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THE PEOPLE OF BAN CHIANG: AN EARLY BRONZE SITE IN NORTHEAST THAILAND[1]

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ABSTRACT

Mahalanobis' Generalised Distance and stepwise discriminant function analysis are applied to 28 measurements recorded in 2,490 male crania representing 55 different prehistoric, modern and near modern human groups. Included are crania from Polynesia, Micronesia, Melanesia, Australia, Southeast Asia, East Asia and North Asia. The results of two separate analyses are discussed. In the first analysis, Bronze-age crania from Ban Chiang are compared to crania from Khok Phanom Di (central Thailand), Neolithic Laos/Vietnam, Anyang (Bronze-age northern China) and Jomon Japan. The five prehistoric groups are well differentiated. In discriminant space and in a cluster analysis of distances, Ban Chiang is moderately similar to Anyang. Broader comparisons demonstrate two major population complexes, one which includes all Asian cranial groups and a second which includes cranial series from Australia, Melanesia and Polynesia. Ban Chiang, Khok Phanom Di and Neolithic Laos/Vietnam are marginal members of this Asian sub-division. Ban Chiang demonstrates craniometric similarities with several modern and prehistoric cranial series including the Ryukyu Islands, Anyang and Khok Phanom Di. The latter is morphologically closest to several modern cranial samples from mainland and island Southeast Asia, Ban Chiang and the Ryukyu Islands. The cranial series representing Neolithic Laos and Vietnam are most similar to island Southeast Asian cranial series. Ainu and Jomon form a separate cluster within the Asian complex unrelated to Polynesians. The Mongolians are the most isolated of the Asian groups investigated.

INTRODUCTION

Archaeological excavations at Ban Chiang, in Northeast Thailand, conducted by the Thai Fine Arts Department and the University Museum of the University of Pennsylvania in 1974-75, uncovered the remains of approximately 112 inhumation burials (Gorman and Charoenwongsa 1976). These skeletal remains have been the subject of on-going research at the University of Hawaii since 1974. Although several small preliminary articles on the physical anthropology of the site have appeared (*e.g.*, Pietrusewsky 1978, 1982, 1984a), a final report has been delayed following the tragic death of Dr. Chet Gorman in 1981. Changes in the original chronology of the site (White 1982, 1986) and substantial improvements in the methods of osteological analysis, prompted a complete re-analysis of the Ban Chiang remains at the University of Hawaii in 1991. This work is being undertaken by me and one of my graduate students, Michele Douglas, who will use these and other skeletal remains from Northeast Thailand in her doctoral dissertation work. A final report, which will detail all aspects of our recent work, will be published by the University Museum, University of Pennsylvania.

Studies of cranial form have a long history in physical anthropology. Typically, this earlier work lacked objective means of expressing biological variation and the approach used was typological. Some of the earliest studies of human skeletal remains from Southeast Asia, like those initiated by the French sponsored Geological Survey of Indochina (*e.g.* Mansuy and Colani 1925; Fromaget and Saurin 1936; Verneau 1909) in the first decades of the present century, are representative of this

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[1] Readers should note that the tables for this paper are grouped together at the end, after the text.

early period. Improved statistics, especially the use of multivariate statistical procedures and other advances in evolutionary biology, led to more objective interpretations of skull variation and reconstructions of population history.

The ease with which measurements can be recorded and their continuous nature make this category of variation extremely attractive to researchers, as do the conservative nature of skull morphology and the existence of a strong heritability component for many aspects of cranial variation.

In this study, multivariate statistical procedures are applied to measurements recorded in twelve of the most complete male skulls from Ban Chiang and other cranial series representing prehistoric and more modern skeletal populations from Southeast Asia, East Asia and the Pacific. The approach used is model free, where measures of biological distance and discriminant function analysis are used to investigate patterns of biological variation, which in turn, provide a basis for reconstructing the phylogenetic histories of these populations. This new craniometric analysis expands on earlier work (e.g. Pietrusewsky 1984b, 1990a, 1990b, 1992, 1995; Pietrusewsky *et al.* 1992) which focuses on cranial variation in Australasian and Pacific groups. These new comparisons allow a number of summary statements regarding biological connections between the early inhabitants of Thailand, Southeast Asia and neighbouring regions to be advanced.

MATERIAL

Only complete or nearly complete male crania are used in the present study. In addition to the specimens from Ban Chiang, four other prehistoric male cranial series from Southeast Asia are used in the present analysis. Three series are from Southeast Asia (Figure 1) and one each is from China and Japan. Other, more detailed information on these early skeletal series is presented here.

1. *Ban Chiang, Northeast Thailand* [N=12]

The majority (10) of the specimens from Ban Chiang are from the earliest phases of the site (ca 3600-1000 BC) and two are from the Middle Period (ca 1000-300 BC) (White 1986). The exact specimens from this site, used in this study, are given in Table 1.

2. *Khok Phanom Di, Gulf of Siam, Central Thailand* [N=14]

Khok Phanom Di is a prehistoric burial mound located approximately 100 km southeast of Bangkok, on the coast of central Thailand. More than 150 burials were excavated from this site by the Thai Fine Arts Department and the University of Otago in 1985 (Higham and Bannanurag 1990). The excavators estimate a time depth of approximately 500 years (2000-1500 BC) for the burial mound (Higham and Bannanurag 1990). The human skeletal material from this site have been examined by two former University of Otago students, Praphid Choosiri (1988) and Nancy Tayles (1992). I recorded measurements and non-metric observations in the most complete adult crania from this site in the Department of Anatomy of the University of Otago in 1992. In the present analysis, cranial measurements are recorded in 14 of the most complete male crania (Nos. 24, 28, 29, 30, 38, 42, 44, 57, 67, 72, 74, 93, 129 and 132).

3. *Neolithic Laos and Vietnam* [N=10]

Ten adult male crania, from five separate sites located in Northern Vietnam and Laos, were combined to form a single sample designated Neolithic Laos/Vietnam. The specimens derive from work initiated by the French in the early part of the twentieth century under the auspices of the École Française d'Extrême Orient and the Service Géologique de l'Indochine. The skeletal material is curated in the Musée de l'Homme in Paris where I examined it in 1973/75. The specimens investigated in this study are given in Table 2.

4. *Anyang: Bronze-Age China* [N=56], 11th Century BC)

The Shang Dynasty (11th century BC) sacrificial victims, excavated at Anyang in northern Henan Province in northern China (Li 1977), have been used by me (Pietrusewsky 1992, 1995) and several previous investigators (e.g. Howells 1983, 1984, 1990; Brace and Tracer 1992; Turner 1990, 1992a, 1992b). This material is curated in Academia Sinica in Taipei where I examined it in 1989 and again in 1991. A random selection of 15 adult male crania was used in the first analysis and a larger series of 56 is used in the second analysis.

5. Late to Latest Jomon, Japan [N=51], 1,500 BC-AD 1)

The specimens are from the Late to Latest Jomon period on Honshu Island of the Japanese Archipelago. The largest series are from Ebishima (11) in Iwate Prefecture in Tohoku District and Tsukumo (12) in Okayama Prefecture in Chugoku District. All data were recorded by me in 1990.

In addition to these five early cranial series, 50 comparative cranial series representing modern and some ancient crania from all parts of Oceania (Polynesia, Micronesia, Melanesia, Island Southeast Asia), Australia, Southeast Asia and East Asia are included in the second analysis. The names, number of crania, locations where the specimens were examined and other information are given in Table 3. The approximate locations of these comparative series are shown in the map in Figure 2.

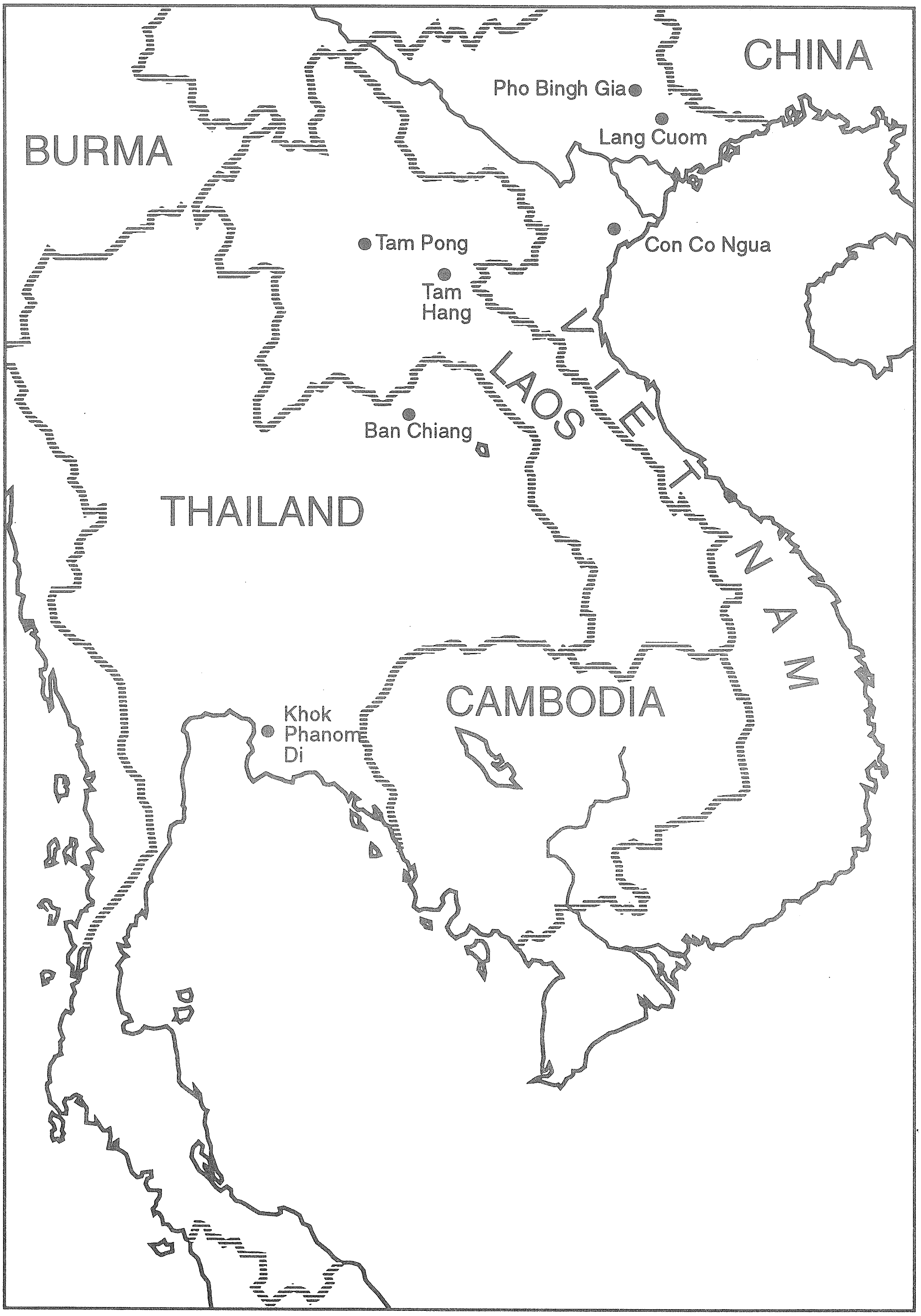

Figure 1: Map showing the location of the early skeletal series from Thailand and Southeast Asia.

