METHOD AND THEORY FOR INVESTIGATING THE PEOPLING OF THE AMERICAS

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Paleobiological Evidence of the Peopling of the Americas: A Morphometric View

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A metrical analysis of 8,500- to 10,000 year old human skeletal remains from North America substantiates that their closest affinities are with Asian populations. Earlier (Paleoindian and Early Archaic) North American skeletal samples are distinguished by their relatively long and narrow crania and small, narrow faces. Later populations tended to be more brachycranic and exhibited larger, broader faces. Where Paleoindian specimens differed from modern northern Asians, they tended to structurally resemble southern Asian and European populations. These assessments generally support the inference that populations entered the Americas from northern Asia, but before the cranial features of modern northern Asians and Native Americans were fully developed. Based on the data examined, no date can be specified for time of entrance of the first populations, but the lack of any archaic *Homo sapiens* features supports the contention that entrance into the Americas was a relatively recent event. The number of founding populations cannot be established on the basis of these metric data.

Currently, few biological anthropologists wishing to reconstruct the origins and evolution of American populations rely on the oldest skeletal remains recovered from the Americas. Rather, they have turned to the comparative analyses of Late Holocene or extant American Indian, Asian, and other world populations, typically relying on biological data other than osteometrics. As examples of this approach, Turner (1971, 1983a,b, 1985a,b, 1986a,b, 1987) has compared relatively recent world populations on the basis of discrete characters of the dentition; Brace and colleagues (Brace and Nagai 1982; Brace et al. 1984; Brace and Hunt 1990) have compared Asian populations on the basis of linear dimensions of the face; and Ossenberg (1969, 1974, 1976, 1977, 1986) has compared Asians and American Indians on the basis of discrete traits of the skeleton. With the exception of Turner (1983b) and Turner and Bird (1981), these researchers have compared samples with little consideration given to their relative antiquity.

There are a variety of reasons underlying the reliance on the comparative analyses of recent populations. Most significant is the meager and fragmented nature of the skeletal remains of the early populations. There are fewer than 50 North American sites that contain human skeletal remains older than 5,000 years B.P., and probably no more than 25 of these sites are older than 8,000 B.P. (Table 1). More frustrating is the fact that the earliest sites are represented by one or two very incomplete and fragmented skeletons. Only five of the Paleoindians are represented by crania free of distortion and complete enough for a detailed osteometric analysis.

This reliance on comparative analyses of recent populations, however, dictates that two assumptions be accepted. The first is that little or no evolutionary change has occurred in the populations during the past 10,000 years. Unfortunately, if all descendent populations have altered the ancestral condition, then none can be used as a valid model of the ancestor. The second assumption is that gene flow between populations has not occurred. If any gene flow did occur, then the relative dissimilarities between the populations are no longer solely a reflection of how long ago these groups separated from their common ancestor. Because these assumptions may not always be correct, it is necessary to verify them against the fossil record. Steele and Powell (1992), and Neves and Pucciarelli (1989, 1991) have evaluated the evolutionary history of the American populations based upon the fossil record, and found the earlier populations to differ structurally from more recent indigenous populations of the Americas. The present study is an elaboration of Steele and Powell's (1992) study, comparing the craniofacial structure of the earliest recovered North American and Northern Asian samples with more recent samples from Eurasia and the Pacific rim region.

MATERIALS AND METHODS

The emphasis in this paper is a morphometric evaluation of the craniofacial dimensions of the earliest human remains recovered from North America. Skeletal remains from 16 sites are currently considered by us to be verifiably the oldest North American remains (Steele and

Table 1. Probable and Affirmed Paleoindian Specimens in North America. (Those above the line used in this study.)

LOCALITY	N	REMAINS	DATES (YR B.P.)
Whitewater Draw, AZ (1)	2	skeletons	8,000–10,000
Gordon Creek, CO (2)	1	skeleton	9,700 ± 250
Browns Valley, MN (3)	1	skeleton	8,700 ± 110
Pelican Rapids, MN (4)	1	skeleton	—
Sauk Valley, MN (5)	1	skeleton	—
Wilson-Leonard, TX (6)	1	skeleton	9,000–11,000
Horn Shelter, TX (7)	2	skeletons	9,000–10,000
Shifting Sands, TX (8)	1	T fragments	—
Arlington Springs, CA (9)	12	femora	10,000 ± 310
La Brea, CA (10)	1	skeleton	9,000 ± 80
Mostin, CA (11)	1	fragments	10,000–11,000
Marmes, WA (12)	3	C fragments	10,000–11,000
Fishbone Cave, NV (13)	1	PC fragments	10,900–11,200
Anzick (Wilsal), MT (14)	2	C fragments	8,620–10,500
Vero Beach, FL (15)	1	C fragments	—
Warm Mineral Springs, FL (16)	1	PC fragments	10,260 ± 190

C = cranial, PC = post cranial, T = tooth.

(1) Waters 1986
(2) Breternitz et al. 1971
(3) Jenks 1937
(4) Jenks 1936
(5) Jenks and Wilford 1938
(6) Steele 1989; Weir 1985
(7) Young 1986, 1988
(8) Owsley, personal communication
(9) Orr 1962
(10) Berger 1975, Kroeber 1962
(11) Kaufman 1980, Taylor et al. 1985
(12) Fryxell et al. 1968
(13) Orr 1956, 1974
(14) Taylor 1969; Stafford et al. 1987
(15) Stewart 1946
(16) Clausen et al. 1975.

Powell, 1992), and are identified as Paleoindians (Table 1). Following a variety of scholars (Roberts 1940; Steele and Powell 1992; Young 1985, 1986, 1988, Young et al. 1987) we are using the term "Paleoindian" to refer to the oldest known inhabitants of the Americas, rather than using the term to refer to a distinct subsistence economy based on hunting now-extinct megafauna (Griffin 1979; Shafer 1977, Suhm et al. 1954).

Because the sites are so widely scattered within North America, and because the associated artifacts at some sites indicate different subsistence patterns, we do not presume that these individuals represent a single lifestyle. As examples, Horn Shelter (Redder 1985) and Whitewater Draw (Sayles and Antevs 1941; Sayles 1983; Waters 1985, 1986) are associated with a generalized hunting and gathering mode of subsistence, and Anzick (Taylor 1969) and Shifting Sands (Daniel S. Amick, personal communication), appear to have been associated with big-game hunting economies. Similarly, we realize that these samples do not represent a single local breeding population. In fact, the analyzed material has been recovered from localities as disparate as the American Southwest and the upper Midwest. In spite of the geographical distribution of the sample, the combined Paleoindian sample which we are using has a range of variation for the individual measurements that does not differ significantly from the ranges present in larger and more recent comparative samples. Therefore, we believe that this assemblage of late Pleistocene/early Holocene human remains (Table 1) is collectively the best representation of the earliest Americans currently available.

We have not included skeletal remains more recent than 8,500 years B.P. in our Paleoindian sample, following Steele and Powell (1992), Young (1986, 1988), and Young et al. (1987). This date coincides with the last of the Great Plains fluted-point traditions and their derivatives, such as Firstview, Cody, Eden and Scottsbluff (Jennings 1983), but is more recent than the 10,000 B.P. date assigned for the Early Archaic east of the Mississippi (Fagan 1991; Jennings 1983). This overlap in time between the sites which we have identified as Paleoindian and eastern samples which have been identified as Archaic reflects the confusion created by using these terms to indicate either antiquity or adaptation type. It also is a reflection of the different times in various regions of the Americas when the megafauna became extinct or lost their significance as a resource base for humans.

The sample in Table 1 includes skeletal remains of 21 individuals from 16 sites. Remains from the first eight sites are the most securely dated, and represent the sample used in the morphometric analysis. This portion of the sample also represents the primary evidence used in the subjective assessment of the sample, although in some instances (as indicated in the discussion) the other specimens were also considered. In addition to the remains in Table 1 there are other sites which may ultimately prove to be of great antiquity, but for the present the age of these sites is not secure. For example the Midland specimen (Wendorf et al. 1955, Wendorf and Krieger 1959) was not included because of the wide range of dates which have been proposed for it, even though in all probability it is mid-Holocene or even older in age. Similarly, the Bonner Springs specimens were excluded because this channel bar assemblage, which includes mineralized remains, is currently undergoing evaluation (Dort and Martin 1988; Steele et al. 1991). Other specimens, previously considered to be of great antiquity, have been excluded because more recent assessments have failed to substantiate their antiquity (Cotter 1991; Taylor et al. 1985).

We conducted both a subjective assessment of the skeletal remains and metric analyses. The subjective analysis focuses on trying to determine if any characters indicative of an affinity with Old World Archaic *Homo sapiens* or *Homo erectus* are present in the Paleoindian assemblage. The metric analyses complement the subjective analysis and focus on a more detailed comparison of the Paleoindians with 33 male and 31 female late-Holocene human populations from North America, northern Asia, the southern Pacific and Australia, and Europe. Additionally, the Paleoindians were compared with the late Pleistocene/early Holocene material from the Jomon culture of Japan, the Minatogawa site on Okinawa Island, and the site of Upper Cave in China. The names, localities, and antiquity the sites as well as the published sources for the measurements used are presented in Table 2.

