunal samples from the region (cf. Bentley 2006). As this is our first study in the Mun Valley, our isotopic map is a work in progress, and we base our preliminary expectations on the regional geology. Ban Lum Khao is situated on the southern portion of the Khorat Plateau, which covers about 180,000 km^2 and comprises eight sandstones and shale formations ranging from the early Jurassic to late Cretaceous, overlain by 100 Ma evaporites of halite and anhydrite (the Maha Sarakham formation), which in turn is conformably overlain by the Tertiary nonmarine mudstones of the Phutok Formation (Charusiri et al. 2006; Timofeef et al. 2006; Workman 1977). The sandstones are mainly fluvial, up to 5 km thick, consisting of continental, clastic sediments (including metamorphic detritus, acid and intermediate volcanic clasts), which, as paleocurrent indicators show, were originally transported by large braided river systems flowing out of the northeast during the Triassic to Cretaceous eras (Carter and Bristow 2003; Timofeef et al. 2006). Within the Khorat group, the Khok Kruat Formation contains red arkose sandstones (Charusiri et al. 2006), which can have quite high $^{87}Sr/^{86}Sr$ (>0.710), as reflected in the local human values at Ban Chiang (Bentley et al. 2005). In contrast, the evaporite formation, probably created by ocean flooding during the Cretaceous (Timofeef et al. 2006), should contribute a $^{87}Sr/^{86}Sr$ signature of Cretaceous seawater, or about 0.7070–0.7075. Hence we can expect a diverse range of $^{87}Sr/^{86}Sr$ ratios from the Khorat Plateau, anywhere from 0.7075–0.709 wherever weathered Maha Sarakham evaporates are the major source to the soil solutions, to above 0.7115 over outcrops of the red sandstones of the Khok Kruat Formation.

Beyond the Khorat Plateau, we expect the highest $^{87}Sr/^{86}Sr$ ratios from the Triassic/Jurassic granitoid belts distributed throughout Thailand, which would be the likely source of much higher $^{87}Sr/^{86}Sr$ ratios (Beckinsale et al. 1979; Charusiri et al. 1993). The Khao Daen granites, for example, which outcrop near the western coast of Thailand, have whole rock $^{87}Sr/^{86}Sr$ values ranging between 0.749 and 0.820, while the Hub Kapong Triassic granite complex, southwest of Khok Phanom Di in the northern Thai Peninsula, has whole-rock $^{87}Sr/^{86}Sr$ values of 0.775–0.789 (Beckinsale et al. 1979).

