The People of Ban Chiang: Bioarchaeology of the 1974 and 1975 Skeletons

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I. Introduction

In this paper, I discuss how I personally became involved with the Ban Chiang site and what we have learned from studies of the human skeletons from the American-Thai excavations in 1974 and 1975, skeletons that are currently curated at the University of Hawaii. The topics reviewed include the health, life span, diet, life style, and the biological relationships and possible origins of the ancient inhabitants of Ban Chiang. Special mention is made of one of the noteworthy burials from the 1974 excavation, BC Burial 23, which was dubbed, “Vulcan”, by the excavators.

My initial involvement with studies of human skeletons from Thailand was the result of a number of fortuitous events in my academic training and my appointment as an Assistant Professor at the University of Hawaii in 1969. In Hawaii, I began to work with UH archaeologists, most notably, Bill Solheim and two of his students, Donn Bayard and Chet Gorman, who were finishing their dissertations. My first involvement with Southeast Asia was a study of the skeletons excavated from the 1965-66 excavations at Non Nok Tha, a site located in northeast Thailand, at the Siriraj Hospital in Bangkok in the summer of 1970 (Pietrusewsky 1974a).

II. Thai Fine Arts Department-University of Pennsylvania Excavations at Ban Chiang Site (1974 and 1975)

My second opportunity to study ancient skeletons from Thailand was my participation in the Thai Fine Arts Department-University of Pennsylvania 1974 excavation at Ban Chiang. Not long after he had moved to Philadelphia to take up a position with the University Museum of the University of Pennsylvania, Chet Gorman (with funding from the Ford Foundation) invited me, along with other specialists [e.g., Charles Higham-faunal specialist; Doug Yen-palaeoenthnobotanist] to join him and FAD (Fine Arts Dept.) co-director Pisit Charoenwongsa for the first season (1974) of excavations at Ban Chiang. Except for a very brief encounter with an excavation of an Indian ossuary in Ontario, Canada as a graduate student, I had not participated in a major archaeological excavation. While the work at Ban Chiang in 1974 was challenging, especially in the high humidity and heat of the monsoon season, it was a very rewarding experience for me. Living in a small rural village in northeast Thailand was also a new and exciting adventure for a young physical anthropologist.

In addition to participating in the 1974 excavation, I was asked to analyze the skeletons from the 1974 and 1975 excavations, skeletons that are currently curated at the University of Hawaii. Thus began my more than four decades of involvement with the individuals excavated at Ban Chiang.

Many Thai students, some with royal heritage, participated in the fieldwork at Ban Chiang. The basics of human osteology and bone identification were introduced during the fieldwork that...
helped to facilitate the excavation and preparation of the remains for eventual shipment to Hawaii. Also, many students at the University of Hawaii assisted in the initial analysis of the human skeletons from Ban Chiang.

My report (Pietrusewsky 1980), the only one completed before Chet Gorman’s untimely death, summarized what we had learned from the human skeletons from these excavations. Although I continued to use the Ban Chiang skeletal data in a number of publications since then, a second, more detailed examination of the Ban Chiang skeletons was undertaken by Michele Toomay Douglas in the 1990s for her dissertation research (Douglas 1996). This new research, including detailed descriptions of the paleopathology, and new data not previously recorded by me resulted in the monograph of the skeletons from this site published by the University of Pennsylvania Museum of Archaeology and Anthropology in 2002 (Pietrusewsky and Douglas 2002a). The excavations at Ban Chiang and comprehensive analysis of the Ban Chiang skeletons (Douglas 1996; Pietrusewsky 2002a) have provided a standard against which all subsequent excavations and bioarchaeological reports in Southeast Asia and beyond have been measured.

**Ban Chiang site**

Ban Chiang is a modern village located in Udon Thani Province, northeastern Thailand (Figure 1). The village rests on a large mound where three streams meet at approximately 170m above sea level. Ban Chiang came to the attention of the international community in the late 1960s and early 1970s when looting revealed a previously unknown cultural tradition beneath the village. The first excavations in the modern village of Ban Chiang were conducted in 1967 and 1972, excavations that yielded burials and evidence of bronze and iron metallurgy.

![Figure 1. Map showing the location of Ban Chiang and Non Nok Tha in northeast Thailand.](image-url)
Two separate sites in the village of Ban Chiang, about 100m apart, were excavated under the direction of Chester Gorman (University of Pennsylvania) and Piset Charoenwongsa (Thai Fine Arts Department-FAD) in 1974 and 1975. The 1974 excavation, referred to as the Ban Chiang (BC) excavation, was in the yard of a private house that had minimal disturbance from looters, and the 1975 excavation, the Ban Chiang Eastern Soi (BCES) excavation, was in the middle of a road (Charoenwongsa 1982; Gorman 1977; Gorman and Charoenwongsa 1976; Pietrusewsky and Douglas 2002a; White 1982, 1986). Altogether, approximately 142 inhumation burials, which were predominantly primary, supine and extended, were excavated from the two seasons’ of work at Ban Chiang. Grave goods associated with the burials included pottery, bone tools, clay pellets and beads, metal adzes, spear points, bracelets and anklets. Additionally, skulls and limb bones of pigs and/or cows were placed with the human burials as mortuary offerings at this site.

Ban Chiang is a mortuary and occupation site with varied usage including habitation and occupation activities. The stratigraphic sequence of burials at Ban Chiang was divided into ten phases grouped in three periods (Early, Middle, and Late) within the date range 2100 B.C.–200 A.D. (Table 1). Recently, Higham et al. (2015), using extensive radiocarbon dating, placed the transition to the Bronze Age at Ban Chiang in the 11th century B.C. Regardless of the issues of dating, the Ban Chiang burials examined here were interred over the course of approximately 2000 years, a time period that covers the transition from hunting and gathering to agriculture in Southeast Asia (Pietrusewsky and Douglas 2002a; White 1982).