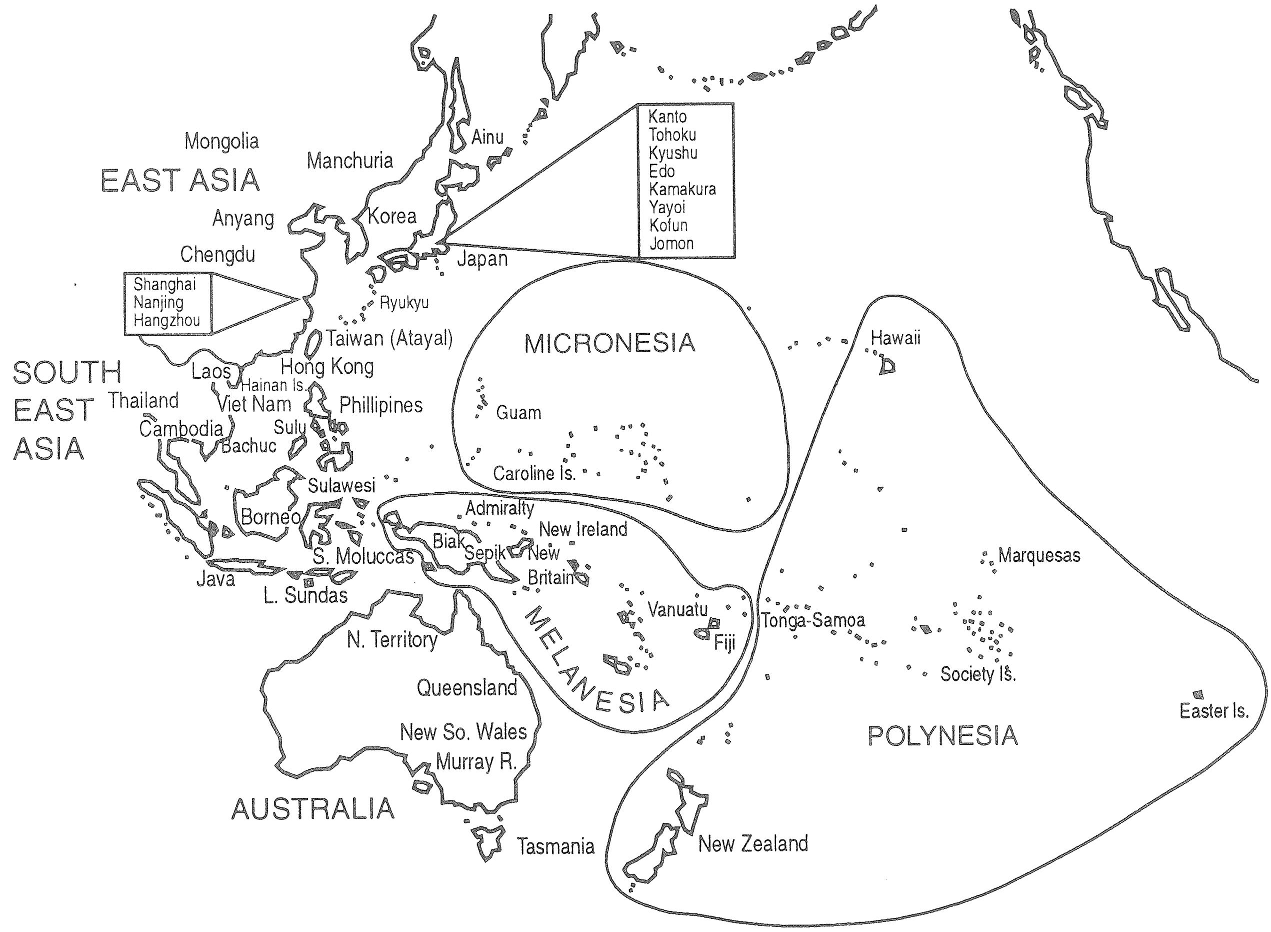

Figure 2. Map showing the approximate locations of the comparative cranial series from Asia and the Pacific used in the present study.

CRANIAL MEASUREMENTS

Twenty-eight standard cranial measurements (see Table 4) were used in the present study. Missing measurements were replaced with regressed values obtained through stepwise regression analysis using the computer program, PAM (Dixon and Brown 1979). Because the specimens initially selected were complete, or nearly complete, only a few measurements were replaced using this method.

Multivariate Statistics

Two multivariate statistical procedures are used in the present study, stepwise discriminant function analysis and Mahalanobis' Generalised Distance.

Stepwise Discriminant Function Analysis

The major purpose of discriminant analysis is to maximise the ratio of between-group variance to total variance, while taking into account the intercorrelation of variables, by producing a finite series of orthogonal functions. The first few canonical variates, or functions, account for most of the variation among the groups. The technique further identifies which variables are most responsible for the observed differentiation. In this study, the interpretation of discriminant functions and the patterns of group separation is based on an inspection of standardised canonical, or discriminant, coefficients. Finally, after the stepping process has been completed, each individual specimen is classified into one of the original groups based on the several discriminant scores it receives. The results are presented in the form of a classification matrix. The 'correct' and 'incorrect' classifications provide a general guide for assessing the homogeneity or heterogeneity of the original series. Although originally designed to assign an unknown specimen to one or more groups, discriminant analysis has been shown to be especially useful as a measure of variation between groups (Campbell 1978). The mathematical basis of this technique is discussed in Goldstein and Dillon (1978). Because many of the general assumptions of multivariate normality and equality of group covariance matrices are rarely met (Corruccini 1975), tests of significance are not used in interpreting group differences identified in the present study. The computer program, BMDP-7M (Dixon and Brown 1979), was used to perform the discriminant function analysis in the present study.

Mahalanobis' Generalised Distance

Mahalanobis' Generalised Distance, or the sum of squared differences, provides a single quantitative measure of dissimilarity (distance) between individual groups using many variables while taking into account intercorrelation between the variables (Mahalanobis 1936). The average linkage within group (or Unweighted Pair Group Method) clustering technique was the algorithm selected to construct the diagrams of relationship, or dendrograms, based on Mahalanobis' Distances. This technique combines clusters so that the average distance between all cases in the resulting cluster is as small as possible and the distance between two clusters is taken to be the average between all possible pairs of cases in the cluster.

Removal of the Size Based Component: Z-Scores and C-Scores

Raw measurements were converted into Z-scores which in turn were used to generate C-scores as defined by Howells (1989). In this method, raw measurements are subject to a double standardisation procedure. Z-scores are computed both across variables for each case (so that equal weighting is given to each variable) and across cases for each variable (to negate absolute size differences between individuals) (Green 1990:299). Z-scores, which may be negative or positive, are equal to the number of standard deviation units by which each measurement in question departs from the mean of all the population (or general) means. This latter procedure avoids undue weighting by uneven sample sizes. Size is defined as the magnitude of a vector of measurements on an organism while shape is a function of relative proportion normalised by size (Corruccini 1987: 289, 290). Several researchers (e.g. Howells 1989; Brace and Hunt 1990; Brace and Tracer 1992; Brace *et al.* 1990) have advocated the use of C-scores as a way to compensate, at least partially, for the size differences which may then have an unequal influence on the patterns of variation. However, the present study, as well as previous work (e.g. Green 1990; Pietrusewsky 1995) have demonstrated that removal of this size-based component has had little or no effect in interpreting patterns of craniometric variation. For that reason, the results using C-score measures will be not presented.

RESULTS

The results of two analyses, both using 28 cranial measurements, are reported separately. In the first, Ban Chiang crania are compared with crania from Khok Phanom Di, Neolithic Laos/Vietnam, Anyang and Jomon Japan. In the second, these same crania are compared with prehistoric and more modern cranial series from Southeast Asia, East Asia, Australia and the Pacific.

ANALYSIS I: 5 MALE GROUPS, 28 MEASUREMENTS

In this analysis, stepwise discriminant function analysis and Mahalanobis' Generalised Distance are applied to 28 cranial measurements recorded in five early archaic series. The means and standard deviations for 28 cranial measurements recorded in Ban Chiang and four additional cranial series from Asia used in the first analysis, are presented in Table 4.

Stepwise Discriminant Function Analysis

A ranking of 28 cranial measurements, arranged according to the F-values received at each step of the discriminant analysis, is summarised in Table 5. The measurements which are ranked the highest in this analysis include bistephanic breadth, orbital and nasal breadths, alveolar length, nasion-alveolare length, nasal height, orbital breadth, mastoid height and cranial vault length. The remaining variables contribute far less to the total discrimination and have non-significant values.

Eigenvalues, the percentage of total dispersion and the level of significance for the first four canonical variates, or discriminant functions, are presented in Table 6. The first three variates, or functions, account for 87.0% of the total variation. The first three eigenvalues are significant at the 1% level.

Canonical coefficients for 28 cranial measurements for the first three canonical variates are listed in Table 7. Group separation on the first canonical variate is heavily influenced by nasal height and nasal breadth, alveolar

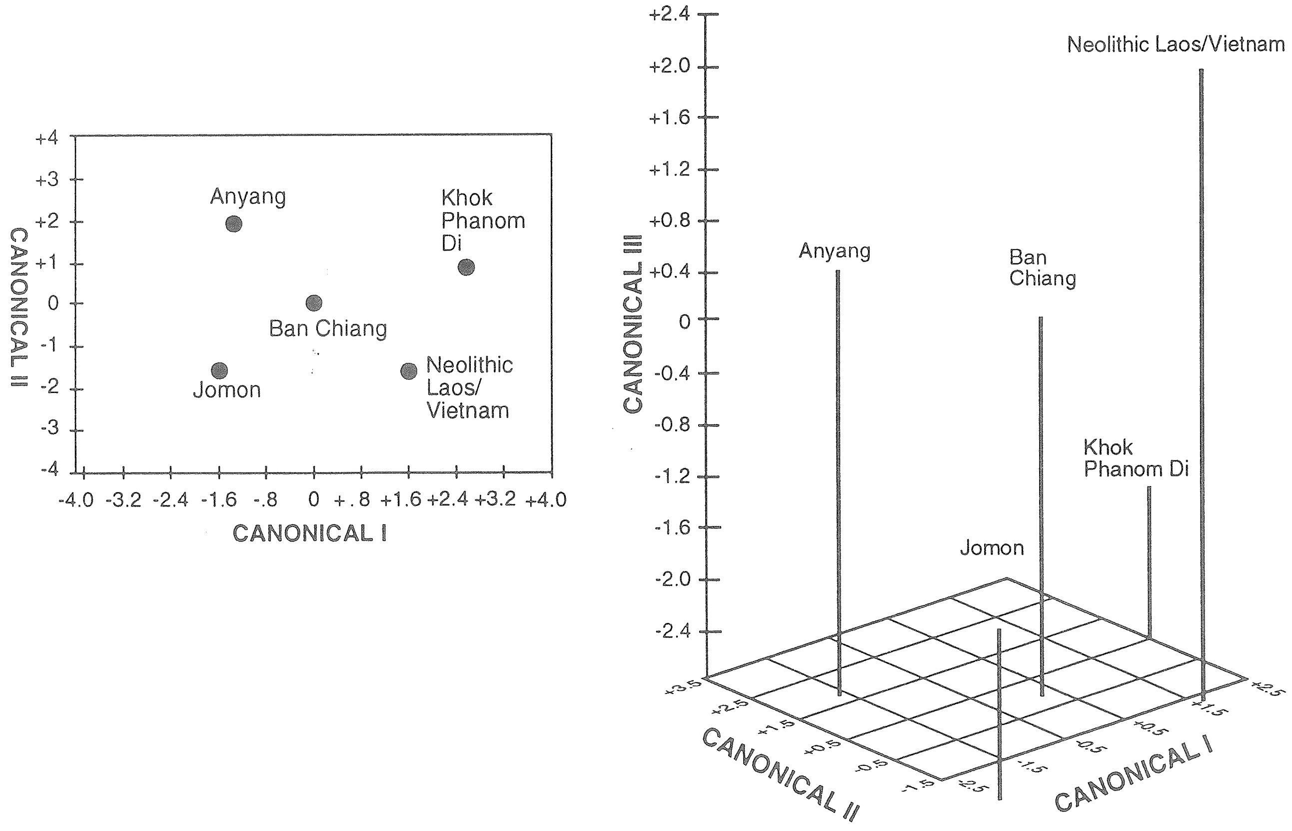

Figure 3: Two- and three-dimensional canonical plots of the 5 group means using 28 cranial measurements.

length, nasio-frontal subtense and mastoid height. The first function can be described as a nasal height/breadth, upper facial height, palate length discriminator. Differences in biorbital breadth, orbital height, nasal height and maximum frontal breadth are responsible for the group separation achieved in the second canonical variate. The discrimination produced in the third canonical variate is based primarily on differences in bifrontal and biorbital breadth, mastoid width, bistephanic breadth, alveolar length and maximum frontal breadth.