So far, from prehistoric Thailand we have human and animal isotopic signa-

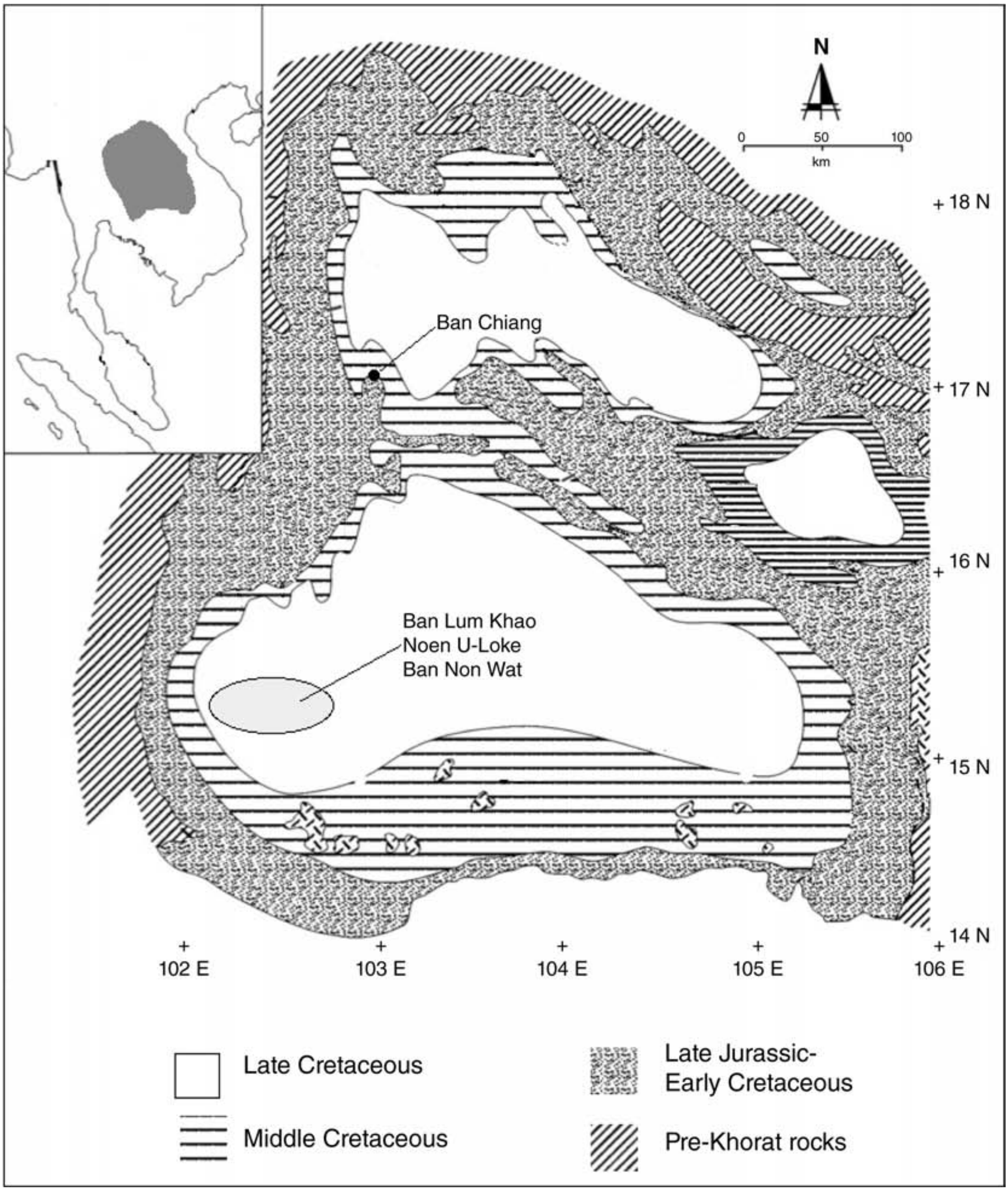

Fig. 3. Simplified geology of the Khorat Plateau in northeastern Thailand, including the Mun Valley. After Charusiri *et al.* (2006: Fig. 1).

tures from several sites, including Ban Chiang on the Khorat Plateau (Bentley et al. 2005), and Khok Phanom Di near the coast near modern Bangkok (Bentley et al. 2007). The $^{87}Sr/^{86}Sr$ range at Ban Chiang should be close to 0.712, judging by the clustered values from sedentary females as well as two archaeological dogs

(Bentley *et al.* 2005), and it is difficult to be more precise due to the both the mobility of people at Ban Chiang and the variability of the Khorat sedimentary geology as just described. Indicative of this variability, values from two dogs and two deer from Ban Na Di (a site near to, and contemporary with Ban Chiang) suggest a possible local $^{87}Sr/^{86}Sr$ ratio of 0.7116, but also that localized values as low as 0.7094 and as high as 0.714 may not be far away. At Khok Phanom Di, the local $^{87}Sr/^{86}Sr$ is just slightly above the seawater value of 0.7092, as expected at a coastal site. We are acquiring new data from Noen U-Loke, a few km from Ban Lum Khao, where local $^{87}Sr/^{86}Sr$ ratios among humans appear to lie between 0.7096 and 0.7099.