Table 1. Archaeological sequence at Ban Chiang (after Douglas and Pietrusewsky 2007:302; White 2008; White personal communication) ¹

<table>
<thead>
<tr>
<th>Period (Phase)</th>
<th>Resource base</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Period (IX – X)</td>
<td>Wet rice agriculture.</td>
<td>ca 300 B.C. – A.D. 200</td>
</tr>
<tr>
<td>Middle Period (VI – VIII)</td>
<td>Appearance of water buffalo bones, iron; gain in forest, frequent low intensity burning.</td>
<td>ca 900 – 300 B.C.</td>
</tr>
<tr>
<td>Early Period (V)</td>
<td>Hunter-gatherer-cultivator economy. Bronze and domesticates. Slow forest recovery from Middle Holocene.</td>
<td>ca 1500-900 B.C.</td>
</tr>
<tr>
<td>Early Period (I-IV)</td>
<td>Hunter-gatherer-cultivator economy. Premetal, bronze appears as a grave good in Phase III. Domesticates, including rice.</td>
<td>ca 2100 – 1500 B.C.</td>
</tr>
<tr>
<td>Initial</td>
<td>Evidence for large scale burning that began about 4400 B.C.</td>
<td>?-ca 2100 B.C.</td>
</tr>
</tbody>
</table>

¹ The bold line in this table indicates the point of division for the temporal division between early and later burials at Ban Chiang

Although the prehistoric inhabitants of Ban Chiang had knowledge of domestication from the first settlement of the village, evidence from various sources including the burials (e.g., Douglas
and Pietrusewsky 2007; Pietrusewsky and Douglas 2002a), indicates they were not intensive farmers. While there was an increasing reliance on domesticated animals through time, as well as cultivation of rice and yams, the early inhabitants at Ban Chiang relied substantially on hunted game, fish and wild fruits. Cord-marked ceramics are present in the earliest Ban Chiang phases, and distinctive white carinated (red-on-buff) ceramics appear in the Middle Period (approximately first millennium B.C.), at which time water buffalo bones and iron implements, common accouterments for intensified wet-rice agriculture, also appear (Higham 2002:187). Palaeo-environmental evidence from during and after the middle phases of occupation at Ban Chiang is consistent with the intensification of rice agriculture (Higham and Kijngam 1979; Penny 1999; White et al. 2004). Since its discovery, the Ban Chiang site has figured prominently in investigations on the origins and dissemination of rice agriculture and metallurgy in Southeast Asia.

III. Research Involving the Skeletons from 1975 and 1974 Excavations at Ban Chiang

Collaborative research involving the Ban Chiang skeletons by me and my students have resulted in the publication of at least 2 books/monographs, 10 journal articles, and 5 book chapters (Appendix A). In addition, two doctoral dissertations at the University of Hawaii have focused on the skeletons from Ban Chiang and Non Nok Tha (Douglas 1996; King 2006). Sian Halcrow also used the subadult skeletons from Ban Chiang in her doctoral dissertation at the University of Otago.

The predominant issues in archaeological research in Southeast Asia include the historical and biological relationships of the inhabitants, origins of intensified wet-rice agriculture, and origins of complex societies. These issues often center on two contrasting models – the agricultural expansion theory and the continuity model, models evolved from early archaeological excavations in Thailand, including those at Ban Non Nok Tha, and Ban Chiang (Higham 1989). These models will be discussed in more detail later.

In addition to studies of the health and life style of the early inhabitants of the Khorat Plateau region of northeast Thailand, that involve the systematic recording of thousands of measurements and nonmetric observations and detailed descriptions of paleopathology, there have been more specialized chemical analysis of bone and teeth from Ban Chiang including isotope analysis and, most recently, attempts to obtain ancient DNA from these skeletons.

Others who have examined the skeletons from Ban Chiang stored at the University of Hawaii include:

- Analysis of dental measurements by C. Loring Brace (University of Michigan)
- Analysis of dental nonmetric traits by Christy G. Turner II (Arizona State University).
- Studies of teeth and crania by Hirofumi Matsumura (Sapporo Medical School) Tsunehiko Hanihara (Saga Medical School) and Hajime Ishida (University of the Ryukyus).
- Analysis of subadult skeletons by Sian Halcrow (University of Otago).
- Studies of paleopathology by Michele Toomay Douglas (University of Hawaii)
- Analysis of carbon and nitrogen stable isotopes by Christopher King (University of Hawaii)
- Analysis of strontium ($^{87}$Sr/$^{86}$Sr) and oxygen ($^{18}$O) isotopes by Alex Bentley (University College London and now at the University of Houston)
• aDNA analysis by Ron Pinhasi (University College Dublin)

It has been a privilege to serve as the sole curator of the skeletons from the 1974 and 1975 excavations at Ban Chiang, which were sent to Hawaii soon after they had been excavated. This rather long period of curation, now exceeding four decades, has meant that new studies, many involving the latest refinements in field of bioarchaeology, could be undertaken allowing researchers to address a variety of new research questions never before possible.

Next, I would like to discuss some of the important things we have learned from studies of the Ban Chiang individuals. First, what we know about health, diet, life span, and lifestyle of some of the earliest inhabitants of Northeast Thailand, people who were in the transition from a hunting and gathering lifestyle to one that increasingly relied on agriculture. Second, what we have learned about the biological relationships of the ancient inhabitants of Ban Chiang and their relationship with the people in the surrounding regions of Southeast Asia and beyond. Lastly, I would like to mention one particular burial from these excavations, BC Burial 23, given the nickname, “Vulcan” from the 1974 excavation.