We used craniometric data to more objectively determine the relationship between Paleoindians and more recent human populations from Europe, Asia, and the Americas. Metric data offer the advantage of being easily standardized, relatively objective, and easy to analyze. In addition, metric data have been collected for virtually every living population and for many prehistoric groups. Cranial dimensions were recorded for each individual in the Paleoindian sample following the techniques described in Howells (1973). These data are presented in Table 3. Because of the fragmentary nature of the Paleoindian crania, only a limited number of cranial and facial dimensions were available for morphometric analysis. The dimensions used in this study included maximum cranial length (GOL), maximum cranial breadth (XCB), upper facial height (NPH), bizygomatic diameter (ZYB), nasal height (NLH), nasal breadth (NLB), orbital height (OBH), and orbital breadth (OBB). Falk and Corruccini (1982) found that five of these eight "traditional" dimensions were more useful in discriminating between modern human populations than less traditional basicranial and nonlinear measurements of the skull. In order to compare the Paleoindian cranial dimensions to those of modern human populations, we compiled the means for the eight cranial dimensions from published sources (Tables 4 and 5). These data form the basis of all univariate and multivariate analyses presented here.

Table 2: Age and Location of Populations used in Univariate Comparisons

POPULATION NAME	LOCATION	AGE	REFERENCE
European			
Armenian	Gagra and Akhalkalak, Armenia (CIS)	Modern	Abdushelishvili 1960
Berg	Carinthia, Austria	Modern	Howells 1973
Georgian	Rustavi, Georgia (CIS)	Modern	Abdushelishvili 1960
Lombards	Austria, Germany, Hungary, Italy	Medieval	Kiszely 1979
Norse	Oslo, Norway	Medieval	Howells 1973
Zalavar	Zalavar, Hungary	Medieval	Howells 1973
African			
Bushman	Kalahari Desert, South Africa	Modern	Howells 1973
Dogon	Bandiagara Plateau, Mali	Modern	Howells 1973
Egypt	Gizeh, Egypt	Prehistoric	Howells 1973
Teita	Teita, Kenya	Modern	Howells 1973
Zulu	Wits, South Africa	Modern	Howells 1973
Australian/Melanesian			
Andaman	Andaman Islands (South Pacific)	Modern	Howells 1973
Mokapu (Polynesian)	Oahu, Hawaii	Prehistoric-Modern	Howells 1973
South Australia	Lake Alexdrina, Australia	Modern	Howells 1973
Tasmania	Tasmania, Australia	Modern	Howells 1973
Tolai (Melanesian)	Ralûm, Papua New Guinea	Modern	Howells 1973
East Asian			
Buriats	Lake Baikal, Siberia, CIS	Modern	Howells 1973
Chinese (Peking)	Peking, China	Modern	Black 1928[a]
Chukchi	Chukchi Peninsula, CIS	Modern	Hrdlička 1944
Japanese (Kanto)	Japan	Modern	Morita 1950[a]
Jomon (Kanto)	Japan	Neolithic	Suzuki 1969[a]
Minatogawa	Naha City, Okinawa	Upper Pleistocene	Suzuki 1982
Ostiak	Little Ob River, CIS	Modern	Hrdlička 1944
Upper Cave	Zhoukoudien (Peking), China	Upper Pleistocene	Weidenreich 1938[a]
Native American			
Pre-Aleut	Aleutian Islands, Alaska	Prehistoric	Hrdlička 1944
Aleut	Aleutian Islands, Alaska	Modern	Hrdlička 1944
Arikara	Sully Site, South Dakota	Protohistoric	Howells 1973
Eskimo (Inugsuk)	Southeastern Greenland	Modern	Howells 1973
Indian Knoll	Ohio Co., western Kentucky	Prehistoric	Snow 1948
Northwest Coast	British Columbia, Canada	Modern	Hrdlička 1944
Pecos Pueblo	Northcentral New Mexico	Prehistoric	Hooton 1930
Peru	Huarochiri and Yauyos Provinces, Peru	Prehistoric	Howells 1973
Texas Archaic	Oso and Palm Harbor Sites, Texas	Prehistoric	Comuzzie et al. 1986; Woodbury & Woodbury 1935
Tennessee Archaic	4 middle and west Tennessee sites	Prehistoric	Boyd 1988
Tennessee Woodland	6 east Tennessee sites	Prehistoric	Boyd 1988
Tennessee Mississippian	6 middle and east Tennessee sites	Prehistoric	Boyd 1988

[a] As cited in Suzuki 1982

Modern: 300 yr B.P. to Present
Protohistoric: 450–150 yr B.P.
Prehistoric: 450–10,000 yr B.P.
Upper Pleistocene: 10,000–18,000 yr B.P.

Table 3: Cranial Dimensions of Female and Male Paleoindian Specimens

	FEMALES		MALES		
	Pelican Rapids[1]	Gordon Creek[2]	Browns Valley[3]	Sauk Valley	Horn Shelter[4]
Maximum Cranial Length	179	173*	193	186	187
Maximum Cranial Breadth	138	138*	142	137	140
Basion-bregma Height	127	—	142	138	—
Auricular Height	116*	100*	124*	—	138*
Minimum Frontal Breadth	93*	—	92*	—	95*
Basion-alveolar Length	(94)	—	—	—	—
Basion-nasion Length	102	—	—	102	—
Bizygomatic Breadth	127	—	140	135	—
Upper Facial Height	67*	57*	66*	—	—
Total Facial Height	114*	108*	110*	—	—
Nasal Height	47*	47*	51*	—	—
Nasal Breadth	21	—	24	28	24
Orbital Height	34*	29*	36*	—	—
Orbital Breadth	38*	37*	38*	—	—

( ) = estimated or reconstructed

*data drawn from original source; all other data recorded by authors

1 Jenks 1936

2 Breternitz et al. 1971

3 Jenks 1937

4 Young 1986

Univariate and bivariate examinations of the data were conducted to determine whether the Paleoindian sample differed significantly from more recent Holocene populations. *T*-tests for differences in mean craniofacial dimensions between the Paleoindian and other populations were conducted using Bonferroni's experimentwise alpha protection. The Bonferroni alpha protection for each variable was obtained by dividing the typical 0.05 level of significance by the number of pairwise *t*-tests conducted. In some cases, the sample size of either the Paleoindians or the comparative population was one. In these situations, a point *t*-test, which allows a single observation to be compared to a population, was performed (Sokal and Rohlf 1969). In addition to univariate tests of significance, selected data were plotted in bivariate scattergrams (Figures 1–3) showing the position of Paleoindians relative to other groups.

Multivariate analyses offer an advantage over univariate comparisons between populations because they can present a simultaneous picture of population relationships (Howells 1969). In most cases, we did not have access to the original data for the comparative samples. Distance measures typically used to display relationships among populations, such as Mahalanobis' generalized distance (Mahalanobis 1936), could not be computed without the covariation matrix of the original data. Rao (1952) and Penrose (1954) have suggested approximations of generalized distance, but these measures require the acceptance of assumptions which cannot be met by most anthropometric data.

We chose a principal components analysis (PCA) as an alternative to an analysis of the generalized distances between populations (Goodman 1972; Reyment et al. 1984). In the case of PCA, there is no *a priori* grouping of the data; in other words, the relationship between populations is not affected by their geographic proximity or other factors, and is strictly a proximity based on morphological similarity. Other researchers (Kamminga and Wright 1990; Neves and Pucciarelli 1991) have had success in analyzing vectors of population means with PCA to determine relationships between modern and fossil human populations. All statistics and plots for the principal components analysis were generated using the PROC PRIN procedure in SAS (SAS Institute, 1985).

One problem in assessing morphological similarities derived from metric data is the effect of similarities in size compared to similarities derived from shape alone. Some researchers have elected to eliminate size through log-scaling of the data (Reyment et al. 1984; Simmons et al. 1991) or by dividing each measurement by the geometric mean of variables in that case (Darroch and Mosimann 1985; Simmons et al. 1991). We have eliminated size effects by using a Q-mode correction of the data following Corruccini (1973) and Neves and Pucciarelli (1991).

Table 4: Male Means and T-test Results for Selected Craniometric Dimensions in Paleoindians, Prehistoric, and Modern Populations throughout the World[1].