Carbon isotopes ^{12}C and ^{13}C fractionate during primary production of organic matter, such that C_3 plants (e.g., rice) have $\delta^{13}C$ (relative to the Pee Dee Belemite [PDB] carbonate standard) values between −23 and −34 (e.g., Heaton 1999). For settlements of the Mun Valley, given their similar levels of temperature, humidity, insolation, altitude, and forest cover—all of which have secondary effects on $\delta^{13}C$ in plants (e.g. Heaton 1999)—the $\delta^{13}C$ we measure in tooth carbonate should reflect the differing amounts of marine foods, meat and/or plant foods (C_3 vs. C_4) in the diet (Ambrose et al. 1997; DeNiro and Epstein 1978). King (2006) has already found the collagen preservation in BLK bones to be poor, so we measured $\delta^{13}C$ in the tooth enamel apatite, which reflects $\delta^{13}C$ in the whole diet, enriched by 9.4 (Ambrose et al. 1997). This difference of 4.4 is very nearly what we found when comparing our enamel $\delta^{13}C$ value from BLK 49 (−14.05) to the collagen value (−17.9) retrieved by King (2006: appendix C3) on the same individual. At BLK, effects on $\delta^{13}C$ variations could include: (a) consumption of freshwater fish, the remains of which show it was an important food at Ban Lum Khao (Thosarat 2004); (b) terrestrial meat consumption, as $\delta^{13}C$ increases by about one per mil per trophic level (DeNiro and Epstein 1978); (c) forest density, whereby plants growing beneath a dense forest canopy have $\delta^{13}C$ values several per mil more negative than similar plants in cleared areas (Heaton 1999); and (d) altitude, whereby high-altitude plants (above 1000 m, adapted to lower partial pressure of CO_2) tend to be enriched in ^{13}C by a few per mil (Körner et al. 1991).

Oxygen isotope compositions ($\delta^{18}O$, relative to Standard Mean Ocean Water [SMOW]) in mammalian enamel is often reflective of geographic origins (e.g., Balasse et al. 2002; Budd et al. 2004; Kohn 1996). Determined largely by temperature, the mean annual $\delta^{18}O$ in precipitation depends on latitude and altitude (Bowen and Wilkinson 2002), and also on topographic relief, distance from large bodies of water, and relative humidity. In humans from settled communities, whose water supply is more consistent, the variations in tooth enamel $\delta^{18}O$ are typically about 1 (Budd et al. 2004). In Southeast Asia, geographic variation of $\delta^{18}O$ in prehistoric human enamel may not be systematic enough to resolve human communities (cf. Bentley et al. 2005; Krigbaum 2003). Nevertheless, in theory, we may expect ^{18}O generally to be depleted in enamel from people from higher altitudes and greater distance from the sea, as rain clouds will be depleted progressively in heavy oxygen as they move upland and inland. As King (2006) points out, there is a rain shadow effect as the monsoon rains move into Thailand; most of their water is precipitated before reaching the Khorat Plateau, where the least rain falls in the west and center.

PROCEDURES

We measured strontium, carbon and oxygen isotopes in tooth enamel from selected human skeletons, with sampling preference for the second molar (crown complete between ages 7–8 years [Hillson 1997: 123]) or third molar (ages 12–16) wherever possible. Many studies indicate that buried prehistoric bone tends to be contaminated from groundwater strontium, so while human bone may help identify the local $^{87}Sr/^{86}Sr$ value at the site, we focus our analyses on the tooth enamel, which robustly resists isotopic contamination (e.g., Hoppe et al. 2003; Trickett et al. 2003).

Using our standard procedure, we purified enamel samples through columns of Sr-spec resin, and analyzed $^{87}Sr/^{86}Sr$ by mass spectrometry at the National Oceanography Centre (NOC), Southampton, and also at the Arthur Holmes Isotope Geology Laboratory, Durham University. We then measured $\delta^{18}O$ and $\delta^{13}C$ in the carbonate (CO_3) component of the tooth enamel (cf. Balasse et al. 2002; Krigbaum 2003) at the Stable Isotope Laboratory, Earth Sciences Department, Durham University. The details of the lab procedures are as described by Bentley et al. (2005, 2007).

RESULTS

The isotope values from the three mortuary phases (MP) are listed in Table 3 and plotted in Figure 4 (with outliers omitted). From all sampled individuals, the mean $^{87}Sr/^{86}Sr$ is 0.70969 ± 0.00067, quite similar to that among Bronze–Iron Age humans from Noen U-Loke (data in prep.), which is about 15 km to the west, up the Prasat stream. Almost certainly, the majority of these individuals reflect origins within the Mun Valley.