IV. Health, Diet, Life Span, and Lifestyle of Some of the Prehistoric Inhabitants of Ban Chiang

Skeletons represent the most direct evidence of the biology of past populations, and their study (today, the field known as bioarchaeology) provides insight into health and well-being, dietary history, lifestyle activity, violence and trauma, ancestry (biodistance), and demography (Larsen 2015). These areas help inform our understanding of a range of issues, such as the causes and consequences of adaptive shifts in the past (e.g., foraging to farming, sedentarism), the biological impact of invasion and colonization, differential access to food and other resources (e.g., by gender or status), and conflict and warfare.

Indicators of health

A central concern in bioarchaeology is the interaction between biology and behavior and the role of environment on health and lifestyle. Although physiological stress cannot be measured directly, a variety of indicators, observed in the skeleton, may be used to infer stress and its impact on the individual and population. The model that most bioarchaeologists now use to study health in the past is one developed by Goodman and co-workers (Goodman et al. 1984; Goodman and Armelagos 1989) (Figure 2). This model focuses on the causes and skeletal manifestations of stress (Figure 2), thus allowing researchers to systematically examine stress and reflect on the adaptive process and the central role of health to this process.

![Figure 2 Stress model adapted for studies in bioarchaeology (Goodman et al. 1984; Goodman and Armelagos 1989).](image-url)
General indicators of metabolic stress include mortality and fertility measures, adult stature, cribra orbitalia, and dental enamel hypoplasia. Linear enamel hypoplasia (LEH) is visible as one or more bands of decreased enamel thickness on the crown surfaces of teeth. Linear enamel hypoplasias provide a nearly indelible indicator of stress during tooth crown formation during infancy and childhood. These defects are associated with acute forms of stress including infection, inadequate nutrition, and weanling diarrhea. Cribra orbitalia, a porosity of the orbital roof is commonly attributed to synergisms between inadequate diet, poor iron absorption, increased iron utilization, parasitic infection, gastrointestinal infections, and blood loss. Specific indicators of health include dental pathology (dental caries, abscessing, attrition, antemortem tooth loss-ATML etc.), osteoarthritis, infection, and trauma.

As has been shown elsewhere, with the transition to and intensification of agriculture, there are increases in such indicators as fertility, dental caries, dental hypoplasia (LEH), cribra orbitalia, trauma and infectious disease, and a decrease in mean age-at-death, dental attrition, and stature. In other words, human health declined after the adoption of farming (agriculture) and the rise of civilization.

The archaeological sequences at Ban Chiang (Table 1) broadly span the transition to agriculture and include pre-metal burials, Bronze Age burials, and burials associated with the first appearance of water buffalo, introduction of iron, and intensified agriculture. This region of the world also overlaps one of the known major homelands of agriculture in the world. Thus, the skeletons from Ban Chiang, which were divided into an earlier and later group of burials, provide a glimpse of human health and disease during the transition from hunting/gathering/cultivating toward intensified agriculture and further allow us to see if Southeast Asia follows this global trend of a decline in health with sedentism and the intensification of agriculture.

Ban Chiang skeletons

The physical anthropology of the Ban Chiang skeletons excavated in 1974 and 1975 was fully documented in our monograph (Pietrusewsky and Douglas 2002a), a study included thousands of measurements and observations. There, and elsewhere (e.g., Pietrusewsky and Douglas 2002b; Douglas and Pietrusewsky 2007), we have reported data for a number of paleodemographic indicators, dental pathologies (e.g., dental caries, antemortem tooth loss, periodontal disease, and attrition), linear enamel hypoplasia, cribra orbitalia, stature, and evidence for trauma and infectious disease.

While some of the results are mixed, our analysis showed a decrease in life expectancy and mean age at death over time, both of which are expected with agricultural economies and suggestive of a decline in health (Tables 2 and 3). Likewise, there were increases over time in linear enamel hypoplasia (when all teeth are included) and adult cribra orbitalia (two indicators of childhood health), which are also consistent with expectations demonstrated by studies of agricultural intensification elsewhere in the world.
Table 2. Some indicators of health recorded in the adult Ban Chiang skeletons.

<table>
<thead>
<tr>
<th></th>
<th>Early</th>
<th>Late</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life expectancy at birth (years)</td>
<td>30.4</td>
<td>28.1</td>
<td>Douglas and Pietrusewsky (2007)</td>
</tr>
<tr>
<td>Life expectancy at age 15 (years)</td>
<td>24.4</td>
<td>20.8</td>
<td>Douglas and Pietrusewsky (2007)</td>
</tr>
<tr>
<td>Mean age-at-death (years)</td>
<td>39.3</td>
<td>35.8</td>
<td>Douglas and Pietrusewsky (2007)</td>
</tr>
<tr>
<td>Linear enamel hypoplasia (LEH) (C+I) (^1)</td>
<td>13.4%</td>
<td>12.3%</td>
<td>Douglas and Pietrusewsky (2007)</td>
</tr>
<tr>
<td>Linear enamel hypoplasia (LEH)-all teeth</td>
<td>9.3%</td>
<td>15.8%</td>
<td>Pietrusewsky and Douglas (2002b:165)</td>
</tr>
<tr>
<td>Cribra orbitalia(^2)</td>
<td>8.7%</td>
<td>40.0%</td>
<td>Douglas and Pietrusewsky (2007)</td>
</tr>
<tr>
<td>Male stature (cm)</td>
<td>165.4</td>
<td>166.0</td>
<td>Douglas and Pietrusewsky (2007)</td>
</tr>
<tr>
<td>Female stature (cm)</td>
<td>153.9</td>
<td>154.4</td>
<td>Douglas and Pietrusewsky (2007)</td>
</tr>
<tr>
<td>Infection(^4)</td>
<td>1.7%</td>
<td>1.7%</td>
<td>Douglas and Pietrusewsky (2007)</td>
</tr>
<tr>
<td>Trauma(^5)</td>
<td>1.8%</td>
<td>1.9%</td>
<td>Douglas and Pietrusewsky (2007)</td>
</tr>
</tbody>
</table>

\(^1\) Combined frequencies of LEH in the canine (C) and incisor (I) teeth.
\(^2\) Frequencies based on adult individuals.
\(^3\) Frequency of dental caries scored per tooth.
\(^4\) Frequency of infection based on bone element.
\(^5\) Frequency of trauma based on bone element.