Two and three dimensional plots of the group means are shown in Figure 3. The plot of the group means on the first two canonical variates, which account for 63.3% of the separation, shows a more or less even scatter of the five groups. When the third dimension is added, Ban Chiang assumes a position closest to Jomon and Anyang. Khok Phanom Di and Neolithic Laos/Vietnam are the most isolated of these groups.

A summary of the classification results is given in Table 8. The total percentage of correct assignments is very high, 95.5%, indicating the groups are well differentiated. One of the cases originally assigned to Ban Chiang is mis-classified as Anyang and one of the cases originally assigned to Anyang is mis-classified as Ban Chiang. Further, one of the Neolithic Laos/Vietnam specimens is classified as Ban Chiang. No misclassifications occurred among the Khok Phanom Di or Jomon series. The jack-knifed classification results (not shown) resulted in much poorer results with only 53.0% correct classification.

Mahalanobis' Generalised Distance

Mahalanobis' Generalised Distance was applied to 28 cranial measurements recorded in the five male cranial series analysed by discriminant function analysis. The distances are presented in Table 9. Because of small

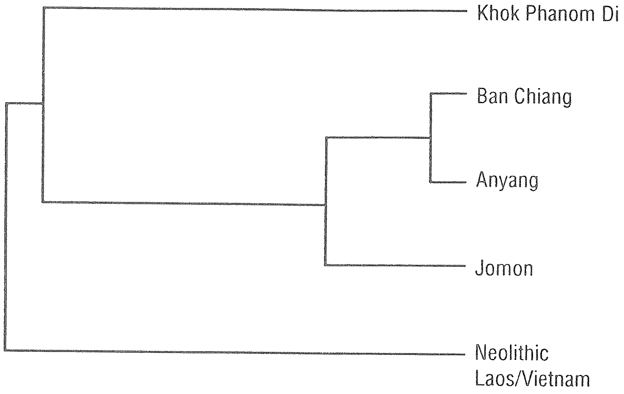

Figure 4: Diagram of relationship based on a cluster analysis (UPGMA) of Mahalanobis' Generalized Distances using 28 cranial measurements recorded in 5 male groups.

sample sizes, tests of significance could not be performed except for the distance calculated for Jomon-Anyang which was found to be non-significant. Applying the Unweighted Pair Group Method clustering algorithm results in the dendrogram shown in Figure 4. Ban Chiang crania cluster with Anyang and Jomon crania in this diagram. Khok Phanom Di and Neolithic Laos/Vietnam occupy marginal positions in this diagram. Inspection of the raw distances in Table 9 confirms that the smallest distances are those between Ban Chiang, Anyang and Jomon.

ANALYSIS II: 55 MALE GROUPS, 28 MEASUREMENTS

In the second analysis, stepwise discriminant function analysis and Generalised Distance are applied to 28 measurements recorded in 2,490 crania representing 55 male samples.

Stepwise Discriminant Function Analysis

Table 10 presents a ranking of the 28 cranial measurements according to the F-values received at each step of the discriminant analysis. Maximum cranial breadth, alveolar length, nasion-alveolare, nasio-occipital length, nasal height and minimum cranial breadth are among the highest ranked variables.

Eigenvalues, the percentage of total dispersion and level of significance for the 28 canonical variates are given in Table 11. The first three variates account for 65.0% of the total variation. The first twenty-four eigenvalues are significant at the 1% level.

Table 12 presents the canonical coefficients for the first three canonical variates. The length of the hard palate (alveolar length), biorbital breadth, nasio-occipital and maximum cranial length contribute most significantly to the group separation on the first variate. The first function can be identified as palate length, upper facial height, upper facial breadth and vault length discriminator. The measurements contributing most to the group separation on the second variate are nasal height, cheek height, alveolar breadth, minimum cranial breadth and orbital height. The second function primarily discriminates on the basis of nasal and cheek height, palate breadth, minimal cranial breadth and the height of the eye sockets. The measurements contributing most to the separation in the third canonical variate are nasio-occipital length, nasal breadth, interorbital breadth, nasio-frontal subtense and nasal height.

A plot of the group means on the first two canonical variates is shown in Figure 5. The Australian/Tasmanian and Melanesian cranial series form a relatively well differentiated constellation. Likewise, the Polynesian and two Micronesian series (Caroline and Guam) form a second cluster. The group means for the Admiralty and Tonga-Samoa series, when plotted on these first two functions, are remarkably close. Cranial series from island Southeast Asia form a third constellation in this representation. The cranial series from mainland Southeast Asia are scattered within a grouping that includes most of the cranial series representing prehistoric and modern Japan. The Neolithic Laos/Vietnam series falls within the island Southeast Asian group and is closest to the Lesser Sunda series. Ban Chiang and Khok Phanom Di are closest to the Japanese cranial series in this two-dimensional plot. The cranial series from China, Korea, Manchuria and Mongolia form a distinct grouping. The Atayal of Taiwan occupy a peripheral position in the constellation comprised mainly of cranial series from Japan and mainland Southeast Asia.

Figure 6 is the plot of some of 55 group means on the first three canonical variates, or functions. The Australian, Melanesian and Polynesian series form separate clusters well differentiated from the Asian constellation. The three archaic Southeast Asian cranial series fall within the Asian constellation. Examining more closely the relationships implied in Figure 6, Ban Chiang is closest to several modern cranial series from Japan (Kanto, Kyushu, Edo), Kamakura, Jomon and the Ryukyus. Khok Phanom Di is somewhat close to Vietnam, Philippines, modern Thailand and Bachuc Village (Vietnam). The

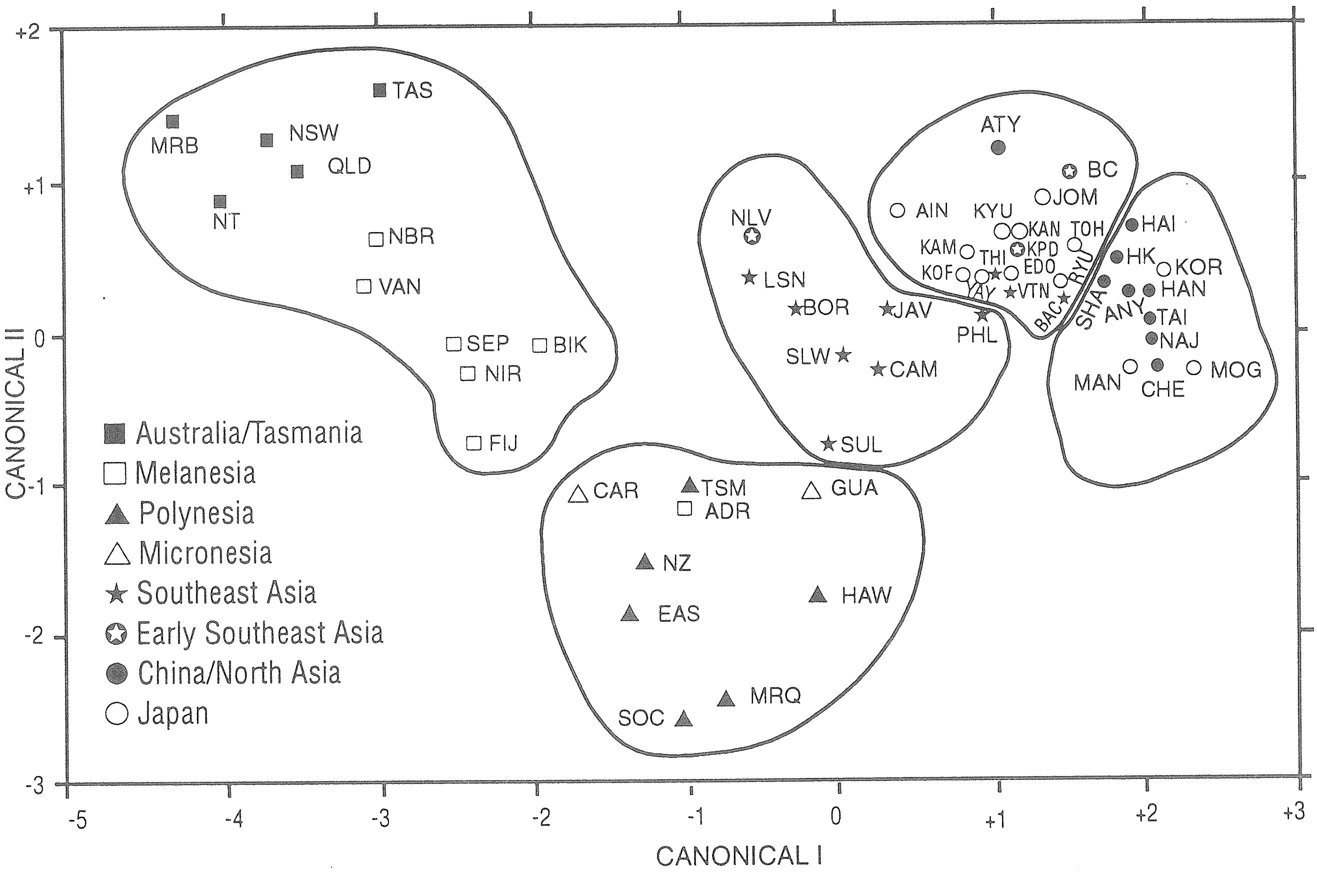

Figure 5: Plot of 55 group means in the first two canonical variates using 28 cranial measurements.

Neolithic Vietnam/Laos series occupies a more isolated position aligning with Lesser Sundas and Borneo. Eliminating many of the groups (Figure 7) facilitates closer inspection of these patterns among these early crania series from Southeast Asia. Further evidenced in this partial representation is a close clustering of several of the southeast Asian series (e.g., Sulawesi, Java, Sulu, Cambodia/Laos). Chinese from Taiwan and Hainan Islands are not far removed from Anyang. Manchuria, Mongolia and Korea form a cluster. Jomon and Ainu and to a lesser extent, Atayal, are set off from the rest of these series. Returning to Figure 6, a distinct clustering occurs among some of the Polynesian series, for example, Hawaii, Marquesas and Society group together as do Easter Island and New Zealand. Further attracted to these Polynesian series are Guam, Caroline Islands and the Admiralty Islands.