POPULATION	CRANIAL LENGTH (GCL)	CRANIAL BREADTH (XCB)	BIZYGOMATIC BREADTH (ZYB)	UPPER FACIAL HEIGHT (NPH)	NASAL HEIGHT (NLH)	NASAL BREADTH (NLB)	ORBITAL HEIGHT (OBH)	ORBITAL BREADTH (OBB)
Paleoindian	188.67	139.67	137.50	66.00	51.00	25.33	36.00	38.00
Norse	188.47	141.87	134.44	68.93	51.96	25.42	33.74	40.38
Berg	180.32	147.61	135.55	67.89	51.71	25.46	33.75	40.14
Zalavar	185.22	141.39	133.06	68.50	51.41	25.37	32.65	39.98
Lombards	188.21	136.79	132.03	70.00	50.99	23.94	32.44	—
Georgians	175.50*	150.54*	135.44	70.59	52.71	24.57	34.17	42.03
Armenians	172.44*	144.23	133.27	73.50	54.11	25.41	34.70	42.11
Egypt	185.62	139.22	128.83*	68.43	51.74	24.83	32.95	39.50
Teita	183.88	129.85*	131.00	66.00	50.09	27.91	33.29	39.65
Dogon	177.85*	137.29	129.56*	64.85	47.83	28.35	33.79	39.71
Zulu	185.13	134.11	129.94*	67.33	50.00	28.65	33.76	40.44
Bushman	178.37*	133.58	123.56*	57.51	43.76	27.17	30.83	39.27
Andaman	167.81	135.38	123.69*	60.69	46.54	24.50	32.58	37.54
Tolai	183.53	130.36*	136.00	66.07	48.44	27.82	32.24	41.18
Mokapu	186.31	143.72	138.82	68.61	53.31	27.39	35.06	40.69
S. Australian	190.31	131.94*	136.77	64.77	49.69	27.88	33.46	41.86
Tasmanian	185.29	138.18	135.73	62.41	48.70	28.86	31.04	40.70
Upper Cave	206.00*	144.00	143.00	76.00	58.00	33.00	34.00	45.00
Chinese	178.50	138.20	132.70	75.30	55.30	25.00	35.50	44.00
Minatogawa	182.00	148.00	144.00	63.00	49.00	26.00	30.00	46.00
Jomon	181.90	144.10	144.60	66.00	49.60	27.10	33.00	43.20
Japanese	178.90	140.30	132.90	70.70	52.00	25.00	34.30	42.70
Buriat	181.83	154.96*	144.43	74.50	56.89	28.48	35.87	41.52
Chukchi	185.70	142.70	142.50	79.60	55.10	24.40	—	—
Ostiak	183.10	142.80	141.10	75.70	54.00	25.70	—	—
Pre-Aleut	186.90	142.60	144.10	76.40	52.80	25.60	36.20	39.70
Aleut	180.40*	150.80*	144.20	74.30	51.60	25.40	—	—
Eskimo	188.30	133.94	139.59	71.70	54.11	23.68	36.18	41.96
NW Coast	177.40*	144.00	142.80	76.00	51.90	24.50	36.00	—
Pecos Pueblo	175.74*	137.84	138.56	72.85	50.96	25.80	34.90	39.49
Arikara	179.48*	141.55	140.88	71.69	54.45	27.09	34.95	40.55
TX Archaic	185.00	130.80	142.00	—	—	25.00	34.00	41.00
Indian Knoll	178.80*	135.40	136.00	70.00	51.00	24.40	33.30	42.70
TN Archaic	179.08*	136.08	136.14	69.48	—	—	—	—
TN Woodland	173.83*	143.33	136.17	69.16	—	—	—	—
TN Missisippian	165.78*	147.83	139.71	73.57	—	—	—	—
Peru	177.96	*137.94	134.93	67.78	50.34	25.24	34.27	38.25

* Significant at $p= 0.05$ using Bonferroni's alpha protection.

[1] T-test for upper facial height, nasal height, nasal breadth, orbital height, and orbital breadth were conducted using a point t-test for comparison of a single Paleoindian observation to a population mean (Sokal and Rohlf 1969:224). All other tests utilzed a standard Student's t. Sample sizes and standard deviations available upon request.

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Table 5: Female Means and T-test Results for Selected Craniometric Dimensions in Paleoindians, Prehistoric, and Modern Populations throughout the World[1].

POPULATION	CRANIAL LENGTH (GOL)	CRANIAL BREADTH (XCB)	BIZYGOMATIC BREADTH (ZYB)	UPPER FACIAL HEIGHT (NPH)	NASAL HEIGHT (NLH)	NASAL BREADTH (NLB)	ORBITAL HEIGHT (OBH)	ORBITAL BREADTH (OBB)
Paleoindian	176.00	138.00	127.00	62.00	47.00	21.00	31.50	37.50
Norse	179.93	136.29	124.44	64.25	49.16	24.18	33.22	39.20
Berg	170.53	140.36	126.38	63.49	48.23	24.89	32.75	38.38
Zalavar	176.44	136.89	125.44	63.18	48.49	24.67	32.09	38.67
Lombards	179.88	136.95	126.56	67.80	48.45	23.12	32.57	—
Georgians	167.81	139.62	124.93	64.28	48.41	23.68	32.68	40.09
Armenians	166.19*	140.92	124.30	69.06*	51.02	24.00	34.09	40.52
Egypt	175.58	135.57	120.06	64.06	48.96	24.02	32.83	37.87
Teita	174.61	126.37*	124.14	60.98	46.43	27.18	32.18	37.75
Dogon	169.83	132.21	121.09	61.43	46.09	27.70*	32.75	38.07
Zulu	179.38	131.91	122.89	63.40	47.34	27.98*	32.91	39.25
Bushman	171.71	128.37*	116.53	56.12	42.86	25.92	30.96	37.67
Andaman	160.61*	131.61	118.18	56.68	43.79	24.07	32.39	36.61
Tolai	174.74	128.11*	126.40	62.80	46.65	26.67	32.29	39.07
Mokapu	175.39	138.67	126.88	63.75	49.39	26.02	34.12	39.43
S Australian	181.10	127.51	125.78	61.14	46.51	26.24	33.10	39.96
Tasmanian	177.90	133.02	125.62	58.36	45.36	27.64*	30.74	39.59
Upper Cave[2]	190.00	133.50	134.00	68.75	48.75	25.75	30.15	42.95
Minatogawa[2]	171.00*	136.00	136.00	58.00	46.00	24.00	—	31.00
Buriat	171.82	148.42*	134.45	69.45	53.42*	26.82	34.91	39.78
Chukchi	177.50	136.80	132.00	73.90*	51.00	23.80	35.70*	39.00
Osnak	174.10	139.60	131.10	69.90*	50.60	24.90	34.50	37.90
Pre-Aleut	178.80	138.20	133.5	71.40*	49.50	24.40	35.10	38.70
Aleut	171.90	144.20	133.80	70.20*	49.20	24.20	35.40	38.60
Eskimo	180.81	131.02	130.17	67.06	50.39	23.31	35.13	40.46
NW Coast	170.10	138.50	131.20	68.90	49.60	24.00	35.30	37.70
Pecos Pueblo	163.65*	138.04	129.87	69.04*	48.20	25.33	34.49	38.14
Arikara	171.11	136.48	130.67	67.63	50.52	25.81	34.63	39.22
TX Archaic	181.50	130.00	—	57.00	—	25.00	38.00	—
Indian Knoll	172.10	131.50	127.40	65.40	47.60	23.80	32.80	40.40
TN Archaic	176.29	135.10	—	64.44	—	—	—	—
TN Woodland	163.00	143.00	—	67.80	—	—	—	—
TN Missisippian	159.35*	144.92	—	70.82*	—	—	—	—
Peru	169.00	134.93	125.60	63.65	47.65	23.96	34.14	36.82

*Significant at $p = 0.05$ using Bonferroni's alpha protection.

[1] T-test for upper facial height, nasal height, nasal breadth, orbital height, and orbital breadth were conducted using a point t-test for comparison of a single Paleoindian observation to a population mean (Sokal and Rohlf 1969:224). All other tests utilized a standard Student's t. Sample sizes and standard deviations available upon request.

[2] Single individual compared to the Paleoindian sample using a point t-test (Sokal and Rohlf 1969:224).