Table 3. Frequencies of dental pathology recorded in early and late burials from Ban Chiang (after Douglas and Pietrusewsky 2007)

<table>
<thead>
<tr>
<th>Dental Pathology</th>
<th>Early</th>
<th>Late</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caries(^1)</td>
<td>7.5</td>
<td>4.3</td>
</tr>
<tr>
<td>AMTL</td>
<td>6.3</td>
<td>8.0</td>
</tr>
<tr>
<td>Periapical</td>
<td>5.2</td>
<td>9.4</td>
</tr>
<tr>
<td>Calculus(^2)</td>
<td>23.8</td>
<td>37.3</td>
</tr>
<tr>
<td>Alveolar resorption(^2)</td>
<td>14.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Attrition(^3)</td>
<td>16.4</td>
<td>14.7</td>
</tr>
</tbody>
</table>

\(^1\) Corrected caries rate
\(^2\) Advanced (moderate and marked)
\(^3\) Advanced (pulp exposure or wear to roots)

On the other hand, there is no evidence in the Ban Chiang skeletal series for other changes expected with intensified agriculture. Also, the expected decline in adult stature was not observed in the Ban Chiang skeletons. The mean adult stature estimates increase over time in both males and females from Ban Chiang suggesting an increase in caloric intake and/or a relaxation of other stressors on subadult growth. Further, we did not find the expected increases in dental caries, skeletal infection, or traumatic injury in the Ban Chiang skeletons expected with the transition to agriculture.

Some of the dental pathologies (Table 3) revealed increases over time (AMTL, periapical activity, calculus), but dental caries, alveolar resorption, and attrition decreased. The frequencies of many of these dental variables at Ban Chiang fall in the range of “pre-agricultural or mixed-economies” populations.

Although not significant, there is a slight increase in the frequency of traumatic injury over time at Ban Chiang. Again, there are no patterns of injury that suggest interpersonal violence or warfare. Finally, there are no patterns of infectious disease to suggest the presence of
tuberculosis, treponemal disease, or other endemic infection in the Ban Chiang skeletal series. Using element frequencies no significant increase in the frequency of infection is observed between the Early Group (1.7%) and the Late Group (1.7%) burials at Ban Chiang.

A detailed study of six prehistoric sites in northeast Thailand, including Ban Chiang, and one in southeast Thailand, Halcrow (2006) reported moderate to high levels of LEH and CO in the subadult skeletons and moderate levels of dental caries in the deciduous teeth from Ban Chiang (Halcrow et al. 2013). The prevalence of skeletal pathology, most likely due to infectious diseases, was also found to be moderately high in the subadult Ban Chiang skeletons (Halcrow 2006). Apart from skeletal pathology, comparisons of non-specific indicators of stress and dental health among subadult skeletons from seven prehistoric Thai skeletal series, including Ban Chiang, indicated no distinct changes in health over time (Halcrow 2006).

Southeast Asia appears to be one region of the world that does not follow the general global decline in health with increased sedentism and/or the adoption and intensification of agriculture, especially those dependent on maize and wheat, documented in paleopathological studies elsewhere (see e.g., Pietrusewsky and Douglas 2002a,b; Oxenham et al. 2006; Douglas and Pietrusewsky 2007; Tayles et al. 2000, 2009; Halcrow et al. 2013). Contrary to general expectations, the evidence from Ban Chiang, and other sites in northeast Thailand, suggests an improvement in health over time. The evidence from Ban Chiang also serves as a good example of regional variation in the biological response to sedentism and agriculture present in prehistoric Thailand. Likewise, this evidence indicates that the transition from hunting, gathering, and cultivating to intensified agriculture was a slow process. The reasons for this variation might include the reduced susceptibility to carious infections due to eating rice, the late commitment to intensified (wet-rice) agriculture, and sustained broad spectrum foraging even with agriculture, among others. Overall, these are indications of continuity in health of Ban Chiang’s prehistoric inhabitants, suggesting a continuous reliance on a broadly based subsistence system (Pietrusewsky and Douglas 2002a,b; Douglas and Pietrusewsky 2007).

Evidence of spatial variation in Ban Chiang skeletons

Limited analyses of cranial, dental, and postcranial variation in the BCES burials indicated some evidence for genetic affiliations within the spatial groups as well as across spatial groups suggesting the burials were selected from a larger affiliated group. While there is some evidence that spatial variation in burial deposition noted among the BCES graves reflects genetic relationships overall, there is very limited and subtle spatial and temporal variation in the Ban Chiang skeletons. This is remarkable given the long prehistory for the site.

The cranial and dental non-metric traits recorded in the Ban Chiang skeletons suggest consistencies as well, both temporal and spatial, between the BC and BCES locales and between the sexes, but there are some interesting inconsistencies. For example, the majority of individuals with winging of the central incisors are from BCES, and statistically significant sex differences in the frequencies of some cranial traits suggest that males may be more closely related to each other than to females (Pietrusewsky and Douglas 2002a: 42).