Some of the group classification results are summarised in Table 13. The total percentage of cases correctly classified is only 44.6%, suggesting the groups, on average, are not well differentiated. However, half of the Ban Chiang and Neolithic cases are correctly classified to their respective series. The classification results for Khok Phanom Di are better with 78.6% of the cases being correctly assigned. The six mis-classified Ban Chiang specimens are classified as Hangzhou (1), Korea (1), Kofun (1), Ryukyu (2), Neolithic Laos/Vietnam (1). The three mis-classified Khok Phanom Di cases are assigned to Ban Chiang (1), Neolithic Laos/Vietnam (1) and Anyang (1). Five Neolithic Laos/Vietnam cases are misclassified as Atayal (2), Borneo (1) and Ban Chiang (2).

Groups with the highest percentage of correct classifications include Mongolia (82.0%), Atayal (75.0%), Khok Phanom Di (78.6%), Tasmania (69.2%), Easter Island (66.0%), Guam (65.2%), Bachuc (62.7%) and Cambodia/Laos (62.5%). Groups having the poorest classification results are Lesser Sundas (17.8%),

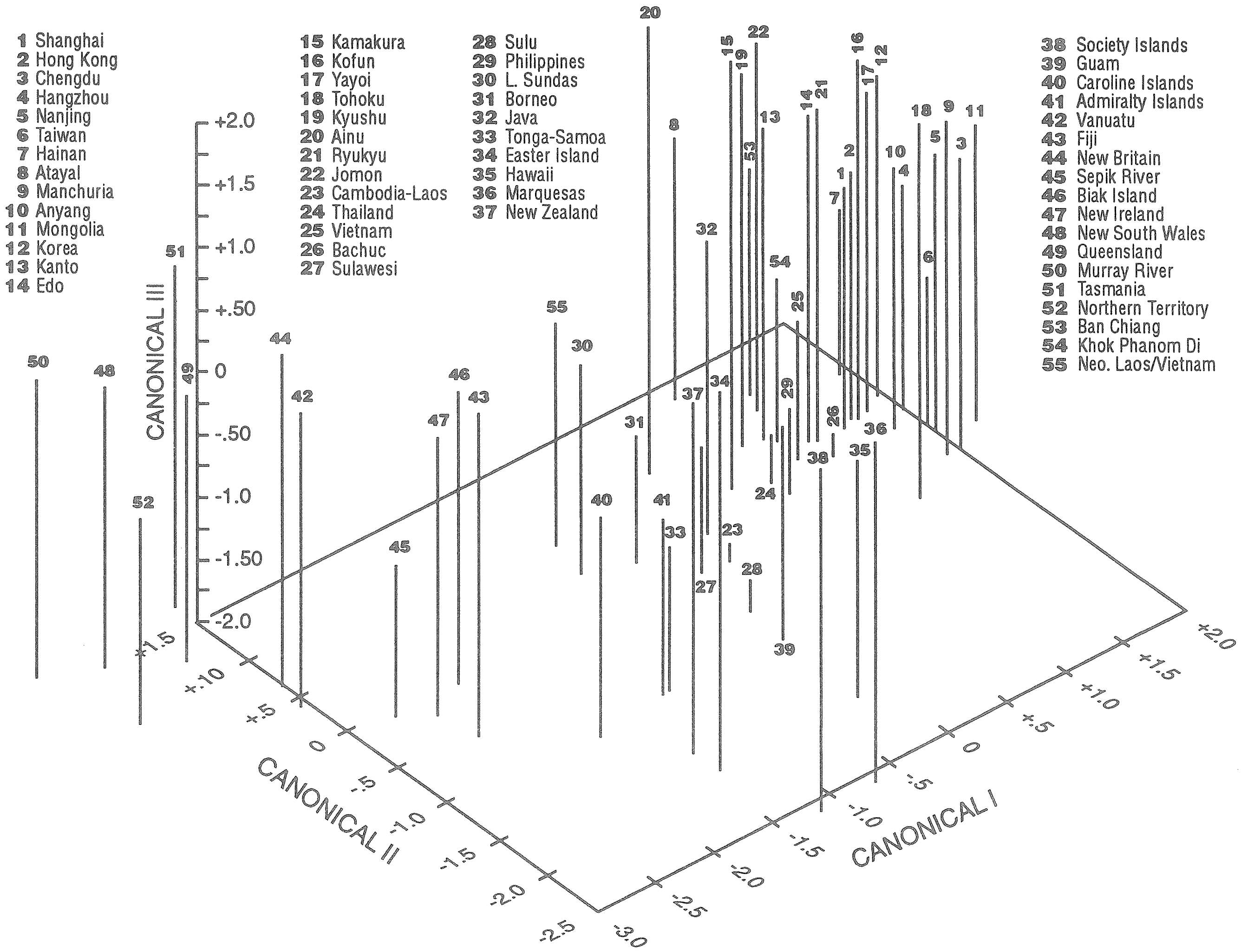

Figure 6: Plot of 55 group means on the first three canonical variates using 28 cranial measurements.

Hangzhou (22.0%), Yayoi (22.6%), Caroline (25.0%), Kamakura (26.9%), Korea (28.1%) and Nanjing (28.6%).

Mahalanobis' Generalised Distance

Some of the distances which result from applying Mahalanobis' Generalised Distance to 28 measurements recorded in 55 male groups are presented in Table 14. Applying the Unweighted Pair Group Method clustering algorithm results in the dendrogram shown in Figure 8.

Two major branches are indicated in the dendrogram presented in Figure 8, one containing all the Asian cranial series and a second that includes the series from Australia, Melanesia and Polynesia, although the latter, with the exception of the Admiralty and Fijian series, occupies a distinct and separate branch. Within the Asian branch, cranial series from China, Korea, Manchuria and Japan group together. The Chinese from eastern and western China and Hong Kong form a separate sub-branch. The Japanese (including Ryukyu Islands), from Yayoi to modern times, group with Korea and Manchuria. Taiwan Chinese, Hainan Is. Chinese, Atayal and Bronze-age Anyang form a separate sub-branch. The Ainu and Jomon series cluster together and join the aforementioned series. The cranial series representing Southeast Asia (mainland and island) form another distinct branch. Ban Chiang and Khok Phanom Di form a

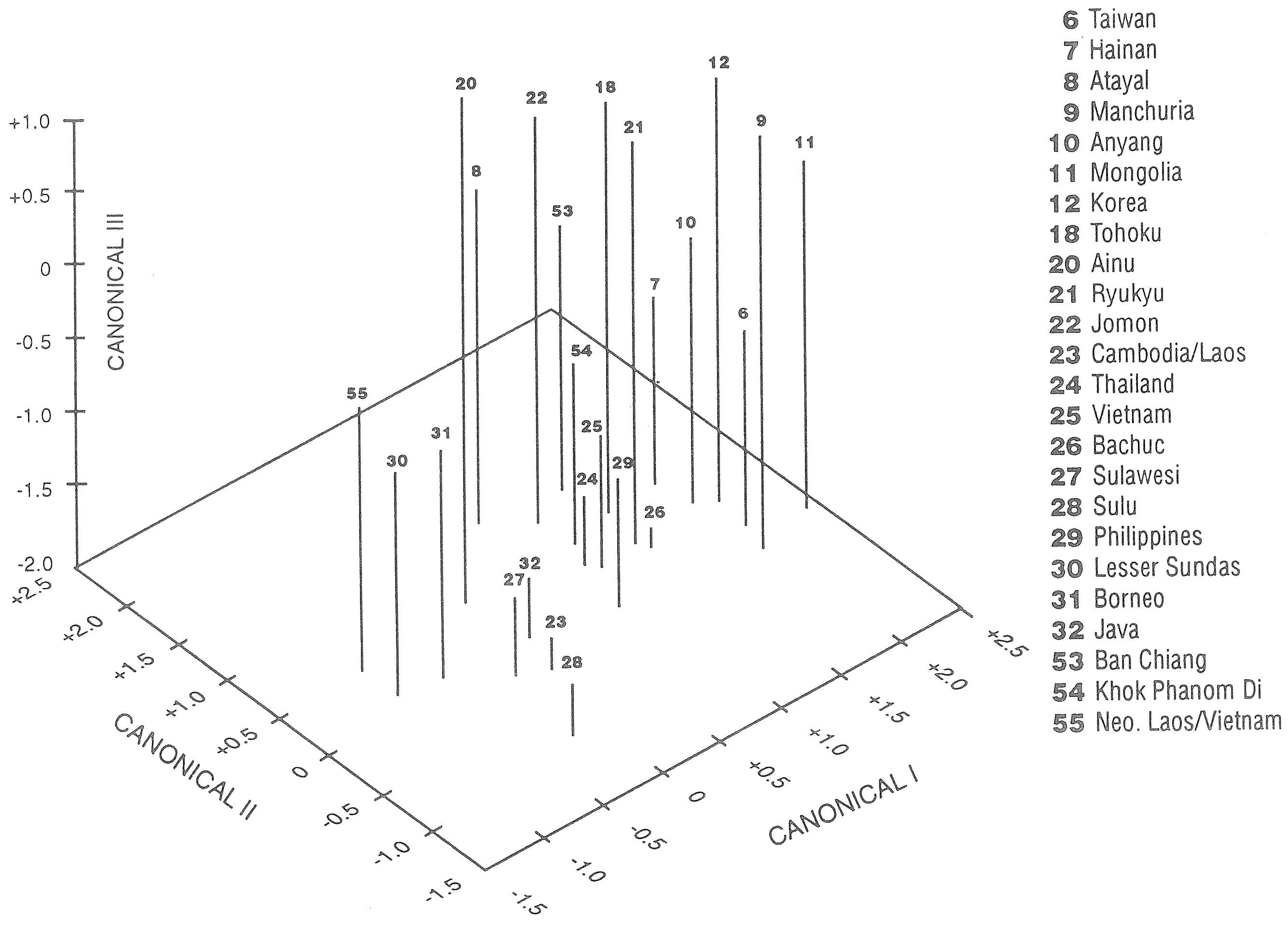

Figure 7: Plot of 24 of the 55 group means on the first three canonical variates using 28 cranial measurements.

loose association which then connects with this major Asian grouping. The Neolithic Laos/Vietnam and Mongolian series are the last to join the latter subdivision.

CONCLUSIONS

The results of these new craniometric analyses, which include recently examined crania from Ban Chiang and Khok Phanom Di, allow some tentative conclusions to be made. When compared with a limited number of early cranial series from Thailand, China and Japan, Ban Chiang is closest to the 11th century BC Chinese cranial series from Anyang in northern China followed by the 3,500 to 2,000 year old Jomon crania from Japan. The 4,000 year old Khok Phanom Di series, from central Thailand and a composite sample representing Neolithic crania from Laos and Vietnam occupy more marginal positions in this analysis. Relatively few cranial measurements, namely frontal breadth, the heights and breadths of the orbits and nasal apertures, palate length and upper facial height are responsible for the differences seen in this first analysis.