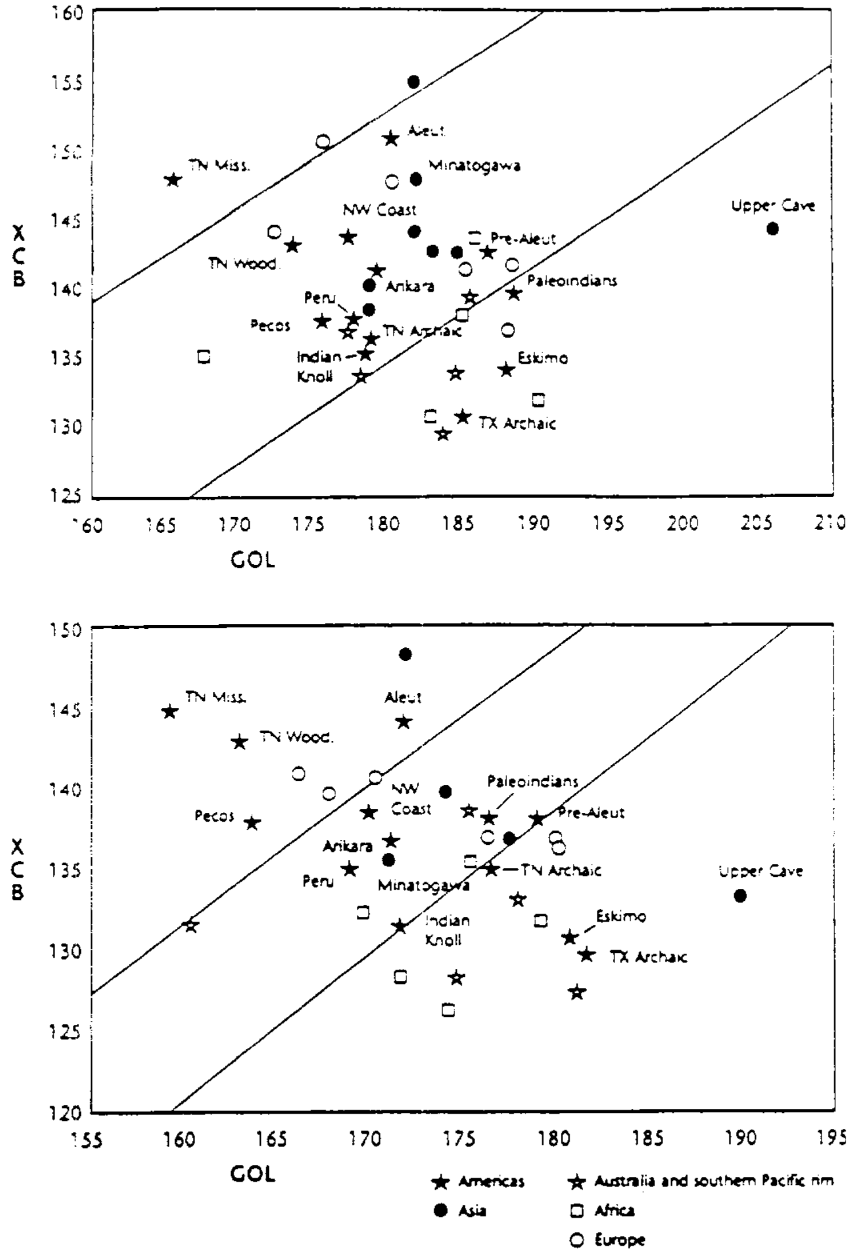

Figure 1. Plot of mean cranial length (GOL) vs. mean cranial breadth (XCB) for males (upper portion) and females (lower portion) in modern and prehistoric world populations. Lines (top to bottom) separate brachycranic, mesocranic, and dolicocranic groups.

The Q-mode correction involves dividing each measurement in a case by the arithmetic average across all measurements for that particular case. This type of correction is similar to that of Darroch and Mosimann (1985), but uses the arithmetic average rather than the geometric mean. The Q-mode correction eliminates size differences by giving each population "the same average character state or magnitude over all the measurements taken on it" (Corruccini 1973:747).

The results of the PCA for the uncorrected vector of population means (i.e., size-and-shape data) are presented in Figures 4 and 5, and in Tables 6 and 7. The Q-mode corrected PCA (i.e., shape only), presented in Figures 6 and 7 and Tables 8 and 9, can be contrasted with the size-and-shape results to determine the effects of size on relationships between the populations examined.

We also analyzed the population means using a canonical discriminant function analysis generated by PROC CANDISC in SAS (SAS Institute, 1985). Each population was assigned to one of five major geographic

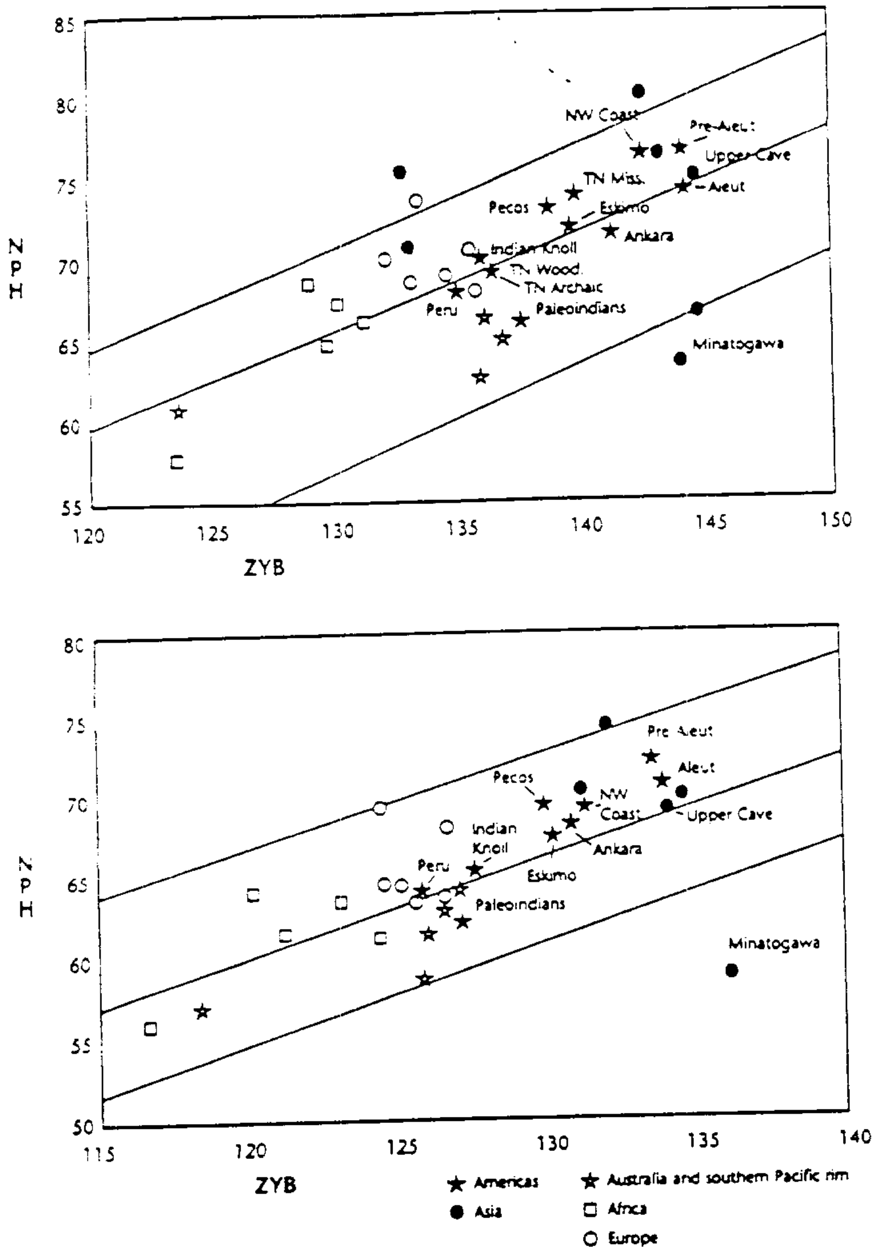

Figure 2. Plot of mean bizygomatic breadth (ZYB) vs. mean upper facial height (NPH) for males (upper) and females (lower) in modern and prehistoric world populations. Lines (top to bottom) separate leptene, mesene, Euryene, and hypereuryene.

groups based on a presumably common cultural and biological history: Europeans, northeast Asians, southern Pacific populations (including Australians, Tasmanians, and Melanesians), and American Indians. These *a priori* classes were entered into the canonical discriminant analysis, where the algorithm attempts to best summarize the differences between classes and partition them through a linear combination of the variables. The Paleoindian, Upper Cave, Minatogawa, and Jomon populations were not assigned to a particular geographic group, so that their positions among the classes could be better assessed. The results of this analysis are presented in Figures 8 and 9 and Table 10.