The skeletal evidence suggests both males and females led strenuous lives at Ban Chiang, but there is also evidence for division of labor between males and females. Most of the activity-
induced indicators are found in males, such as osteoarthritis of the upper vertebral column, suggesting carrying loads on the head and neck, and osseous changes to the bones of the feet suggesting strenuous use of the feet and ankles. The lack of significant differences in indicators of activity and stress in the Ban Chiang skeletons also correlates with the lack of evidence for differential wealth among in the graves at Ban Chiang.

V. Isotope Studies: Reconstruction of Diet, Migration

There have been two major studies involving stable isotopes derived from bone and tooth samples from Ban Chiang. The first is the analysis of carbon and nitrogen stable isotopes, which have been widely used in bioarchaeology to reconstruct paleodiet (past diets) of prehistoric people. These isotopes have been used to study diets of marine versus terrestrial (land based) animals and the consumption of particular types of plant resources (e.g., maize and millet). These kinds of studies allow researchers to understand better how ancient people made use of natural resources, including how they modified their own environments in order to produce food. The second category of isotope studies analyzes strontium ($^{87}$Sr/$^{86}$Sr) and oxygen ($^{18}$O) isotopes to reconstruct past movements of both people and animals within a particular time and place.

Carbon and nitrogen stable isotopes

King (2006, 2009) and King and Norr (2006) used carbon and nitrogen isotope composition to reconstruct diet of the early inhabitants of Ban Chiang. These studies demonstrated temporal changes in diet from earlier to later inhabitants of this site. The prehistoric inhabitants of Ban Chiang had varied diets consisting primarily of C$_3$ plants, C$_3$ terrestrial animals, and freshwater fish. Isotope values for the earlier inhabitants of this site suggest that females were consuming a wider variety of protein foods than males from this same time period. Isotope values for the later burials from this site suggest that female diets relied more on open field carbohydrate foods and more fish and/or carnivorous animals while males from this time period were consuming more domesticated animals and less wild game.

Strontium and oxygen isotopes

In a second study researchers (Bentley et al. 2005) measured the varying signatures of strontium, oxygen and carbon isotopes in the second or third molar teeth from the Ban Chiang skeletons during the period of the introduction and intensification of agriculture. Preliminary results indicate the arrival of immigrant men, followed by a change in the relationship between the sexes whereby women grow up consuming local food, while the men have access to more widespread resources. This system, where forager men raised elsewhere marry into farming communities was interpreted as representing a matrilocal system. This observed pattern is very different from the cultural pattern of patrilocality that led to the relatively more rapid introduction of agriculture into central Europe (Bentley et al. 2002).

VI. Biological Relationships of the People of Ban Chiang, Southeast Asia and Surrounding Regions

Here, I will briefly summarize some of the biological distance, or biodistance, studies involving the Ban Chiang skeletons. Specifically, I discuss what we have learned about the biological
relationships of the ancient inhabitants of Ban Chiang and their relationship with the people in
the surrounding regions of Southeast Asia and beyond. First, I discuss biological distance studies
and the use of cranial morphology in physical anthropology.

There is a long history in physical anthropology of documenting temporal and spatial patterns of
biological relatedness, so-called biological distance, or biodistance, studies based on
morphological variation for reconstructing population history (Buikstra et al. 1990). While the
earliest attempts were flawed and mired in typological racial classifications, advances in
evolutionary theory, including quantitative and population genetics, and improvements in
computing and statistical procedures now provide a much sounder basis for measuring and
interpreting morphological variation within and between human groups (Pietrusewsky 2014).

Given the demonstrated correlation between phenotypic and genotypic similarities, measures of
biological distance in bioarchaeology are generally determined through the application of
quantitative methods to metric and nonmetric variation recorded in skulls, teeth, and skeletons.
Groups that display more phenotypic similarity (metric and nonmetric traits) are the more closely
related than groups not sharing these same features (Larsen 2015). Ancient DNA (aDNA) and
other biochemical and geochemical traits are recent additions.

There is now near universal acceptance that cranial variation in humans is geographically
structured making it highly attractive for reconstructing population history and for assessing
ancestry. Because cranial measurements are continuous in their distribution and amenable to
advanced multivariate statistical procedures, this category of variation continues to occupy a
central role in modern biological distance studies.

While the human cranium is subject to dietary and climatic influences, there is now widespread
consensus that cranial morphology (especially cranial measurements) conforms to a neutral
model of evolution where mutation, genetic drift and gene flow, rather than natural selection, are
viewed as being responsible for the observed geographically patterned variation (e.g., von
Cramon-Taubadel 2014). In turn, this has led to the view that craniometric data can be used as a
proxy to genetic data (von Cramon-Taubadel 2013:5).

In addition to the selective neutrality of craniometric variation, the demonstration of a genetic
component have made them ideal for investigating biological relationships of past groups (e.g.,
Martínez-Abadías et al. 2009). Applying population genetic models to phenotypic (both metric
and nonmetric) data, so-called model-bound approaches, researchers are able to investigate
population structure and patterns of genetic variation (i.e., gene flow, genetic drift) and the
influence of geography and other isolating mechanisms on biological relationships of past
populations (e.g., Relethford and Blangero 1990). Both model-bound and model-free approaches
are used extensively in biological anthropology for tracing biological relationships, temporally
and spatially, as well as a broad spectrum of other research topics in skeletal biology,
bioarchaeology, and forensic anthropology (Pietrusewsky 2014).
Measurements/Multivariate statistics

Traditional landmark measurements recorded using hand-held calipers, as well as Cartesian coordinates of cranial landmarks recorded in two or three dimensions using digitizing equipment, are used in biological distance studies.