When these same early cranial series are compared with a larger sampling of prehistoric and modern crania from Asia and the Pacific, Ban Chiang and Khok Phanom Di are peripheral members of a greater Asian subdivision. In discriminant function space, Ban Chiang is closest to several modern and prehistoric cranial series from Japan and the Ryukyus. Khok Phanom Di is closest to modern Thailand, Vietnam and the Philippines. The

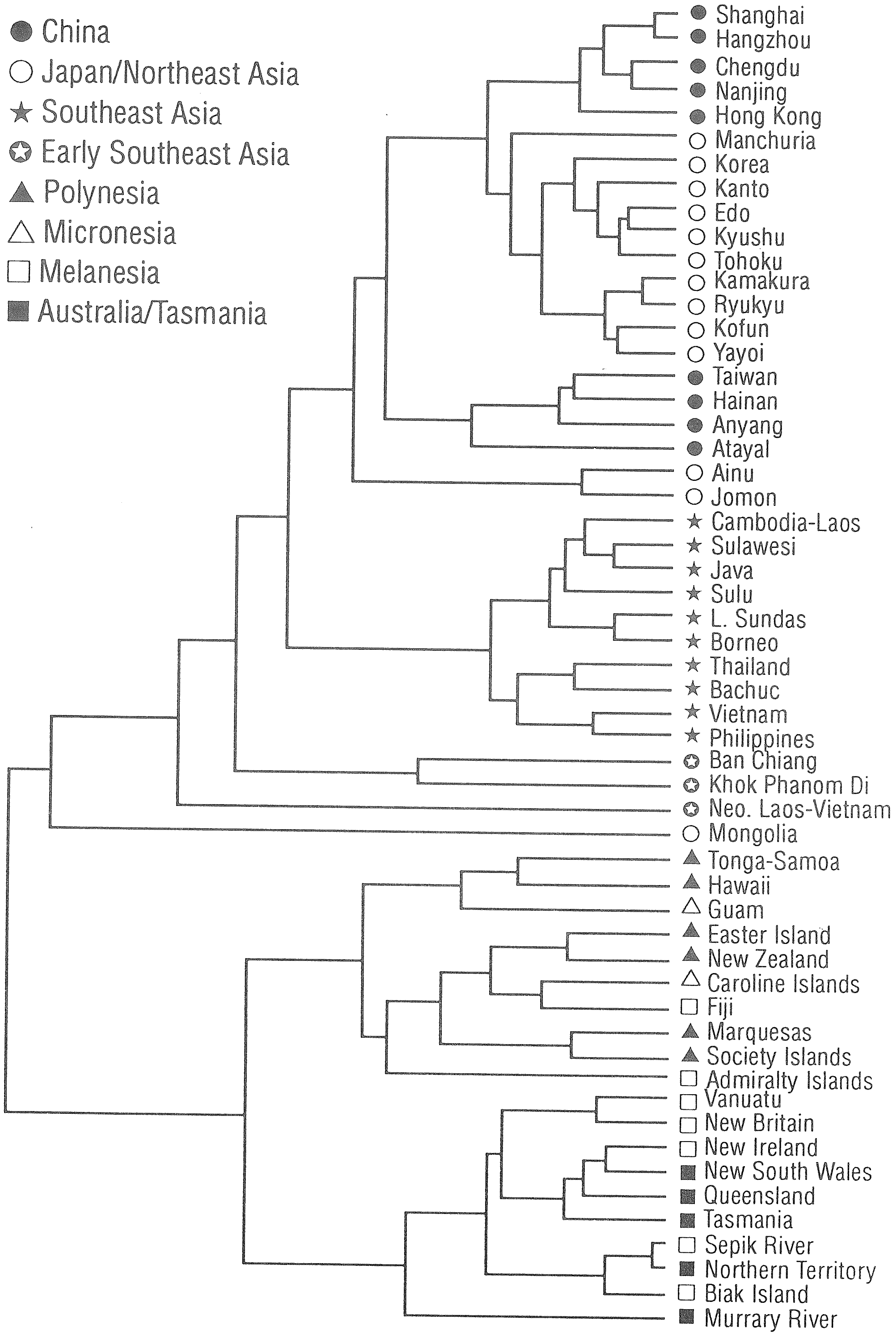

Figure 8: Diagram of relationship based on a cluster analysis (UPGMA) of Mahalanobis' Generalized Distances using 28 cranial measurements recorded in 55 male cranial series.

Neolithic Laos/Vietnam series aligns with island Southeast Asian (*e.g.* Lesser Sundas, Borneo) samples and is removed from both Ban Chiang and Khok Phanom Di. Jomon crania group with Ainu and, together, these two series form an isolated cluster, distinct from more modern Japanese (from Yayoi to modern times). The Ainu-Jomon cluster is not part of a Pacific (Polynesian) cluster as advanced by Brace and Tracer (1992) and Brace *et al.* (1990). Further, in these broader comparisons, the Bronze-age Anyang series is not far removed from other Chinese series. Crania representing one aboriginal group from Taiwan, the Atayal, is closest to a cluster (in the dendrogram based on distances) containing crania from Taiwan, Hainan Island and Anyang, a connection demonstrated in previous work (Pietrusewsky 1995).

Overall, two major population complexes are identified in the broader comparisons. One division contains all the Asian cranial series while the second includes the Australian Aboriginal and Melanesian cranial series. Polynesians, in the cluster analysis of distances, form a separate sub-branch, which appears to connect with the Australian-Melanesian sub-branch. However, closer inspection of these results indicates that Polynesians are closest to Southeast Asians rather than to the latter complex. The modern cranial series from mainland Southeast Asia are closest to those from island Southeast Asia. Mongolia is one of the most isolated series investigated.

Although the number of specimens representing Ban Chiang and several other early Southeast Asian cranial series used in the present analysis are limited, the preliminary comparisons suggest some long term connections between Bronze-age inhabitants of Thailand, East Asia and modern Southeast Asia. The implied connections between Ban Chiang, Anyang, Jomon and the Ryukyu Island series, found in the present results, are worthy of further investigation.

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Table 1: The Ban Chiang specimens

Burial No.	Age (in years)	Phase Provenience (White 1986)
(1974) #20	35-40	MPVI
#23	45-50	EPV
#43	35-40	EP2
(1975) #22	Mid-aged	MPVIII
#31	45-50	EPIVB
#35	45-50	EPIV
#45	45-50	EPIV
#47	45-50	EPIII
#50	25-30	EPIVA
#51	40-45	EPIVA
#65	40-45	EPIVA
#72	35-40	EP1-III

Table 2: Neolithic specimens from Laos and Vietnam

Museum/Burial #	Age	Site	Provenience	Reference
No. 20539	YA	Tam Hang-Sud, Laos	Paleolithic-Neolithic	Fromaget & Saurin (1936)
No. 20540	YA	Tam Hang-Sud, Laos	Paleolithic-Neolithic	Fromaget & Saurin (1936)
No. 20541	YA	Tam Pong, Laos	Mesolithic	Fromaget & Saurin (1936)
No. 20542	MA	Tam Pong, Laos	Mesolithic	Fromaget & Saurin (1936)
No. 19416	A	Lang Cuom, N. Vietnam	Early Neolithic	Mansuy & Colani (1925)
No. 19418	MA	Lang Cuom, N. Vietnam	Early Neolithic	Mansuy & Colani (1925)
No. 19455	YA	Lang Cuom, N. Vietnam	Early Neolithic	Mansuy & Colani (1925)
No. 18504		Pho Bing Gia, N. Vietnam	Bacsonian	Verneau (1909)
No. 3	Old	Con Co Ngua, N. Vietnam	Neolithic	Pietrusewsky (1988)
No. 4	MA	Con Co Ngua, N, Vietnam	Neolithic	Pietrusewsky (1988)

[YA = Young adult, MA = Middle aged, A = adult]

Table 3: Fifty-five male groups used in the present study

Sample (abbrev.)	No. of Crania	Location[1] and Number	Remarks
East Asia			
Shanghai (SHA)	50	SHA-50	The specimens are mostly from post-Qing cemeteries in Shanghai.
Hangzhou (HAN)	50	SHA-50	Ancient skeletal remains exhumed in the modern city of Hangzhou, Zhejiang Province in eastern China.
Nanjing (NAN)	49	SHA-49	Ancient remains exhumed from the modern city of Nanjing, Jiangsu Province in eastern China.
Chengdu (CHE)	53	SHA-10; CHE-43	A majority of these specimens date to the Ch'en Dynasty (A.D. 1796-1908) and are from Chengdu, Sichuan Province in western China. Ten crania are from Leshan, Lizhong County, Sichuan Province.
Hong Kong (HK)	50	HKU-50	Specimens represent individuals who died in Hong Kong between 1978-1979.
An-yang (ANY)	56	TPE-56	Bronze-age (11th century B.C.) Shang Dynasty sacrificial victims excavated at Anyang in northern Henan Province in northern China (Li 1977).
Taiwan Chinese (TAI)	47	TPE-47; TKM-3	Modern Chinese living in Taiwan who trace their immediate origins to Fujian and Guangdong Provinces on the mainland of China.
Hainan Island (HAI)	47	TPE-47	Chinese immigrants originally from the Canton region of China who began arriving around 200 B.C. (Howells 1989:108). This material was excavated by T. Kanaseki in Haikou City on Hainan Island.
Atayal (ATY)	36	TPE-28; TKM-7; TKO-1	The specimens in Taipei represent slain victims of Atayal, the second largest surviving Aboriginal tribe in Taiwan. The incident took place in 1932 and the specimens were collected by T. Kanaseki in the same year (Howells 1989:109).
Manchuria (MAN)	50	TKO-50	Many of the specimens are from northeastern China or the region formerly referred to as "Manchuria," which today includes Heilongjiang and Jilin Provinces and adjacent northern Korea. A great many of these specimens are identified as soldiers or cavalrymen who died in battle in the late 19th century.
Korea (KOR)	32	KYO-7; SEN-3, TKM-2; TKO-20	Specific locations in Korea are known for most of these specimens.
Mongolia (MOG)	50	SIM-50	The skulls are identified as coming from Ulaanbaatar (Urga), Mongolia and were purchased by A. Hrdlicka in 1912.
Kanto Japanese (KAN)	50	CHB-50	A dissecting room population of modern Japanese from the Kanto District of eastern Honshu. The majority of the individuals were born during the Meiji period (1868-1911) and most died well before 1940.
Tohoku Japanese (TOH)	53	SEN-53	Dissecting room specimens of modern Japanese from the Tohoku District in northern Honshu Island.
Kyushu Japanese (KYU)	51	KYU-51	Modern Japanese which derive mostly from Fukuoka Prefecture in Kyushu Island. Other specimens are from Yamaguchi, Saga Nagasaki and adjoining prefectures.
Edo (EDO)	55	NSM-52	The specimens are from the Joshinji (Tokyo) site and date to the Edo Period or approximately the 17th to mid-19th centuries.