RESULTS

Because the model depicting the makers of Clovis projectile points as the first colonizers of the Americas is not universally accepted (Carter 1978; Gruhn 1987; Simpson

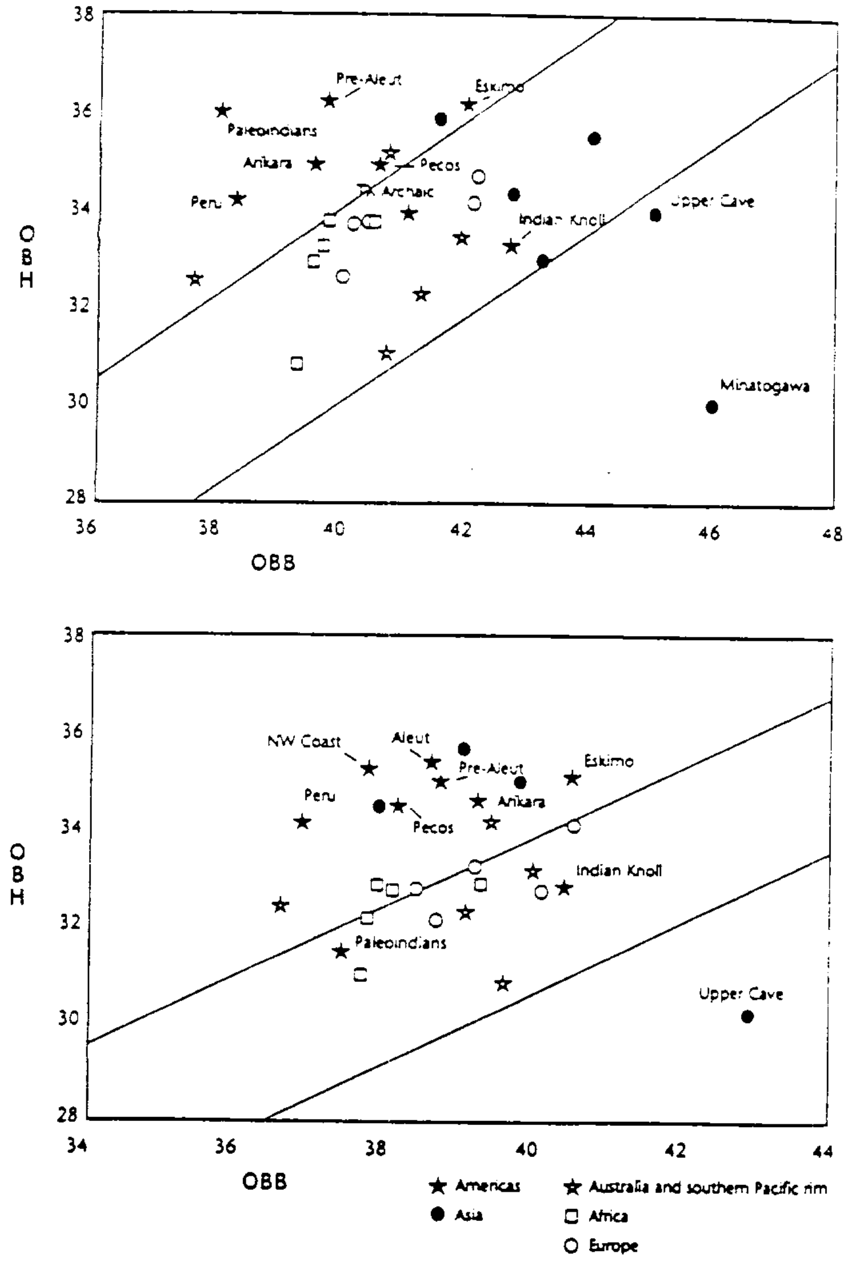

Figure 3. Plot of mean orbital breadth (OBB) vs. mean orbital height (OBH) for males (upper) and females (lower) in modern and prehistoric world populations. Lines (top to bottom) separate hypsiconch, mesoconch, and chamaeconch groups.

1978; Simpson et al. 1986), proposed early human remains are typically examined for "primitive" features which would link them to earlier human populations such as *Homo erectus* or archaic forms of *Homo sapiens* (Givens 1968a,b; Bryan 1978; Davis et al. 1980). Primitive features usually considered diagnostic of earlier populations are massive and protruding browridges, a low rising frontal, marked postorbital constriction of the frontal, thick cranial elements, a prominent and protruding occipital, small mastoid processes, and a massive face.

Of the Paleoindians specimens listed in Table 1, the Browns Valley, Gordon Creek, Horn Shelter, La Brea, Pelican Rapids, Sauk Valley, Whitewater Draw, and Wilson-Leonard remains are represented by cranic complete enough to evaluate one or more of the primitive features. Browns Valley, Sauk Valley and the Horn Shelter adult are the most robust, and all three are considered to be male based on the features of the *os coxae* and the robustness of the skeleton. Gordon Creek, Pelican Rapids, La Brea, and Wilson-Leonard are considered adolescent or

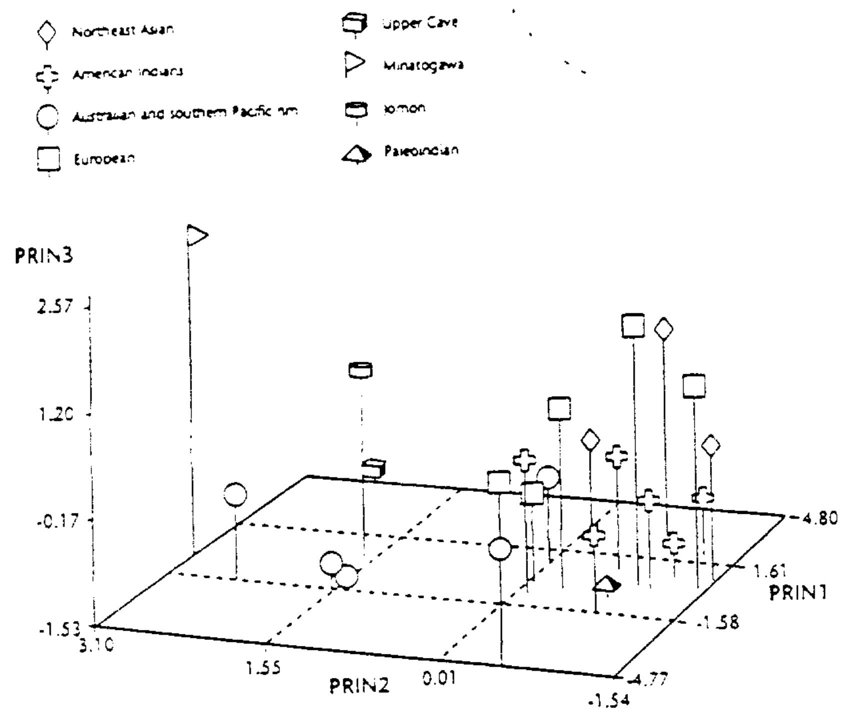

Figure 4. Principal Component Analysis of size and shape data for males showing the first, second, and third principal components.

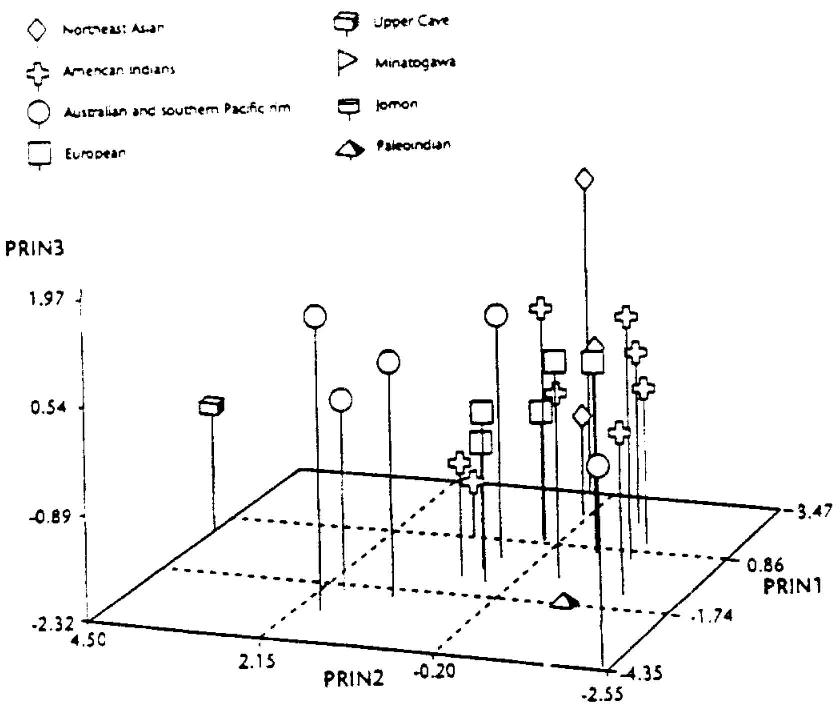

Figure 5. Principal Component Analysis of size and shape data for females showing the first, second, and third principal components.

adult females and are distinguished by their gracile skeleton. The browridges of Browns Valley and Sauk Valley have been characterized as robust and prominent (Jenks 1936, Jenks and Wilford 1938, Smith 1976), but in both of these specimens it is the supracilliary arches near glabella which are prominent (here we follow the browridge terminology established by Schwalbe 1909, as cited in Russell 1985). In contrast, the supraorbital sulcus is present in both specimens and the lateral extension of the supraorbital arches are reduced. This browridge configuration is typical of robust anatomically modern male crania. The Horn Shelter male differs from these two only in its slightly more prominent development of the supraorbital arch. In the Horn Shelter male, the lateral aspect of the supraorbital arch approximates the size of the arch seen in Middle and Upper Paleolithic specimens such as the Middle Paleolithic Skhul V, Israel, and the Upper Paleolithic Predmost 3, Czechoslovakia (Day 1986). Although uncommon, we have also seen supraorbital arches this prominent in Late Archaic and Late Prehistoric specimens from the Texas coast, and in other anatomically modern assemblages.