The two most extreme $^{87}Sr/^{86}Sr$ ratios are from MP 1. With all the other BLK values between 0.709 and 0.710, the $^{87}Sr/^{86}Sr$ ratios from MP 1 Burials 64 (0.71129) and 44 (0.70685) are clear outliers, even compared with values at Noen U-Loke, suggesting these two individuals may have immigrated from outside the

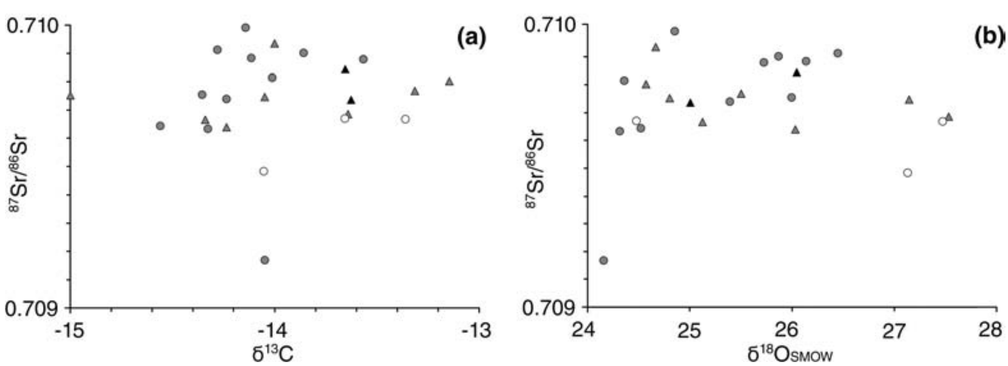

Fig. 4. Isotope values in BLK burials, showing (a) $\delta^{13}C$ vs. $^{87}Sr/^{86}Sr$ and (b) $\delta^{18}O$ vs. $^{87}Sr/^{86}Sr$. Circles, females; triangles, males. MP 1 burials shaded black, MP 2 gray, and MP 3 white. Two outliers (Burials 44 and 64, both MP 1) have $^{87}Sr/^{86}Sr$ outside the plotted range.

Mun Valley. The $^{87}Sr/^{86}Sr$ ratio from Burial 64 (adult female) is consistent with sites in the Songkhram Basin, farther north on the Khorat Plateau, such as Ban Chiang and Ban Na Di (Bentley et al. 2005), whereas the anomalously low ratio from Burial 44 (adult male) suggests a province of basaltic lavas, possibly the major outcrops east of the Mekong River, in Laos and Cambodia (Workman 1977). These two burials are also unique among our BLK sample as they feature type 10 as either the only or the predominant pottery vessel (>60%).

Two other burials with non-local $^{87}Sr/^{86}Sr$ ratios are Burials 19 and 49, both female. Burial 49 (0.70948), from MP 3, was the only one with pottery types 9 and 15, contained a clay potter's anvil, and may have been significantly later than the rest of the BLK burials (Higham and Mather 2004). Burial 19 (0.70917), from MP 2, also had the lowest $\delta^{18}O$ of the BLK sample (24.16) and distinctive pottery forms.

Groups of socially distinct women?

Among the females, the isotopic values clearly correlate with certain burial goods, particularly pottery type, found in the grave. Burials with pottery types 1 (1 and/or 1A) had significantly higher $^{87}Sr/^{86}Sr$ than the rest of the group ($p < 0.004$, two-tailed t-test), five of which have $^{87}Sr/^{86}Sr$ ratios above 0.7098. The three sampled females associated with both pot types 1 and 1A (Burials 17, 21, 42) have virtually identical $^{87}Sr/^{86}Sr$ ratios (0.70989 ± 0.00001) and similar $\delta^{18}O$ values (25.7–26.5). Only two other BLK burials contained both these pottery styles, one of which (Burial 85) had no teeth to sample, and the other (Burial 82) was a male. All three of these females had bangles, and in fact all but one of the females with $^{87}Sr/^{86}Sr$ above 0.70990 had a bangle in the burial, a significant pattern ($p < 0.03$, t-test). Burial 19 also had a bangle (Table 3), so females with both pottery type 1 and bangles tend to have non-local $^{87}Sr/^{86}Sr$ ratios, with only one exception (Burial 82).