Table 3 (cont'd)

Kamakura (KAM)	52	NSM-9; TKO-43	Specimens are from the Medieval mass burial sites of Zaimokuza and Gokurakuji in the city of Kamakura, victims of a war which occurred in 1333.
Kofun (KOF)	62	KYO-5; KYU-53; NSM-4	The Kofun period follows the Yayoi period and these sites are dated from approximately the third century A.D.
Yayoi (YAY)	62	KYU-62	A combined sample of Yayoi specimens from Doigahama (39), Yoshimohama (14) and Nakanohama (2) sites in Yamaguchi Prefecture. The rest (7) are from Koura, Shimane Prefecture, in southern Honshu Island.
Jomon (JOM)	51	TKO-16; NSM-19 KYO-15; SAP-1	All specimens represent Late to Latest Jomon sites on Honshu Island. The largest series are Ebishima (11) in Iwate Prefecture in Tohoku District and Tsukumo (12), Okayama Prefecture in the Chugoku District.
Ainu (AIN)	50	SAP-18; TKM-5 TKO-27	Skeletons collected by Koganei in 1888-89 from abandoned Ainu cemeteries in Hokkaido (Koganei 1893-1894).
Ryukyu Island (RYU)	62	KYU-34; KYO-18 TKO-10	Specimens are from the Sakishima (13), Okinawa (13) and Amami (49) groups, respectively. Six more are identified only as Ryukyu Island.
Mainland Southeast Asia			
Viet Nam (VTN)	49	HCM-49	Specimens are from Hanoi (Van Dien Cemetery) and Ho Chi Minh City.
Bachuc (BAC)	51	BAC-51	Victims of the 1978 Khmer Rouge massacre in Bachuc Village in western Angiang Province, Viet Nam.
Cambodia & Laos (CAM)	40	PAR-40	A combined sample of crania from various locations in Cambodia and Laos collected between 1877 and 1920.
Thailand (THI)	50	SIR-50	Most of the specimens represent dissecting room cases from Bangkok.
Bronze Thai (BZT)	14	UHM-12; DUN-2	Sample includes specimens (10) from Ban Chiang, a neolithic site (First-Fourth millennia B.C.) in northeastern Thailand and two specimens each are from Ban Na Di (1000 B.C.-300 B.C.) and Non Pa Kluay (prehistoric Bronze to Iron period), sites located in northeastern Thailand.
Island Southeast Asia			
Philippines (PHL)	28	BER-9; DRE-19	Most specimens are from Luzon Island.
Lesser Sundas (LSN)	45	BAS-5; BER-6; BLU-2; CHA-1; DRE-17; LEP-1; PAR-6; ZUR-7	Crania from Bali, Flores, Sumba, Lomblen, Alor, Timor, Wetar, Leti and Barbar Islands.
Borneo (BOR)	34	BER-2; BRE-2; DRE-6; FRE-4; LEP-8; PAR-12	A great many of the specimens are indicated as representing Dayak tribes, some have elaborate decorations.
Sulawesi (SLW)	41	BAS-7; BER-10; DRE-4; FRE-7; LEP-5; PAR-8	An exact location is known from many of these specimens.
Java (JAV)	50	BER-1; BLU-8; CHA-9; DRE-1; LEP-24; PAR-7	Crania were collected from several different localities in Java.

Table 3 (cont'd)

Sulu (SUL)	38	LEP-1; PAR-37	The specimens in Paris were collected by Montano-Rey circa 1900.
Polynesia			
Tonga-Samoa (TOG)	12	BER-3; AMS-1 DRE-1; PAR-1 BPB-4; AIM-2	Eight specimens are from Tonga and four are from Samoa.
Easter Island (EAS)	50	BER-5; DRE-9; PAR-36	Most of the crania in Paris were collected by Pinart in 1887 at Vaihu and La Perouse Bay.
Hawai`i (HAW)	49	BPB-49	Specimens represent prehistoric Hawaiians from Mokapu, O`ahu Island.
Marquesas (MRQ)	63	PAR-49; LEP-1; BLU-1; BPB-12	Crania are from four islands, Fatu Hiva, Tahuata, Nuku Hiva and Hiva Oa.
New Zealand (NZ)	50	BRE-3; PAR-21; SAM-1; AIM-13; GOT-1; ZUR-5; DRE-6	A representative sample from North and South Islands of New Zealand.
Society (SOC)	44	PAR-33; BPB-11	Crania are from the island of Tahiti.
Micronesia			
Guam (GUA)	46	BPB-42; PAR-4	Most of the specimens in the Bishop Museum were collected by H.G. Hornbostel at Tumon Beach on Guam during WWII.
Caroline Islands (CAR)	24	TKO-7; DRE-9; PAR-4; GOT-3; AMS-1	Specimens are from Kosrae (1), Pohnpei (6) and Truk (7).
Melanesia			
Admiralty Islands (ADR)	50	DRE-20; GOT-9; CHA-6; TUB-15;	Specimens from Hermit, Kaniet and Manus Islands.
Vanuatu (VAN)	47	BAS-47	Most of the specimens were collected by F. Speiser in 1912 from Malo, Pentecost and Espiritu Santo Island.
Fiji (FIJ)	32	BER-1; AMS-3; PAR-8; QMB-1; DRE-4; SAM-3; FRE-3; CHA-1; BPB-8	Crania are from all major islands including the Lau Group in the Fiji Islands.
New Britain (NBR)	50	CHA-20; DRE-30	The specimens in Dresden were collected by A. Baessler in 1900 and those in Berlin were collected by R. Parkinson in 1911.
Sepik R. (SEP)	50	DRE-33; GOT-10; TUB-7	The specimens in Dresden were collected by O. Schlaginhaufen in 1909.
Biak Islands (BIK)	48	DRE-48	Most (45) of the specimens were collected by A.B. Meyer in 1873 on Biak Island (Mysore) in Geelvink Bay, Irian Jaya.
New Ireland (NIR)	53	AMS-4; BER-2; BLU-6; DRE-18; GOT-15; QMB-1; SAM-6; TUB-1	The crania in Dresden were mostly collected by Pöhl in 1887-1888 from the end of the island; the specimens in Göttingen were collected during the Südsee Expedition in 1908.

Table 3 (cont'd)

Australia/Tasmania

Murray R. (MRB)	50	AIA-39; DAM-11	These crania were collected by G.M. Black along the Murray River (Chowilla to Coobool) in New South Wales between 1929-1950.
New South Wales (NSW)	62	AMS-21; DAS-41	The specimens are from the coastal locations in New South Wales.
Queensland (QLD)	54	AMS-21; DAS-3; QMB-30	This sample is drawn from the southeastern and middle-eastern parts of Queensland.
Northern Territory (NT)	50	AIA-4; AMS-3; MMS-1; NMV-38; QMB-1; SAM-3	Crania are from Port Darwin (39) and Arnhemland (36).
Tasmania (TAS)	26	THM-22; CHA-1; SAM-2; NMV-1	The crania represent Tasmanian Aborigines.

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[1] AIA = Australian Institute of Anatomy, Canberra
AIM = Auckland Institute and Museum, Auckland
AMS = The Australian Museum, Sydney
BAC = Bachuc Village, Angiang Province, Viet Nam
BAS = Naturhistorisches Museum, Basel
BER = Museum für Naturkunde, Berlin
BLU = Anatomisches Institut, Universität Göttingen, Göttingen
BPB = B. P. Bishop Museum, Honolulu
BRE = Über-see Museum, Bremen
CHA = Anatomisches Institut der Chairté, Humboldt Universität, Berlin
CHB = Chiba University School of Medicine, Chiba
CHE = Dept. of Anatomy, Chengdu College of Traditional Chinese Medicine, Chengdu, PRC
DAM = Dept. of Anatomy, University of Melbourne, Melbourne
DAS = Dept. of Anatomy, University of Sydney, Sydney, Australia
DRE = Museum für Völkerkunde, Dresden
DUN = Dept. of Anatomy, University of Otago, Dunedin, New Zealand
FRE = Institut für Humangenetik u. Anthropologie, Universität Freiburg
GOT = Institut für Anthropologie, Universität Göttingen, Göttingen
HCM = Faculty of Medicine, Ho Chi Minh City, Viet Nam
HKU = University of Hong Kong, Hong Kong
KYO = Lab of Physical Anthropology, Faculty of Science, Kyoto University, Kyoto
KYU = Dept. of Anatomy, Faculty of Medicine, Kyushu University, Fukuoka
LEP = Anatomisches Institut, Karl Marx Universität, Leipzig
MMS = Macleay Museum, University of Sydney, Sydney
NSM = National Science Museum, Tokyo
NMV = National Museum of Victoria, Melbourne
PAR = Musée de l'Homme, Paris
QMB = Queensland Museum, Brisbane
SAM = South Australian Museum, Adelaide
SAP = Dept. of Anatomy, Sapporo Medical College, Sapporo
SEN = Dept. of Anatomy, School of Medicine, Tohoku University, Sendai
SHA = Institute of Anthropology, College of Life Sciences, Fudan University, Shanghai
SIM = National Museum of Natural History, Smithsonian Institution, Washington, D.C.
SIR = Dept. of Anatomy, Siriraj Hospital, Bangkok
THM = Tasmanian Museum and Art Gallery
TKM = Medical Museum, University Museum, University of Tokyo
TKO = University Museum, University of Tokyo, Tokyo
TPE = Academia Sinica, Nankang, Taipei
TUB = Institut für Anthropologie u. Humangenetik, Universität Tübingen, Tübingen
UHM = Department of Anthropology, University of Hawaii, Honolulu
ZUR = Anthropologisches Institut, Universität Zürich, Zürich

Table 4. Means and standard deviations for 28 cranial measurements recorded in five early Southeast Asian and East Asian series

	BAN CHIANG (N=12)		KHOK PHANOM DI (N=14)		NEOLITHIC LAOS/VIETNAM (N=10)	
MEASUREMENT[1]	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
MAXCRANL	180.2	5.7	181.6	4.5	185.9	6.1
NASOCCIL	176.6	5.6	179.5	4.7	181.5	5.6
MAXCRANB	139.1	6.9	146.6	5.7	138.0	5.6
MAXFRONB	119.3	4.8	125.4	4.9	120.9	4.1
MINFRONB	98.4	5.6	102.1	4.0	99.0	5.1
BISTEPHB	113.9	6.4	121.3	6.5	115.2	5.4
BIAURICB	123.8	6.8	128.9	7.4	123.0	7.1
MINCRANB	77.0	2.6	79.5	4.2	77.1	5.6
BIASTERI	107.7	4.5	113.9	6.5	109.2	4.6
NASIALVE	71.5	3.7	70.5	4.6	68.1	4.5
NASALHGT	52.0	2.7	53.9	2.1	51.9	2.5
NASALBTH	26.2	1.7	27.0	1.4	27.4	1.8
ORBHGTLF	34.5	2.2	33.1	2.2	34.4	2.1
ORBBTHLF	40.3	2.5	41.6	2.2	43.1	3.1
ALVEOLAL	54.3	1.8	54.6	2.9	56.4	2.1
ALVEOLAB	67.6	4.4	70.0	2.6	67.2	3.7
MASTOIDH	25.8	3.8	29.4	4.2	26.0	2.7
MASTOIDW	19.5	3.1	20.3	2.3	18.9	2.2
BIMAXILB	104.8	4.3	106.0	4.8	105.3	4.4
BIFRONTB	108.4	4.3	112.3	3.7	109.3	4.2
BIORBITB	98.6	4.2	99.9	4.4	101.9	4.1
INTERORB	28.0	2.5	28.6	2.5	30.0	2.2
CHEEKGHT	25.8	2.8	27.4	2.4	25.9	1.8
NASIBGCR	111.8	4.0	118.6	4.8	114.1	6.1
BRGLMDCR	113.3	3.9	116.4	4.3	116.7	7.3
LAMOPISC	97.9	4.6	98.3	4.6	97.0	4.3
BIMAXSUB	20.8	3.2	21.4	3.0	22.3	3.1
NASFROSB	12.7	2.4	13.7	2.4	15.0	1.7