Multivariate procedures, which comprise a family of related mathematical procedures that allow the simultaneous analysis of many random but interrelated variables whose effects cannot be interpreted individually in a meaningful manner, remain the most appropriate methods for analyzing traditional and geometric morphometric variation (Pietrusewsky 2008). These procedures are exceptionally well suited for investigating patterns of biological variation, measuring relatedness among groups, and making other inferences of the variables and groups selected. The primary multivariate statistical procedures applied to craniometric traits in biological distance studies include principal components analysis, stepwise discriminant function (canonical) analysis and Mahalanobis’ generalized distance statistic. Various clustering algorithms (e.g., Unweighted Pair-Group Method- UPGMA) and multidimensional scaling techniques provide a useful means of visualizing the results through the construction of dendrograms.

Population history of Southeast Asia

The population history of Southeast Asia is complex and undoubtedly involved considerable migration and movement of people, languages, and material culture producing what some have described as human kaleidoscope (Pietrusewsky 2006). One of the contrasting models, the so-called agricultural expansion or displacement model, argues that colonizing immigrants brought agriculture and other elements of a complex society, including the dispersal of languages into the region, beginning circa 650 B.C. to 1000 B.C. to the indigenous people of present-day Southeast Asia (e.g., Bellwood 2001, 2005, Higham 1996). This expansion of agriculturalists from a northerly source (today, southern China), based on rice domestication, led to a displacement of, or at least admixture with, the earlier indigenous hunter-gathering groups living in Southeast Asia. Increases in population numbers and densities, made possible by the agricultural revolution itself, are cited as being responsible for the demic diffusion of agriculture, people, languages, and material culture in Southeast Asia. An alternative model argues for biological continuity for the inhabitants of Southeast Asia from at least the Late Holocene without replacement by a major intrusion of people and cultures from a more northerly source in East Asia (e.g., Bulbeck 1982; Turner 1987, 1990; Hanihara 1993; Pietrusewsky 2006). This model posits that the ideas for agriculture originated or were adopted in situ.

A number of different biological distance studies involving the skeletons from Ban Chiang have been undertaken (e.g., Pietrusewsky 1974b, 1978, 1981, 1984, 1997, 2006). As will become apparent the evidence provided by the skeletons, especially the skulls, from Ban Chiang and other prehistoric sites in SEA is equivocal. Here, I summarize some of the results of the most recent biodistance study involving Ban Chiang reported in Pietrusewsky (2006).

Two separate analyses, one that used Ban Chiang and six other prehistoric cranial series from Southeast Asia and second that investigates prehistoric cranial series from SEA and a much
larger series of modern crania from Southeast Asia, North and East Asia, the Pacific, and Australia were reported in this paper.

**Analysis 1- Prehistoric Southeast Asia**

The seven prehistoric cranial series from Southeast Asia and East Asia used in the first analysis are presented in Table 4. In addition to the Ban Chiang series, we include crania from Non Nok Tha and Khok Phanom Di and sites in Vietnam, Laos, China, and Japan.

Table 4. Cranial series from Southeast Asia and East Asia used in comparisons (Source: Pietrusewsky 2006:63)

<table>
<thead>
<tr>
<th>Cranial Series (Abbrev.)</th>
<th>Location</th>
<th>No. of Crania</th>
<th>Specimens Used1</th>
<th>Dates (BP)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non Nok Tha (NNT)</td>
<td>Northeast Thailand</td>
<td>17</td>
<td>SIR:Nos. 34,48,55,77,88, UNL:Nos. 9,10,32,33,47,55,61, 62,64,71b,89,90</td>
<td>4800 - 2200</td>
<td>Bayard (1971); Douglas (1996)</td>
</tr>
<tr>
<td>Khok Phanom Di (KPD)</td>
<td>Central Thailand</td>
<td>14</td>
<td>Nos. 24,28,29,30,38,42,44, 57,67,72,74,93,129,132</td>
<td>4000- 3500</td>
<td>Higham and Bannanurag (1990); Pietrusewsky (1997); Pietrusewsky and Douglas (2002a)</td>
</tr>
<tr>
<td>Early Holocene Indo-China (ERH)</td>
<td>Laos and Vietnam</td>
<td>5</td>
<td>Pho Binh Gia, Vietnam (No. 18504); Tam Hang, Laos (Nos. 20539, 20540); Tam Pong, Laos (Nos. 120541, 120542)</td>
<td>10000 - 6000</td>
<td>Pietrusewsky (1997); Pietrusewsky and Douglas (2002a)</td>
</tr>
<tr>
<td>Mid-Holocene Vietnam (MHL)</td>
<td>Vietnam</td>
<td>5</td>
<td>Lang Cuom, (Nos. 19416, 19418,19455); Con Co Ngua (Nos. 3,4)</td>
<td>&gt;6000- 5000</td>
<td>Pietrusewsky (1997); Pietrusewsky and Douglas (2002a)</td>
</tr>
<tr>
<td>Anyang (ANY)</td>
<td>Northern China</td>
<td>15</td>
<td>Random selection of 15 of 56 specimens used in larger comparisons</td>
<td>3385 - 3112</td>
<td>Li (1977); Pietrusewsky (1988)</td>
</tr>
<tr>
<td>Jomon (Late-Latest) (JOM)</td>
<td>Japan</td>
<td>15</td>
<td>Eleven crania are from the Ebishima site, Iwate Prefecture, Tohoku District; four are from the Tsukumo site, Okayama Prefecture, Chugoku District, Honshu Island.</td>
<td>4500 - 2300</td>
<td>Akazawa (1983); Pietrusewsky (1999)</td>
</tr>
</tbody>
</table>

1 BC= 1974 excavations at Ban Chiang; BCES = 1975 excavations at Ban Chiang; SIR = 1965-66 excavation material in Siriraj Hospital, Bangkok; UNL= 1968 excavation material in University of Nevada, Las Vegas; Nos. = catalogue numbers for specimens.