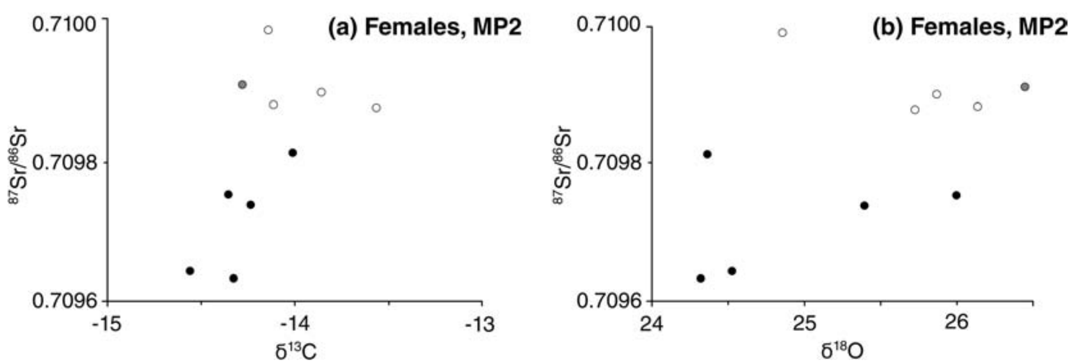

Fig. 5. (a) $\delta^{13}C$ vs. $^{87}Sr/^{86}Sr$ and (b) $\delta^{13}O$ vs. $^{87}Sr/^{86}Sr$ in the sampled BLK females from Mortuary Phase 2 only. The symbols are shaded by the predominant pottery type (the most multiple copies), including pottery type 1 (white), type 5 and/or 6 (black) and no recovered pottery (grey). One outlier (Burial 19) not shown.

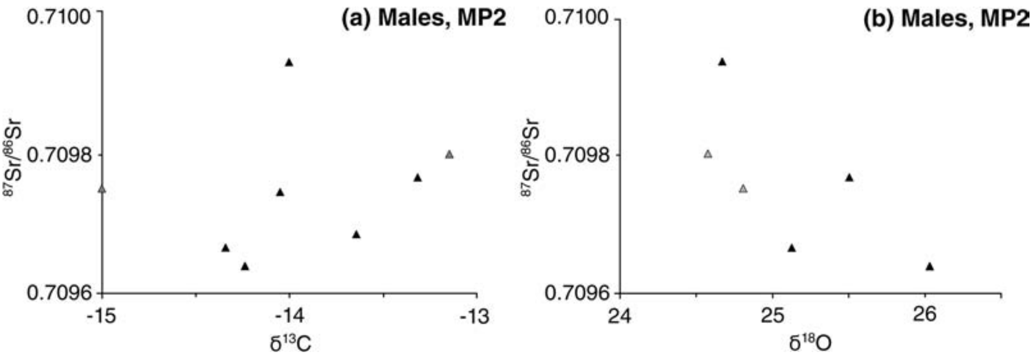

Fig. 6. (a) δ^{13}C vs. ^{87}Sr/^{86}Sr and (b) δ^{13}O vs. ^{87}Sr/^{86}Sr in the sampled BLK males from Mortuary Phase 2. As in Figure 4, symbols shaded white for pottery type 1, black for type 5 and/or 6, and grey for no recovered pottery.

Focusing on the females just from MP 2, the correlation between pottery types and isotopic signature is further illustrated by plots of ^{87}Sr/^{86}Sr vs. δ^{13}C and ^{87}Sr/^{86}Sr vs. δ^{18}O. As shown in Figure 5, if we designate the burial just by the most numerous pottery type, the females with pottery types 1 (1, 1A) group quite distinctly from those with pottery types 5 (5A–5E).