None of the Paleoindian specimens exhibit particularly thick frontals, parietals or occipitals indicative of archaic *Homo* populations. The Sulphur Springs Woman I (Sayles and Antevs 1941) has notably thick parietal elements near the sagittal suture, but upon examination, this thickness is due to an expansion of the diploë with concomitant reduction of the cortical bone, a pattern that suggests the presence of porotic hyperostosis. An examination of the Paleoindian specimens in *norma lateralis* also confirms that the general height of the braincase, the development of the frontal expansion, and the prominence of the occipital protuberance are well within the range of variation of anatomically modern humans, and does not provide evidence for an archaic *Homo* linkage.

The bivariate plots of eight measurements of the braincase (cranial length and breadth) and face (bizygomatic breadth, upper facial height, nasal height and breadth, orbital height and breadth) were used to evaluate the

Table 6: Eigenvalues and Eigenvectors for the First Four Principal Components Using Male Data for Size and Shape.

	COMPONENT I	COMPONENT II	COMPONENT III	COMPONENT IV
Eigenvectors				
GOL	0.32604	0.34876	-0.50657	0.05489
XCB	0.27958	-0.03302	0.67064	0.51308
ZYB	0.39590	0.22737	0.09055	0.30035
NPH	0.43065	-0.36316	-0.02930	-0.26264
NLH	0.49337	-0.22759	0.00117	-0.13806
OBH	0.26983	-0.56044	-0.27832	0.10458
OBB	0.27071	0.34015	0.37800	-0.70460
NLB	0.28952	0.46054	-0.25342	0.21929
Cumulative Eigenvalues:	3.31918	1.92560	1.09902	0.71837
% of Variance:	0.41490	0.65560	0.79297	0.88277

Table 7: Eigenvalues and Eigenvectors for the First Four Principal Components Using Female Data for Size and Shape.

	COMPONENT I	COMPONENT II	COMPONENT III	COMPONENT IV
Eigenvectors				
GOL	0.06214	0.58662	-0.34700	0.12826
XCB	0.36045	-0.25992	0.24775	-0.66163
ZYB	0.45140	0.21475	-0.03007	0.19284
NPH	0.50236	0.02326	-0.14410	0.13017
NLH	0.49695	0.02989	0.04821	-0.17099
OBH	0.38875	-0.31248	0.03625	0.52931
OBB	0.10752	0.57813	-0.01065	-0.34949
NLB	-0.02097	0.32997	0.89039	0.24519
Cumulative Eigenvalues:	3.49486	2.10726	0.91528	0.63651
% of Variance:	0.43686	0.70026	0.81467	0.89424

cranial structure of Paleoindians compared to a selection of anatomically modern human populations. Cranial length and breadth can be used to describe the overall shape of the braincase. The male Paleoindian sample has one of the longest cranial lengths of the 36 samples evaluated (Table 4). Of these 36, only six average 188.0 mm or more, and only two of the samples, South Australians and Upper Cave, exceed the Paleoindian mean of 188.67. Thirteen of the 36 samples possess cranial lengths significantly shorter than those of the Paleoindian males, eight of which are American Indian populations. Nineteen of the 36 samples exceed the Paleoindian sample in cranial breadth, and four of these are significantly broader. The relationship between cranial length and breadth is traditionally presented as the Cranial Index or in a bivariate plot (upper portion, Figure 1). Considering both dimensions simultaneously, the Paleoindians were one of only 10 male samples which are identified as dolichocranic (long-headed). The female Paleoindian sample, on the other hand, is not as long-headed relative to the other female samples, nor as narrow. Even though the female Paleoindians are among the larger of the female samples (mean cranial length = 176.00 mm), 12 of the 33 modern female populations exceed the Paleoindian mean for cranial length. None of these 12, however, are significantly larger; in fact, five female samples are significantly shorter than Paleoindians. In cranial breadth, the Paleoindian females are again among the larger samples (mean cranial breadth = 138.00 mm). Twelve have a greater cranial breadth and one is significantly broader. Three of the 33 samples that have a narrower cranial breadth are significantly smaller. When cranial length and breadth are plotted for the females (lower portion, Figure 1), the female Paleoindian sample is more typical

Table 8: Eigenvalues and Eigenvectors for the First Four Principal Components Using Q-mode Corrected Male Data for Shape Only.

	COMPONENT I	COMPONENT II	COMPONENT III	COMPONENT IV
Eigenvectors				
GOL	-0.34082	0.53975	-0.10066	-0.02548
XCB	0.08922	-0.64265	0.00491	-0.52723
ZYB	-0.28302	-0.27582	-0.45899	0.47804
NPH	0.48987	0.13656	0.12877	0.26803
NLH	0.47608	0.17835	0.32778	-0.05342
OBH	0.42963	0.16579	-0.44034	0.07273
OBB	-0.16648	-0.23854	0.62546	0.52911
NLB	-0.34184	0.29111	0.26465	-0.36456
Cumulative Eigenvalues:	3.11201	1.69382	1.22250	0.95492
% of Variance.	0.38900	0.60073	0.75354	0.87291

Table 9: Eigenvalues and Eigenvectors for the First Four Principal Components Using Q-mode Corrected Female Data for Shape Only.

	COMPONENT I	COMPONENT II	COMPONENT III	COMPONENT IV
Eigenvectors				
GOL	-0.47486	-0.15067	-0.20776	-0.20043
XCB	0.28024	0.51112	0.36498	-0.41138
ZYB	0.10497	-0.67942	0.39145	0.02879
NPH	0.39884	-0.34262	-0.34306	0.20263
NLH	0.38847	0.25861	-0.41720	0.27684
OBH	0.38930	0.03657	0.15341	0.33980
OBB	-0.38796	0.18100	-0.33542	0.31025
NLB	-0.27000	0.18995	0.49254	0.67848
Cumulative Eigenvalues:	3.43595	1.49556	1.11126	0.81009
% of Variance:	0.42949	0.61644	0.75535	0.85661

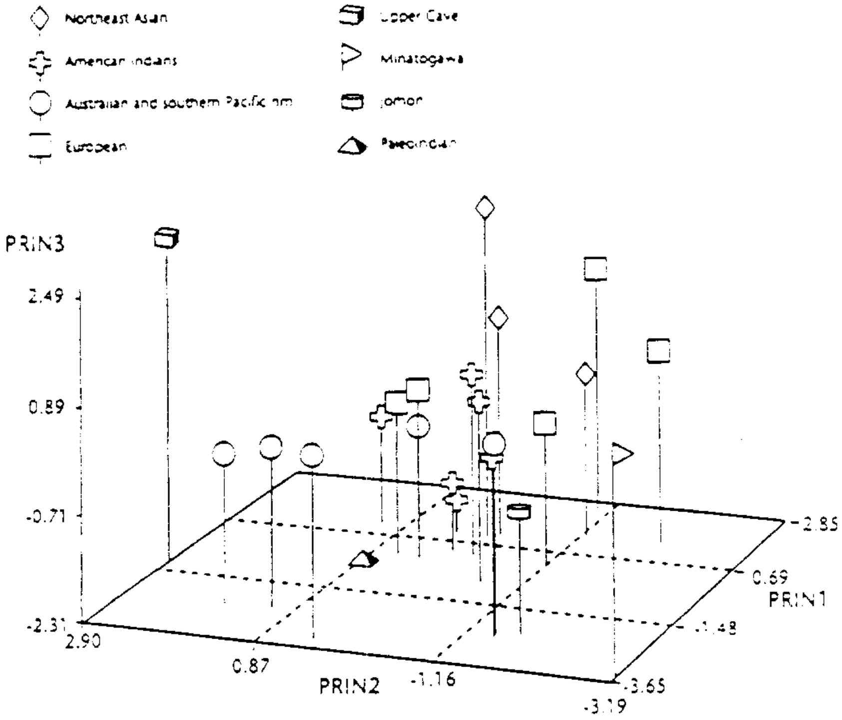

Figure 6. Principal Component Analysis of size-corrected data for males showing the first, second, and third principal components.