	ANYANG (N=15)		JOMON (N=15)	
MEASUREMENT[1]	MEAN	S.D.	MEAN	S.D.
MAXCRANL	178.9	5.6	185.3	6.7
NASOCCIL	176.8	4.8	182.7	6.2
MAXCRANB	136.3	4.0	143.0	6.8

Table 4 (cont'd)

MAXFRONB	115.3	4.3	121.7	6.1
MINFRONB	92.4	4.5	99.1	4.4
BISTEPHB	108.6	5.2	117.7	5.6
BIAURICB	124.2	4.6	126.3	6.6
MINCRANB	75.9	2.5	78.8	6.2
BIASTERI	107.4	4.6	110.0	6.5
NASIALVE	69.7	4.4	67.7	3.1
NASALHGT	51.8	3.7	49.7	2.5
NASALBTH	25.7	1.0	24.8	1.4
ORBHGTLF	33.3	2.7	32.4	1.4
ORBBTHLF	39.3	1.9	41.8	2.2
ALVEOLAL	51.4	3.0	53.3	1.8
ALVEOLAB	65.2	3.5	63.9	2.5
MASTOIDH	28.1	2.8	26.2	3.8
MASTOIDW	18.9	2.2	21.7	2.5
BIMAXILB	101.7	5.4	100.7	5.7
BIFRONTB	104.7	4.1	109.2	4.0
BIORBITB	93.9	4.5	99.0	4.4
INTERORB	27.3	2.7	27.4	1.4
CHEEKGHT	25.7	3.3	23.7	2.3
NASIBGCR	112.5	3.7	110.9	2.7
BRGLMDCR	112.5	6.6	116.9	4.6
LAMOPISC	98.9	4.0	100.8	3.8
BIMAXSUB	20.1	4.6	21.6	2.5
NASFROSB	14.3	2.6	15.1	2.9

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[1] MAXCRANL = Maximum cranial length (M-1); NASOCCIL = Nasio-occipital length (M-1d); BASINASI = Basion-nasion (M-5); BASIBREG = Basion-bregma (M-17; MAXCRANB = Maximum cranial breadth (M-8); MAXFRONB = Maximum frontal breadth (M-10); MINFRONB = Minimum frontal breadth (M-9); BISTEPHB = Bistephanic breadth (H-STB); BIAURICB = Biauricular breadth (M-11b); MINCRANB = Minimum cranial breadth (M-14); BIASTERI = Biasterionic (M-12); NASIALVE = Nasion-alveolar (M-48); NASALHGT = Nasal height (M-55); NASALBTH = Nasal breadth (M-54); ORBHGTLF = Orbital height, left (M-52); ORBBTHLF = Orbital breadth, left (M-51a); BIJUGALB = Bijugal breadth [M-45(1)]; AVEOLAL = Alveolar length (M-60); ALVEOLAB = Alveolar breadth (M-61); MASTOIDH = Mastoid height (H-MDL); MASTOIDW = Mastoid width (H-MDB); BIMAXILB = Bimaxillary breadth (M-46); BIFRONTB = Bifrontal breadth (M-43); BIORBITB = Biorbital breadth (H-EKB); INTERORB = Interorbital breadth (M-49a); MALRLINF = Malar length, maximum (H-XML); CHEEKHGT = Cheek height [M-48(4)]; FORAMGL = *Foramen magnum* length (H-FOL); NASIBGCR = Nasion-bregma chord (M-29); BRGLMDCR = Bregma-lambda chord (M-30); LAMOPISC = Lambda-opisthion chord (M-31); BIMAXSUB = Bimaxillary subtense (H-SSS); NASFROSB = Nasio-frontal subtense (H-NAS). M = Martin (1957); H = Howells (1973).

Table 5: Ranking of cranial measurements according to F-values received in the final step of discriminant function analysis (five male samples)

STEP NO.	MEASUREMENT	F-VALUE	$d.f._B/d.f._W$[1]	*p*[2]
1	BISTEPHB	9.425	4/66	*
2	NASALBTH	8.933	4/65	*
3	ALVEOLAL	4.285	4/64	*
4	NASIAVLE	3.669	4/63	*
5	NASALHGT	4.424	4/62	*
6	ORBBTHLF	4.101	4/61	*
7	MASTOIDH	3.179	4/60	*
8	ORBHGTLF	2.653	4/59	**
9	NASOCCIL	2.542	4/58	**
10	NASIBGCR	3.732	4/57	*
11	MAXCRANL	2.307	4/56	**
12	MASTOIDW	1.961	4/55	N.S.
13	LAMOPISC	1.427	4/54	N.S.
14	MINFRONB	1.200	4/53	N.S.
15	INTERORB	1.273	4/52	N.S.
16	BIMAXSUB	1.202	4/51	N.S.
17	NASFROSB	1.095	4/50	N.S.
18	ALVEOLAB	1.232	4/49	N.S.
19	MAXFRONB	1.082	4/48	N.S.
20	BIAURICB	0.820	4/47	N.S.
21	BRGLMDCR	0.560	4/46	N.S.
22	BIORBITB	0.553	4/45	N.S.
23	BIFRONTB	2.998	4/44	**
24	BIMAXILB	0.661	4/43	N.S.
25	MAXCRANB	0.390	4/42	N.S.
26	MINCRANB	0.171	4/41	N.S.
27	CHEEKHGT	0.213	4/40	N.S.
28	BIASTERI	0.064	4/39	N.S.

---

[1] $d.f._B/d.f._W$ = degrees of freedom between/degrees of freedom within

[2] *$p<0.01$, **$p<0.05$; N.S.=not significant

Table 6: Eigenvalues, percentage of total dispersion, cumulative percentage of dispersion and level of significance for four canonical variates

Canonical Variate	Eigenvalue	%Dispersion	Cumulative %Dispersion	*d.f.*[1]	*p*[2]
1	3.14309	37.6	37.6	31	*
2	2.14769	25.7	63.3	29	*
3	1.98420	23.7	87.0	27	*
4	1.08422	13.0	100.0	25	N.S.

[1] *d.f.* = degrees of freedom = (p + q-2) + (p + q-4)... N.S. = not significant

[2] $p<0.01$ when eigenvalues are tested for significance according to Bartlett's criterion [N-1/2(p + q)] $\log_e(1 + \lambda)$, where N = total number of crania, p = number of variables, q = number of groups, λ = eigenvalue, which are distributed approximately as chi-square (Rao 1952:323).

Table 7. Canonical Coefficients for 28 cranial measurements for the first three Canonical Variables

Variable	Canonical Variate 1 Coefficient	Canonical Variate 2 Coefficient	Canonical Variate 3 Coefficient
MAXCRANL	-0.05242	-0.09357	0.16589
NASOCCIL	0.01458	-0.01775	-0.17103
MAXCRANB	0.03139	-0.03012	-0.05757
MAXFRONB	0.06023	-0.16740	0.18187
MINFRONB	0.10079	-0.00421	-0.01639
BISTEPHB	0.00478	-0.18389	-0.20960
BIAURICB	-0.10035	-0.00693	0.02107
MINCRANB	-0.03030	0.03010	0.01952
BIASTERI	0.02347	-0.00961	0.01512
NASIALVE	-0.27165	-0.06670	0.04498
NASALHGT	0.23784	0.17565	-0.02050
NASALBTH	0.33317	0.06352	-0.15558
ORBHGTLF	-0.01157	-0.07192	0.15802
ORBBTHLF	-0.00819	-0.17751	-0.03935
ALVEOLAL	0.23957	-0.11745	0.19985
ALVEOLAB	0.10702	-0.10812	-0.16461
MASTOIDH	0.15334	0.21051	0.00429
MASTOIDW	-0.08475	-0.08041	-0.28551
BIMAXILB	0.06548	0.03357	0.04443
BIFRONTB	-0.03122	0.18336	-0.33341
BIORBITB	-0.00510	-0.21825	0.33205
INTERORB	0.00735	-0.01433	0.17940
CHEEKGHT	-0.01686	0.08532	0.03617
NASIBGCR	0.08668	0.11503	0.06846
BRGLMDCR	-0.02611	-0.05513	-0.09562
LAMOPISC	0.00834	0.03210	-0.05862
BIMAXSUB	0.02122	0.04983	-0.04716
NASFROSB	-0.17772	0.08298	-0.05427

Table 8. Summary of classification results from Discriminant Function Analysis

GROUP	BC	KPD	ANY	NLV	JOM
Ban Chiang	11	0	1	0	0
Khok Phanom Di	0	14	0	0	0
Anyang	1	0	14	0	0
Neo. Laos/Vietnam	1	0	0	9	0
Jomon	0	0	0	0	15
Total Cases	12	14	15	10	15
No. Correct Assign	11	14	14	9	15
% Correct Assign	91.7	100.0	93.3	90.0	

Table 9: Mahalanobis' Distances (upper half) and Level of Significance (lower half) for five male groups using 28 cranial measurements

GROUP	KPD	BC	ANY	JOM	NLV
Khok Phanom Di	0.0	16.823	22.814	23.864	21.366
Ban Chiang	---	0.0	13.425	14.234	16.437
Anyang	---	---	0.0	17.102	24.393
Jomon	---	---	N.S.	0.0	23.827
Neo Laos/Vietnam	---	---	---	---	0.0

N.S. = not significant
--- = significance cannot be determined

Table 10. Ranking of cranial measurements according to F-Values received in the final step of Discriminant Function Analysis (55 groups, 28 measurements)

STEP NO.	MEASUREMENT	F-VALUE	$d.f._{B}/d.f._{W}$[1]	p[2]
1	MAXCRANB	36.204	54/2490	*
2	ALVEOLAL	28.753	54/2489	*
3	NASIALVE	22.538	54/2488	*
4	NASOCCIL	17.305	54/2487	*
5	NASALHGT	16.029	54/2486	*
6	MINCRANB	14.168	54/2485	*
7	ORBBTHLF	11.952	54/2484	*
8	BIAURICB	9.844	54/2483	*
9	BIMAXILB	9.080	54/2482	*
10	BIMAXSUB	9.504	54/2481	*
11	NASIBGCR	8.867	54/2480	*
12	MAXCRANL	8.363	54/2479	*
13	NASALBTH	7.867	54/2478	*
14	BIORBITB	7.082	54/2477	*
15	BIFRONTB	7.201	54/2476	*
16	NASFROSB	6.571	54/2475	*
17	ALVEOLAB	6.400	54/2474	*
18	INTERORB	6.343	54/2473	*
19	LAMOPISC	6.301	54/2472	*
20	BRGLMDCR	6.065	54/2471	*
21	BISTEPHB	6.046	54/2470	*
22	MAXFRONB	5.043	54/2469	*
23	CHEEKHGT	4.524	54/2468	*
24	ORBHGTLF	4.651	54/2467	*

Table 10 (cont'd)

25	MASTOIDH	4.304	54/2466	*
26	BIASTERI	3.205	54/2465	*
27	MASTOIDW	3.049	54/2464	*
28	MINFRONB	2.915	54/2463	*

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[1] $d.f._B/d.f._W$ = degrees of freedom between/degrees of freedom within

[2] $*p<0.01$

Table 11. Eigenvalues, percentage of total dispersion, cumulative percentage of dispersion and level of significance for four Canonical Variates

Canonical Variate	Eigenvalue	%Dispersion	Cumulative %Dispersion	d.f.[1]	p[2]
1	3.80655	45.3	45.3	81	*
2	0.85911	10.3	55.6	79	*
3	0.78854	9.4	65.0	77	*
4	0.58772	7.0	72.0	75	*
5	0.39441	4.7	76.7	73	*
6	0.28422	3.4	80.1	71	*
7	0.24320	2.9	83.0	69	*
8	0.20182	2.4	85.4	67	*
9	0.16453	1.9	87.3	65	*
10	0.15480	1.9	89.2	63	*
11	0.13138	1.5	90.7	61	*
12	0.10142	1.2	91.9	59	*
13	0.09549	1.2	93.1	57	*
14	0.08585	1.0	94.1	55	*
15	0.07590	0.9	95.0	53	*
16	0.06849	0.8	95.8	51	*
17	0.06768	0.8	96.6	49	*
18	0.05915	0.7	97.3	47	*
19	0.05207	0.6	97.9	45	*
20	0.03371	0.4	98.3	43	*
21	0.02997	0.4	98.7	41	*
22	0.02914	0.4	99.1	39	*
23	0.02516	0.3	99.4	37	*
24	0.01961	0.2	99.6	35	*
25	0.01390	0.2	99.8	33	N.S.
26	0.00949	0.1	99.9	31	N.S.
27	0.00714	0.0	99.9	29	N.S.
28	0.00425	0.1	100.0	27	N.S.