Given these correlations between pottery type and isotopic signatures among the females, it is notable that such correlations are *not* apparent among the males (Figure 6). There is also no noticeable pattern with bangles: three of the sampled males had bangles (Burials 67, 82, 89), and their ^{87}Sr/^{86}Sr ratios (0.70969–0.70975) are no different from the mean value for the whole BLK sample.

DISCUSSION

While the majority of individuals in our sample fall within a relatively limited range of ^{87}Sr/^{86}Sr ratios (0.709–0.710) the most outstanding outliers are a man and a woman from the earliest phase of the cemetery, MP 1, with ^{87}Sr/^{86}Sr ratios (0.7068 vs. 0.7113, respectively) suggesting origins outside the Mun Valley. Their values are nonetheless quite different, indicating these two individuals immigrated from different communities. One of these, Burial 44, has the only example of worked antler at the site, and a similar, Neolithic find at Ban Kao in Kanchanaburi Province, western Thailand, was suggested to show a southern Chinese influence (Sørensen and Hatting 1966: 143). Hence the valley may have attracted original settlers from different locations. In fact, the larger component of the early faunal assemblage suggests that the inhabitants entered new territory and exploited the many wild animals they encountered. Ban Non Wat has earlier occupation but maybe that reflects very localized initial settlement.

Among all the other individuals whose ^{87}Sr/^{86}Sr ratios lie between 0.7096 and 0.7100, none need have a distant origin, and it is most parsimonious to assume they were all from within the Mun Valley. The main range of ^{87}Sr/^{86}Sr ratios at Noen U-Loke (0.7096–0.7099), for example, is quite similar to that at BLK, making it difficult to distinguish these communities by strontium isotope signature alone. In our *very* preliminary efforts to map $^{87}Sr/^{86}Sr$ in the region using archaeological pig teeth, the sites of Ban Lum Khao, Noen U-Loke, and Ban Non Wat (Fig. 1) so far have yielded indistinguishable local $^{87}Sr/^{86}Sr$ values, between 0.70979 and 0.70995 ($n = 4$). However, even if we succeed at resolving the map to the community scale, the scale of personal mobility is likely to be larger, since many of the sites in the Mun Valley are within a day's walk of each other. Hence any clusters within this general local range of $^{87}Sr/^{86}Sr$ ratios (0.7096–0.7099) become all the more notable.

Even while the isotopic "map" of the Mun Valley is being fleshed out over the long term, the isotope data from BLK already provide several novel indications concerning social grouping. Specifically, among the BLK females, indicators of childhood origin ($^{87}Sr/^{86}Sr$ $\delta^{13}O$) and diet ($\delta^{13}C$) are associated with bangles and the most frequent pottery type in the burial. A particularly notable pattern is that the females with $^{87}Sr/^{86}Sr$ above 0.70990 (presumably non-local) appear to have identified themselves with pottery types 1 and 1A and bangles.

Among males, however, there were no such correlations between isotope values and pottery type. The simplest explanation for this is that, in terms of social identity, pottery was more important to females than to males, as suggested elsewhere in the world (Peregrine 2004). Possibly, females immigrated from nearby communities, each with its own pottery tradition, which is further suggested if we include Burials 19 and 49, also female non-locals with distinctive pottery forms. Under a patrilocal kinship system, this is a normal pattern. Notably, the women of each isotope group were distributed in different parts of the cemetery, which could reflect their different respective marriages. It seems unlikely that this cemetery was shared among different communities, given the propensity for living in discrete communities with the cemetery intermingled with occupation in this well-populated valley (cf. Welch and McNeill 1991). Interestingly, the $^{87}Sr/^{86}Sr$ ratios from the pottery 1/1A females (0.70988–0.70991) are essentially the same as a group at nearby Noen U-Loke (0.70986–0.70990). Perhaps these reflect the same location, as future studies may reveal.