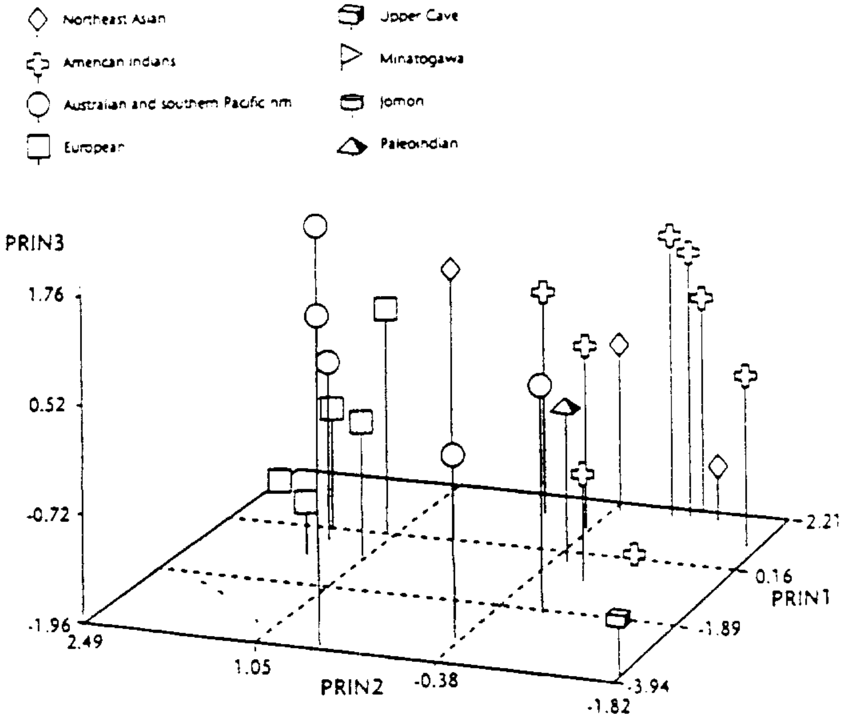

Figure 7. Principal Component Analysis of size-corrected data for females showing the first, second, and third principal components.

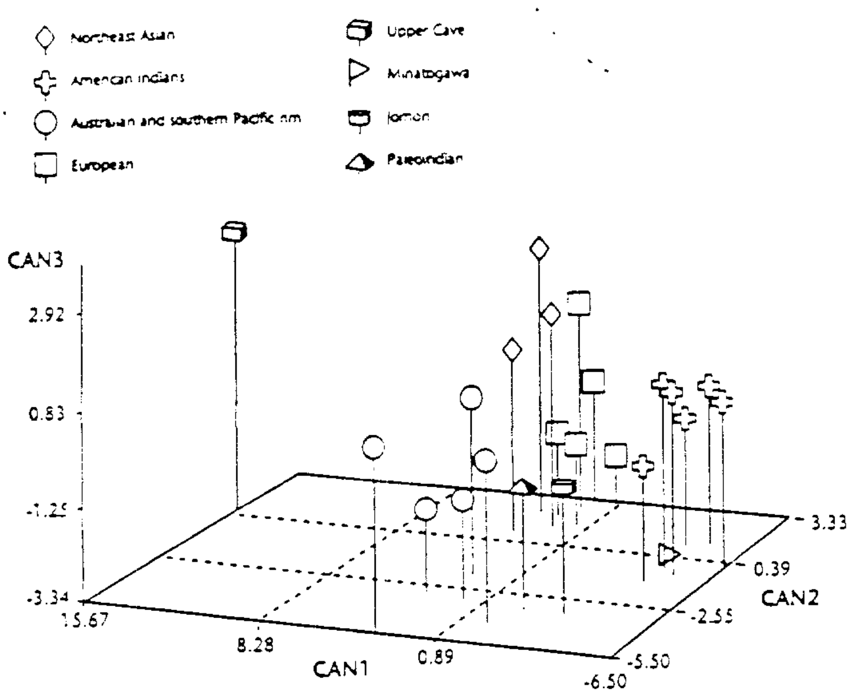

Figure 8. Canonical Discriminant Function Analysis of size and shape data for males showing the first, second, and third variates.

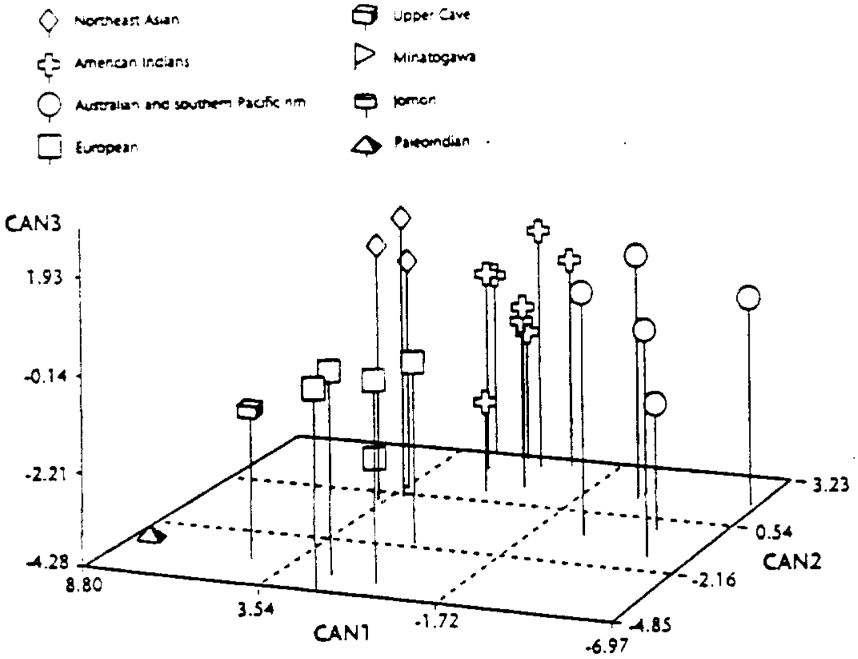

Figure 9. Canonical Discriminant Function Analysis of size and shape data for females showing the first, second, and third variates.

Table 10: Canonical Discriminant Analysis of Male and Female Craniometric Data.

	MALE			FEMALE		
	Canonical Axis I	Canonical Axis II	Canonical Axis III	Canonical Axis I	Canonical Axis II	Canonical Axis III
Variable						
GOL	-0.0384	-0.2072	-0.0628	-0.1192	0.0438	0.1305
XCB	0.0895	0.7795	-0.2081	0.5493	-0.5730	0.2977
ZYB	0.6818	0.2311	-0.0308	0.8612	-0.0009	0.2890
NPH	0.4751	0.6561	0.4456	0.7539	-0.3087	0.4851
NLH	0.3529	0.6946	0.1616	0.6313	-0.4977	0.3323
OBH	0.4739	0.4380	0.5025	0.7702	-0.0141	0.4564
OBB	0.0803	0.5516	-0.1101	0.1880	-0.2170	-0.3626
NLB	-0.4327	-0.4530	-0.1429	-0.5846	0.3229	0.2390
Eigenvalue:	10.6377	2.9819	0.5534	9.7883	1.8753	0.9761
% Variance. (Cumulative)	0.7389	0.9332	0.9711	0.7646	0.9111	0.9873

of other populations and falls within the mesocranic range.

While the bivariate analysis of cranial length and breadth documents relatively similar positions for males and females of the same population, five populations (in addition to the Paleoindians) exhibit marked sexual dimorphism in cranial shape. Three of these populations are American Indian (Tennessee Woodland, Aleut, and Pecos Pueblo) and two are European (Lombard and Georgian). Of the five populations that show sexual dimorphism in cranial shape, only two (Tennessee Woodland and Pecos Pueblo) also exhibit sexual dimorphism in cranial length.

Six measurements were used to describe the shape of the face: facial height and breadth, nasal height and breadth, and orbit height and breadth. When we consider all populations tested, both the male and the female Paleoindians have a relatively broad face, their facial breadth being exceeded by only 15 of 36 male and 12 of 29 female populations. Of these, five of the male samples have significantly narrower faces, while none of the females populations differ significantly. A different perspective is obtained when comparing Paleoindians to northern Asians and American Indians. While not significantly different, the majority of the modern northern Asian and American Indian populations have a broader face.

In contrast, the upper facial height of Paleoindians compared to all populations is shorter than 29 of the male samples and 25 of the female samples, with five of the female samples being significantly longer. When considering just northern Asian and American Indian populations, all of the American Indian populations exhibit longer faces, while the faces of northern Asian populations are approximately the same height. What is particularly noteworthy is that of the five female samples which exhibit significantly longer faces, two of them are North American Indians, and two are modern northern Asian populations. When facial length and breadth are considered simultaneously (Figure 2), however, the relatively short and broad euryene face of the Paleoindian face is apparent. Only four of the male and two of the female populations have relatively broader faces. Considering the relative effects of upper facial height and bizygomatic breadth in determining facial shape, it is apparent that the marked shorter face of the Paleoindians contributes to the euryene (broad) upper facial index.

Examination of the nasal dimensions reveals that the Paleoindians have relatively short and narrow nasal apertures, but only three female samples (Dogon, Zulu, and Tasmania) have significantly broader nasal apertures than the Paleoindians. While not differing significantly, the majority of the northern Asians and American Indians have longer and broader nasal apertures.

Orbit dimensions exhibit a different pattern (Figure 3). The American Indian populations consistently exhibit high orbits, but orbit width is not as diagnostic. The Paleoindian males follow this pattern, exhibiting one of the largest means for orbit height. Paleoindian females, however, do no follow this trend, having one of the smallest orbit heights. Both Paleoindian males and females exhibit narrower orbits than all but a few samples, but there is no clear pattern of orbit breadth in any of the geographical regions.