Discussion of the results of this analysis is restricted to the canonical plots obtain from stepwise discriminant function (canonical) analysis and the dendrogram that results from the Mahalanobis distances.

Examining the canonical plots, Figure 3, the Ban Chiang and Early Holocene sample from Indochina reveal a close similarity, which in turn are related to Non Nok Tha (from northeast Thailand), and Bronze age Chinese and Jomon. The Khok Phanom Di and Mid-Holocene Vietnam series are the most differentiated of all the groups.
Ban Chiang and the Early Holocene Indochina series show a close relationship in the dendrogram of Mahalanobis’ distances (Figure 4). The Khok Phanom Di and Mid-Holocene Vietnamese series are the most differentiated.

Discussion of Analysis I

The relatively close biological relationship between the early pre-metal to Bronze Age inhabitants of Ban Chiang and an early Holocene (pre- 4000 B.C.) cranial series from Laos provides support for local continuity in human groups from the late lithic to Neolithic/Bronze Age of mainland Southeast Asia.

The people buried at Khok Phanom Di, in south central Thailand, and the mid-Holocene crania from Vietnam, on the other hand, are isolated from the remaining prehistoric cranial series examined, a separation which suggests a separate genetic heritage for these groups.

The sharp distinction between coastal sites like Khok Phanom Di and the Mid-Holocene series from Vietnam and inland sites, a major finding in this analysis, may suggest that people living in
coastal regions were generally more mobile than their inland counterparts, a distinction that has considerable antiquity for the region.

**Analysis II: 73 male groups, 24 cranial measurements**

In this analysis Ban Chiang, Khok Phanom Di, and Late to Final Jomon cranial series are compared to 69 modern and near modern series representing Southeast Asia, East/North Asia, the Pacific, and Australia.

In the plot of the group means on the first two canonical variates (Figure 5), the cranial series from Australia and Melanesia group together while Polynesian and two Micronesia series from a second major division. The cranial series from Southeast Asia and East Asia form a tight grouping, one that includes Ban Chiang and Khok Phanom Di. Ban Chiang’s position is peripheral but is nearest to modern cranial series from Thailand and Vietnam while Khok Phanom Di is closest to several Chinese and Southeast Asian series.

Ban Chiang and Khok Phanom Di unite to form an outlier in the dendrogram based on the distance results (Figure 6), closest to a large collection of East Asian and Southeast Asian series. Polynesian cranial series are the last to join this major Asiatic division. The second major grouping is one that contains all cranial series representing Australia, Tasmania, and Melanesia.
Figure 6. Diagram of relationship (dendrogram) based on a cluster analysis (Unweight Pair Group Method Algorithm-UPGMA) of Mahalanobis’ generalized distances using 24 cranial measurements recorded in 73 male cranial series.
Discussion of Analysis II

The results of this second analysis reveal the existence of two major divisions among the inhabitants of eastern Asia and the Pacific. One of these divisions includes all cranial series from Australia, Tasmania, New Guinea, and island Melanesia. The second major grouping is one that contains all cranial series from East Asia, (mainland and island) Southeast Asia, Micronesia, and Polynesia. The sharpness of the separation between these two divisions is highly suggestive of separate and ancient origins for these two major divisions of humanity.

The prehistoric Thai series (Ban Chiang and Khok Phanom Di) are members of the East/Southeast Asian division, which reveal similarities to several modern and prehistoric cranial series from this greater geographical region. These results also demonstrate that there are very close connections between prehistoric and modern inhabitants of Southeast Asia, again suggestive of long-term continuity.

Another noteworthy finding is the clear separation between East/North Asian and Southeast Asian cranial series. Although the results are equivocal, the sharp contrast between East/North Asian and Southeast Asian cranial series does not support models that argue that the indigenous inhabitants of Southeast Asia were replaced by immigrant groups of people of a more northern origin during Neolithic times.

VII. Vulcan: Skilled Village Craftsman of Ban Chiang, Thailand

One of the Early Period burials from the 1974 excavations at Ban Chiang, nicknamed by the excavators, “Vulcan”, after the Roman god of fire and metalworking, because of the rare occurrence of not just one but two classes of metal objects in his grave, deserves special mention (Figure 7) (Douglas and Pietrusewsky 2012).

BC Burial 23, a 45-50 year old male, was represented by a moderately complete skeleton was placed in the grave in a supine position (on his back), arms and legs extended, with his hands by his sides. Post-depositional disturbances (e.g., post holes, pits) resulted in the loss of the right femur and left foot.

Grave goods associated with this burial included a partial ceramic pot at the feet, four bronze bangles around the left forearm, a cache of 30 small clay pellets beyond the right side of the skull, and a socketed bronze adze head at the left shoulder.

Figure 7. Schematic drawing of Burial BC 23 (plan view).
The incomplete pottery vessel, similar to vessels used to steam rice or cook soup in modern villages in Thailand (White 1982:33), found at Vulcan’s feet is unworn and possibly not used. The four bronze (copper-based) bangles had stained the left forearm bones green. Although bracelets and anklets are typically worn by females, today, their presence in a male burial from Ban Chiang suggests a different cultural practice, one that may be associated with social status of the individual. The cache of clay pellets (approximately 2 cm in diameter) were likely used as ammunition for the pellet bow (White 1982:24). The grouping of the pellets in a pile suggests that they were contained in a bag or deliberately stacked. The abundant supply of pellets suggests that Vulcan was provisioned for a journey or the afterlife. The well-made adze head placed at Vulcan’s shoulder was relatively unworn and most likely paced with this burial as a funerary offering. Although the grave goods associated with Vulcan were both decorative and utilitarian suggests Vulcan may have been a wood or metal-working craftsman as well as a capable hunter, someone who would be missed by his family and fellow villagers.