The $\delta^{13}C$ variation is subtle—about 1 —so we cannot be certain whether the variation reflects amounts of fish or rice in the diet, for example, or some of the secondary effects on $\delta^{13}C$, mentioned above. Notably, the males and females fall along different mixing arrays on a plot of $^{87}Sr/^{86}Sr$ vs. $\delta^{13}C$ (Fig. 4a). This perhaps reflects different subsistence emphases—fisherfolk versus rice cultivators, for example. Other evidence suggests that the Mun Valley was culturally integrated, as there are similarities in material culture and mortuary ritual at Ban Lum Khao, Ban Prasat and Noen U-Loke, and Ban Non Wat.

As is often the case with large mounded sites, 150 m^2 of excavation, though large, is still only a very small sample of the Ban Lum Khao site (Higham and Thosarat 2007: Fig. 4:1). Hence the relative homogeneity in burial "wealth" at BLK, or the differences between sexes, *could* merely reflect sampling bias. Perhaps the excavation happened to uncover only a special subgroup within the larger Ban Lum Khao community. In any case, we have characterized this group, however representative it turns out to be, and we present our results hopefully, that is, as a motivation for future researchers to conduct further excavation and similar analysis at Ban Lum Khao and/or other contemporaneous sites of the Mun Valley region.

CONCLUSIONS

Prehistoric complex societies developed with the differentiation of people into distinct yet interconnected groups—not just in terms of the specialization of their activities, but also their social identities. This complexity has to begin with something, and kinship provides one of the surest means of differentiation in egalitarian society (e.g., Fox 1983). Craft specializations and exchange networks would most easily develop along contacts already established through lines of kinship, which govern the social identities, division of labor, and exchange of marriage partners in virtually all pre-complex societies.

A window onto this process is provided by the isotopic analyses of the human burials at Ban Lum Khao, where the isotope evidence appears to reveal distinct groups of women raised in different communities, each associated with particular pottery types. Since this is not a pattern among males, it probably reflects a patrilocal marriage system, with marriages between villages within the Mun Valley. It could be that this limited scope of exogamy persisted through time, as there are dental indicators of close genetic relatedness at Noen U-Loke by the Iron Age (Nelsen et al. 2001). Possibly, we are seeing signs of moderate social differentiation despite kinship exchange with other communities, but without strong evidence of status differentiation. This is despite the large variation in male stature found by Domett (2004). The basis of this remains an enigma.

At first glance, our hypothesis that the apparently egalitarian society at Ban Lum Khao is reflective of close kinship is not upheld by this result, as there are clearly immigrants in the community. Nonetheless these immigrants, although differentiated by the style of grave goods, were not differentiated by the quantity (or quality, although this is more difficult to assess) of goods.

If Ban Lum Khao is representative of the very early origins of complex society in the Mun Valley, then such early social and possibly kin-based differentiation, amid an otherwise egalitarian economy, may represent the seeds from which complexity in the Mun Valley developed over subsequent centuries. An ethos of exogamy and in-migration, as well as increased local specialization and external exchange, might have been important catalysts in the development of the types of regional power centers and status differentiation that herald the emergence of early chiefdoms and states in Southeast Asian Bronze Age and Iron Age societies. In suggesting how human activity shaped longer-term social structure, our results are compatible with Interpretive archaeological theory (Gardner 2007; Shanks 2007), along with views that the movement of women of different social groupings into new communities facilitated the expansion of inter-community exchange during the development of socially ranked and politically complex communities.

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ABSTRACT

Isotopes of strontium, carbon, and oxygen were analyzed in human tooth enamel from the Bronze Age site of Ban Lum Khao (c. 1400 B.C.–500 B.C.) in Thailand. The strontium and oxygen isotopes, which generally reflect place of origin, delimit discrete groups among the individuals. Among the females, different groups determined through isotopic signatures were buried with distinctive pottery types. This suggests that social identity, drawn from village of origin, was conveyed by material culture, at least in burial. Although Ban Lum Khao was probably an egalitarian community, this isotopic and archaeological evidence suggests that different social identities were associated with place of childhood origin in this Bronze Age community. Keywords: prehistoric kinship, matrilocality, patrilocality, strontium isotopes, oxygen isotopes, carbon isotopes, Sr-87/Sr-86, Neolithic, Bronze Age, Southeast Asia.