We have used univariate and bivariate analyses to support the distinctiveness of specific structural features of Paleoindians. To statistically summarize the relationship of the Paleoindians to the other populations using all measurements simultaneously we have used two principal components analyses and one canonical discriminant analysis. The principal-components analysis of the uncorrected size-and-shape data (Tables 6 and 7, and Figures 4 and 5) aligns both the male and female

Paleoindians with the American Indians and northern Asians on the basis of the first two principal components, but separates them slightly along the third component. No discernible relationship among the fossil samples (Paleoindian, Jomon, Upper cave and Minatogawa) can be seen in this analysis. The first three components account for 79.29% and 81.86% of the variance seen in the male and female samples, respectively.

When the data are corrected following Corruccini (1973) so that PCA distinguishes populations on the basis of shape alone, the Paleoindian male sample aligns between the American Indians and southern Pacific populations, and away from modern northern Asians (Tables 8 and 9, Figures 6 and 7). The female Paleoindian sample follows this same pattern, with the American Indian and northern Asian samples forming a loose group along the second component. The fossil samples, while still widely dispersed on the basis of the second and third principal components, are aligned more with the southern Pacific and European samples, rather than with American Indians and northern Asians. For the shape data, the first three principal components account for 75.35% and 75.54% of the male and female variance, respectively.

When the canonical discriminant analysis is examined (Table 10, Figures 8 and 9), the Paleoindian males are separated from the American Indians and move towards southern Pacific and Australian groups. However, the pattern for female samples is more dispersed, with Paleoindians somewhat isolated, but closer to the European populations than with any other group. When the fossil samples are considered, the close similarity of Paleoindians and Jomon is apparent in the males (Figure 8). For Paleoindian females, the closest fossil assemblage is the Upper Cave sample.

DISCUSSION

As noted above, the subjective analysis clearly aligns the 8,500–10,000 year B.P. sample of Paleoindian remains with anatomically modern humans, and there is no anatomical evidence of a morphological linkage to an earlier, isolated Archaic American *Homo* population. If we assume that similarities in craniofacial morphology to some degree reflect genetic relationships between populations, rather than parallel evolution in craniofacial shape, we can make some interpretive statements about the results presented above. Our data suggest that the Paleoindian samples, which currently represent the oldest North American human remains, are genetically derived from the anatomically modern human population which evolved in the Old World before colonizing the Americas. This viewpoint is held by most, if not all, physical anthropologists who have examined the American fossil record (Hrdlička 1923, 1937; Neumann 1956; Protsch 1978; Smith 1976; Steele and Powell 1992; Stewart 1960, 1981; Young 1986, 1988).

The above statement, however, does not preclude the possibility that the North American Paleoindian population differs from later Holocene populations in both the Americas and other populations along the Pacific rim. One of the longest-held views concerning the peopling of the Americas is that the earliest populations entering from the Bering Strait region differed from more recent northern Asian and American Indian populations in several respects. Typically, these early peoples, while still falling within the range of anatomically modern populations, were characterized as dolichocranic (long-headed) with a low rising frontal and commonly with a prominent occipital protuberance.

Dixon (1923), one of the first researchers to describe this suite of features for the first colonizers, proposed that by more recent times these populations had been replaced in the central portions of the Americas by later-arriving brachycranic populations with more typical mongoloid features. This hypothesis is remarkably similar to models of ancestor displacement derived from vicariance biogeography (Rosen 1978). Other researchers expressing this view include Birdsell (1951), Hooton (1930, 1953), Hrdlička (1923), Newman (1962), Rivet (1925), and Stewart (1949, 1973). Neumann (1952), one of the few physical anthropologists to attempt a comprehensive summarization of the structural variation of North American Indians, identified the remnants of these early populations as the "Otamid variety." He based his description of the variety on a Texas central coastal sample of 18 specimens, and identified the Browns Valley Paleoindian male as an early example of an "Otamid." Neumann felt that these "Otamid" descendants of the earliest colonizers were relict populations restricted to marginal environments.

Since both European and southern Pacific populations have a more long-headed cranial shape, many researchers have proposed that these populations were possibly more closely related to Paleoindians by a common ancestor. Neves and Pucciarelli (1991), Neumann (1962), Protsch (1978), and Stringer and Andrews (1988) have all proposed that the Asian ancestors to the American Indians lacked the markedly broad face and cranium associated with modern northern Asians, and in this respect were more European or southern Asian in appearance. Generally, those espousing this view have identified the Asian ancestor as "proto-mongoloid," "archaic-mongoloid," "proto-caucasoid," or "pre-mongoloid" (Kamminga and Wright 1990; Neves and Pucciarelli 1991, Neumann 1962, Protsch 1978). Typically, the Upper Cave male is used as an Asian fossil example of such a dolichocranic ancestor to the American Indians (Kamminga and Wright 1990; Neves and Pucciarelli 1989, 1991; Neumann 1956).

In general, our results and those published elsewhere (Steele and Powell 1992) substantiate the distinctiveness of the Paleoindians. In many of the univariate analyses presented, the Paleoindians are found to fall at one extreme end of the American Indian range, away from northern Asians and nearer to southern Asians and Europeans. The features distinguishing the Paleoindians from the more recent American Indians are the narrower and longer braincase and the smaller and slightly narrower face and nasal aperture. The multivariate morphometric pattern that emerges is one where later Holocene northern Asians, and to a slightly lesser extent the American Indians, fall on one extreme in a suite of craniofacial features, while southern Pacific and European populations fall on the other. Paleoindians, when they differ from more recent American Indians, fall between these two extremes. These assessments are summarized in the principal components analyses and are most markedly illustrated in the canonical discriminant analysis. This more central position of the earliest North American populations among those of the Pacific rim also has been confirmed for early South American populations (Neves and Pucciarelli 1989, 1991).

Turner and colleagues (Greenberg et al. 1986; Turner 1971, 1983a,b, 1985a,b, 1986a,b, 1987; Turner and Bird 1981) have provided the most comprehensive evaluation of the peopling of the Americas, their views being based principally upon dental similarities of populations. Their data, particularly Turner (1985b), verify the distinctiveness of Paleoindians from more recent American Indians and northern Asians.

While there seems to be a long historical record of the recognition of the distinctiveness of the earliest American populations from later populations in the New World, and an apparent consensus among recent scholars on the more moderate structural features of the Paleoindians, we are still cautious in modeling universal American trends towards the simultaneous brachycephalization of the braincase and enlargement of the face in all American populations. In our analyzed sample, two temporal sequences within specific regions permit us to evaluate these changes in late-Holocene North American populations: the Tennessee populations examined by Boyd (1988) and the pre-Aleut and Aleut samples reported by Hrdlička (1944). While both of these sequences depict a consistent increase in the relative width of the braincase through time, the Tennessee samples as reported by Boyd (1988) exhibit a slight reduction in the face over time.

The last point we would like to make concerns the relationship of the Paleoindian sample to the other early Holocene/Late Pleistocene samples of the Pacific rim. As mentioned previously, the Paleoindian population is commonly considered similar to the Upper Cave remains from northern Asia. Further, these latter remains are commonly considered evidence of the presence of a population in China which lacks the typical broad features of later norther Asians (Kamminga and Wright 1990). While this view can be held when considering individual features, the Upper Cave remains (both male and female) appear as aberrant outliers in all of our multivariate analyses. An examination of the two Principal Components analyses reveals that the fossil remains of the Paleoindians, the Upper Cave specimens, and the Jomon sample from Japan are all aligned with southern Pacific and Australian populations on the basis of the first principal component. However, the second and third principal components of each analysis tend to separate these fossil groups from one another. Considering the univariate analyses and the eigenvectors presented in Tables 6–9, it is apparent that in part these components are being influenced by the dolichocranic shape of the braincase. In the canonical discriminant analysis the alignment of Paleoindians with Jomon is apparent in the males, as is the uniqueness of the Upper Cave male. We also feel that it is important to recognize that while the fossil samples differ from one another to a lesser or greater degree, they all differ to a marked degree from modern northern Asians.

In conclusion, we believe that our analysis provides the most careful consideration of the Paleoindian remains to date, and that this analysis supports the distinctiveness of the Paleoindian sample from the more recent Holocene American Indians. Our analysis also supports the previous work describing the structural similarities between Paleoindians, and southern Pacific and European populations. At the present time, it is our opinion that the late Pleistocene and early Holocene populations of northern Asia and the Americas differed morphologically, but we are unsure of the cause of these differences. One view is that these differences substantiate that the earliest colonizing populations entering Beringia had a different genetic structure than later northern Asians and their North and South American descendants. The second view is that these differences reflect an adaptation of later populations to a different environment or lifestyle, possibly associated with the origins of agriculture, and that these adaptations were accomplished by the general plasticity of a common genome. At the present time we cannot resolve this last issue.

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