---

[1] d.f. = degrees of freedom = $(p + q-2) + (p + q-4)$...

[2] $p<0.01$ when eigenvalues are tested for significance according to Bartlett's criterion $[N-1/2(p + q)] \log_e(1 + \lambda)$, where N = total number of crania, p = number of variables, q = number of groups, λ = eigenvalue, which are distributed approximately as chi-square (Rao 1952:323).
N.S. = not significant

Table 12. Canonical Coefficients for 28 cranial measurements for the first three Canonical Variables

Variable	Canonical Variate 1 Coefficient	Canonical Variate 2 Coefficient	Canonical Variate 3 Coefficient
MAXCRANL	-0.09317	0.07505	-0.02088
NASOCCIL	0.10773	-0.06145	0.23298
MAXCRANB	0.03578	0.02101	-0.05267
MAXFRONB	-0.00885	0.05011	-0.00968
MINFRONB	-0.03587	0.01568	0.03031
BISTEPHB	0.03282	-0.04830	0.01111
BIAURICB	0.01346	-0.09835	0.05952
MINCRANB	0.09181	0.11370	-0.01155
BIASTERI	-0.01280	0.03826	0.01883
NASIALVE	0.14890	0.06964	0.05118
NASALHGT	-0.10850	-0.15185	-0.12755
NASALBTH	0.00632	0.04718	-0.16223
ORBHGTLF	0.00632	-0.11218	-0.03449
ORBBTHLF	-0.04597	-0.11068	0.03858
ALVEOLAL	-0.16963	-0.00910	-0.03729
ALVEOLAB	-0.03506	0.11641	-0.05180
MASTOIDH	-0.03095	-0.06367	-0.02244
MASTOIDW	0.04456	-0.04036	0.03088
BIMAXILB	0.08154	-0.00457	-0.00271
BIFRONTB	0.07421	0.09306	0.04513
BIORBITB	-0.18993	-0.02404	0.00404
INTERORB	0.05318	-0.00601	-0.13619
CHEEKGHT	0.05563	-0.13301	0.00520
NASIBGCR	-0.03829	-0.05171	-0.07831
BRGLMDCR	-0.00050	0.00774	-0.06152
LAMOPISC	0.01038	-0.03559	-0.06210
BIMAXSUB	-0.08121	-0.05208	0.04994
NASFROSB	-0.02836	0.00552	-0.13538

Table 13. Summary of some of the classification results based on Discriminant Analysis (55 male cranial series, 28 measurements)

Group	Sha	Tai	Hai	Aty	Man	Any	Mog	Kor	Kan	Edo	Yay	Ain	Ryu
Shanghai	21						3		3		3		
Taiwan		27	6		1	4			1		1		
Hainan		3	15	1		3		1	2			1	2
Atayal		2	1	27					1				
Manchuria	2			1	26		1	3	2	1		1	
Anyang	1	3	2	1		25	1	3	1				2
Mongolia	3				1		41	1					1
Korea		2	3		2	1	2	9		1	1		
Kanto		2	1	3	1	1		3	17	2			2
Edo			3	4	3		1	1	4	7	3	5	3
Yayoi	1				4		2	2	3		14	3	2
Ainu									2	1		28	2
Ryukyu		2	1	2	1	2		3			3	3	17
Jomon			1						1		2	3	2
Camb/Laos				1									1
Thailand	1	1	2	1				1	5		1		
Vietnam	1		1	5						1			
Bachuc		1	2			1							
Sulawesi				1							1		
Philippines	1			1				1			1	1	
L.Sundas			1						1			1	
Borneo	1												
Java			1					1					
Ban Chiang								1					2
Khok Phanom Di						1							
N.Viet.Laos												2	
Total Cases	50	47	47	36	50	56	50	32	50	55	62	50	62
No. Correct	21	27	15	27	26	25	41	9	17	7	14	28	17
% Correct	42.0	57.4	31.9	75.0	52.0	44.6	82.0	28.1	34.0	12.7	22.6	56.0	27.4

Table 13 (cont'd)

Group	Jom	Cam	Thi	Vtn	Bac	Slw	Phl	Lsn	Bor	Jav	Bc	Kpd	Nvl
Shanghai		1	4			1				1	1		
Taiwan				2	2		1						
Hainan			3	1	3		1			1		1	
Atayal													
Manchuria			1										
Anyang					1		2	1		1	1		
Mongolia										1			
Korea								1		3			
Kanto	2		2		1			2					
Edo	1		1				1		1			1	
Yayoi	7		1	3		1					1		
Ainu	6					1		1					
Ryukyu	2		3	1		1	1		1		1	2	1
Jomon	28			2							1	1	1
Camb/Laos		25		1		2		2	1		1		
Thailand	2	2	17	3	5	1	1			1	1		
Vietnam	1	1	2	19	2		3		1	1	2		
Bachuc		2	4	1	32				1	1	1		
Sulawesi		6	1	3	1	11	1	2	5	2			
Philippines				2	1	3	11			2	1		
L.Sundas		3		2		3	2	8	3	1			
Borneo				3	1	2	1		9	1			2
Java		4	2		2	2	1	2		21	1		2
Ban Chiang											6		1
Khok Phanom Di											1	11	1
N.Viet.Laos									1		2		5
Total Cases	51	40	50	49	51	41	28	45	34	50	12	14	10
No. Correct	28	25	17	19	32	11	11	8	9	21	6	11	5
% Correct	54.9	62.5	34.0	38.8	62.7	26.8	39.3	17.8	26.5	42.0	50.0	78.6	50.0

Table 14. Some distances resulting from the application of Generalized Distances to 55 male groups, 28 measurements

Group	Sha	Tai	Hai	Aty	Man	Any	Mog	Kor	Kan	Edo	Yay	Ain	Ryu
Shanghai	0.0												
Taiwan	11.7	0.0											
Hainan	9.4	3.7	0.0										
Atayal	14.0	8.0	7.3	0.0									
Manchuria	7.6	10.3	8.5	11.8	0.0								
Anyang	8.2	4.2	4.1	7.3	6.8	0.0							
Mongolia	11.7	22.3	20.8	22.8	15.3	18.8	0.0						
Korea	6.8	6.4	3.9	6.6	3.8	3.9	14.4	0.0					
Kanto	7.1	9.0	6.4	8.5	7.7	7.7	19.0	4.7	0.0				
Edo	6.7	8.6	5.5	7.1	4.6	6.1	16.8	3.1	2.3	0.0			
Yayoi	6.2	10.6	9.4	10.0	6.3	6.8	9.4	4.8	6.4	4.3	0.0		
Ainu	13.7	18.6	15.8	12.7	11.9	14.7	19.2	10.1	7.4	4.3	6.4	0.0	
Ryukyu	9.1	8.1	6.1	7.7	7.3	4.6	16.3	4.4	6.3	3.1	2.5	5.8	0.0
Jomon	13.9	18.1	14.0	15.8	13.9	14.2	18.5	9.7	7.9	6.2	5.5	3.8	4.8
Camb/Laos	12.9	15.4	10.3	14.9	17.5	12.6	19.9	12.0	13.4	12.2	14.2	19.8	12.3
Thailand	7.2	9.1	5.8	12.0	14.0	8.7	19.6	7.4	6.3	7.3	10.3	14.2	9.0
Vietnam	7.1	7.1	6.3	8.9	12.4	7.8	19.0	7.2	7.1	6.4	7.4	12.2	6.7
Bachuc	10.5	9.1	4.5	13.9	14.6	9.3	25.2	7.8	9.4	9.1	13.2	19.6	10.9
Sulawesi	10.3	14.9	11.3	12.7	15.6	11.0	17.6	10.8	11.4	9.9	10.8	14.3	9.1
Philippines	8.8	9.7	8.3	8.3	14.0	7.4	19.2	8.1	10.4	8.3	10.0	14.0	7.7
L.Sundas	9.8	13.9	10.7	10.5	13.4	10.3	22.5	10.7	9.2	6.3	9.8	9.4	6.9
Borneo	9.9	14.8	11.9	11.2	15.4	11.5	21.6	11.0	10.6	8.8	9.8	12.8	8.2
Java	8.3	14.4	10.2	14.8	14.4	11.1	19.7	10.2	10.6	9.5	11.0	14.4	9.9
B.Chiang	10.3	13.0	9.3	13.5	12.2	8.1	20.1	8.3	13.2	8.8	8.6	14.4	6.7
Khok Phanom Di	17.8	19.6	16.3	23.8	21.5	13.5	24.8	16.4	18.8	16.8	15.1	21.1	14.1
N.Viet.Laos	16.5	26.0	23.5	22.7	23.7	20.8	22.2	20.6	19.2	15.7	13.5	14.6	13.9

Table 14 (cont'd)

Group	Jom	Cam	Thi	Vtn	Bac	Slw	Phl	Lsn	Bor	Jav	Bc	Kpd	Nvl
Shanghai													
Taiwan													
Hainan													
Atayal													
Manchuria													
Anyang													
Mongolia													
Korea													
Kanto													
Edo													
Yayoi													
Ainu													
Ryukyu													
Jomon	0.0												
Camb/Laos	18.7	0.0											
Thailand	13.0	5.5	0.0										
Vietnam	11.7	8.5	4.5	0.0									
Bachuc	17.0	7.2	3.8	5.8	0.0								
Sulawesi	15.4	3.0	5.0	6.9	8.7	0.0							
Philippines	13.8	6.8	5.9	3.1	7.6	4.5	0.0						
L.Sundas	12.5	6.6	7.2	5.8	10.3	3.5	5.4	0.0					
Borneo	13.8	5.4	7.0	5.3	9.7	3.7	5.7	2.5	0.0				
Java	15.1	3.6	4.1	6.5	6.9	2.4	5.6	3.8	4.2	0.0			
B.Chiang	13.0	13.1	11.1	10.6	11.5	13.0	10.6	9.6	11.5	9.8	0.0		
Khok Phanom Di	16.8	14.9	11.4	16.8	14.4	15.2	16.9	16.0	16.6	12.3	9.4	0.0	
N.Viet.Laos	17.1	13.3	15.4	13.3	19.3	10.6	15.5	8.3	7.2	10.1	12.2	16.4	0.0