The osteological features observed in Vulcan’s skeleton also support this interpretation. Vulcan is distinguished by his age, robust size and relatively tall stature of 175 ± 5.0 cm. Muscle markings on his skeleton attest to a very active physical life. Small linear hypoplastic pitting in the enamel of the mandibular canines are the only evidence for physiological stress, during childhood, but his robusticity and long life suggest this stress was temporary and without long term effects.

Vulcan lost only one tooth, a mandibular third molar, before his death. He suffered periodontal disease in both jaws and dental caries in his molar teeth. The extreme wear some of Vulcan’s teeth suggest he may have used his teeth as tools, such as in pulling fibers across the teeth or in repeatedly holding something between the teeth.

Vulcan’s right thumb exhibited a lesion may be the result of pulling the string of a pellet bow. His right shoulder exhibited severe osteoarthritis, possibly due to a secondary infection within the joint. Osseous lesions were also noted in the right fourth metatarsal. Other lesions observed in Vulcan’s ribs suggest he may have died of a pulmonary infection.

Isotopic analysis of Vulcan’s teeth and bone suggests he was non-local, or immigrant. Analysis of carbon and nitrogen stable isotopes, suggests Vulcan’s diet was extremely diverse; taking advantage of a broad array of wild and domestic plant and animal resources.

In summary, BC Burial 23, Vulcan, who lived during the Bronze Age in Thailand was a robust man, who died, possibly of a pulmonary infection, after a relatively long life. He was physically active and very possibly crafted metal or wood and, no doubt, was a hunter. He was an immigrant, perhaps marrying into the village, who contributed valuable skills to his family and the community.

VIII. Future Work and Repatriation

Previous attempts to obtain ancient DNA from the Ban Chiang skeletons proved unsuccessful. With the advent of next-generation sequencing methods and refinements in sampling (e.g., Pinhasi et al. 2015), new bone (petrous portion of temporal) samples have been sent to the University College Dublin/Conway Institute for analysis. While in the early stages, researchers in
Dublin are hopeful of retrieving full genome sequences from the ancient inhabitants of Ban Chiang, data that will help inform on biological relationships.

Currently, the skeletons for the 1974 and 1975 excavations at Ban Chiang are being prepared for repatriation to the Fine Arts Department in Thailand. A full inventory of the skeletons, using Microsoft Access (Database Management System), will accompany the return of this valuable research collection to its country of origin for future work there by Thai and foreign researchers.

IX. Conclusion

Despite the absence of a final archaeological report, valuable information was been obtained from the approximately 142 individuals, excavated more than 40 years ago, by the Thai-American expedition to Ban Chiang in 1974 and 1975. Osteological examination, involving a great many observations and measurements recorded in the skeletons from this site as well as detailed observations of paleopathology and chemical analysis, have yielded evidence about the health, life span, diet, lifestyle, biological relationships and origins of these early inhabitants of the Khorat Plateau region in northeast Thailand. Compared to other regions of the world, the people living during the Bronze and Iron Age cultures in mainland Southeast Asia, such as Ban Chiang, displayed a number of surprising differences. Noteworthy among the findings resulting from the detailed study of the Ban Chiang skeletons:

- No evidence for a rapidly expanding population (as a result of higher fertility/birth rates) as is typical of other agricultural societies.

- Life expectancy at birth, on average, for the early inhabitants of Ban Chiang was 29.5 years; those who survived to 15 years of age could expect to live to 38 years on average.

- Unusually stable health for people spanning the pre-metal to Bronze/Iron Age compared to other regions of the world that typically show a decline in health with the introduction of agriculture.

- The average height of adult males was approximately 166 cm (5 feet, 5 inches) and 154 cm (5 feet, 1 inch) for adult females from Ban Chiang

- No evidence of skeletal trauma due to warfare and little interpersonal violence compared to Neolithic societies and cultures in other regions of the world.

- The early inhabitants of Ban Chiang led physically demanding lives, especially the adult males, as exhibited by degenerative joint disease, enthesiopathies and related conditions associated with activity and workload.

- Skeletal evidence for genetic affiliations within the spatial groups at Ban Chiang.

- Very limited and subtle spatial and temporal variation in the Ban Chiang skeletons.
• Unexpected differences in health, paleodemography, and biological relationships in inland (Ban Chiang) vs. coastal communities in Thailand (e.g., the Khok Phanom Di site) of a comparable time period.

• Evidence of long-term regional continuity of people in mainland Southeast Asia and no convincing evidence that the early inhabitants of Ban Chiang migrated from a more distant region such as present-day China.

• Evidence for changes in diet from earlier to later times, as well as differences in diet between males and females.

• Possible evidence of a matrilocal system where men relocate from other areas to live with their wives’ village.

• Osteobiographical evidence of identity, personal history, and lifestyle of certain individuals buried in the Ban Chiang cemetery.

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My thanks to Michele Toomay Douglas, without whose assistance and collaboration that now spans more than three decades, this and many other papers would not have been possible. Further thanks to Joyce White for her generous support over the years. I am also grateful to the Thai Fine Arts Department of the Ministry of Culture (Thailand) and Udon Thani Province for organizing this conference. Finally, my thanks to the people of Ban Chiang and Thailand for allowing me to study the prehistoric inhabitants of Ban Chiang.

XI. References


Appendix A: Selected articles using the Ban Chiang skeletons from 1974 & 1975 Excavations (listed chronologically)


