

# **PALEOAMERICAN ORIGINS: Beyond Clovis**

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# Circumpacific Populations and the Peopling of the New World: Evidence from Cranial Morphometrics

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## Abstract

The peopling of the New World is now considered to have been a more complicated process than previously imagined. Instead of or in addition to the Bering land bridge route, early populations may have arrived via a coastal route. Most of the evidence supporting a coastal route is archaeological and geological. In this paper we test the hypothesis of a coastal route using cranial morphometrics. Our hypothesis is that early populations from western North America should resemble early circumpacific Asian and modern Pacific populations rather than recent Native Americans. We test this hypothesis using four samples from early California sites dating from about 9000 to 1500 yr B.P. We also use six late-Pleistocene/early-Holocene fossil crania, three from western North America (La Brea, Buhl, and Spirit Cave) and three from Asia (Upper Cave 101 and 103, and Liujang). Early Californians are highly variable, but in general are more similar to modern Pacific populations, such as Polynesians, than they are to modern Native Americans. The individual crania are also highly variable, but those from Asia are not strongly differentiated from early Americans. In particular, the Spirit Cave Mummy and Upper Cave 101 could easily belong to the same population. Early American crania also share large cranial vault size with recent Polynesians and with early Asians, in contrast to recent Native Americans and Asians, which have smaller cranial vaults. We conclude that the morphometric evidence supports a coastal route.

The recent discovery or redating of skeletal remains in the Americas from 8000–10,000 RCYBP has rekindled interest in their contribution to discussions of the peopling of the New World. Morphometric dissimilarity between early crania and recent Native Americans has contributed to the perception that populating the New World was a more complex process than previously imagined. One component of that complexity is the idea that some of the early migrants may not have used a route over the Bering land bridge, but rather a sea route along the coast. The evidence is mainly archaeological or geological (Dixon 1999; Gruhn 1994), but morphology suggesting Pacific affinities of early crania could also support a coastal migration route. Recent craniometric studies showing that early-Holocene crania are more similar to Ainu, Polynesian, or southern Pacific Rim populations (Steele and Powell 1992) can be taken as evidence supporting a coastal route. In this paper we examine some of this evidence in greater detail, focusing on early skeletons from California that have received little attention in morphometric research, and on the few specimens from East or Southeast Asia for which we have data. We also review and reanalyze the cranial morphometrics of the Buhl burial because the few analyses to date have not resulted in a clear picture of this important skeleton.

Our hypothesis is that early crania from California, the western Great Basin, and Plateau should be more similar to modern Pacific populations, such as the Ainu, Polynesians, or Southwest Pacific islanders, than to recent Native Americans. We may also expect these early American crania to resemble early crania from the Asian Pacific rim, as the latter could represent source populations from which the earliest migrants were drawn.

## Methods

As in our previous studies, we use two approaches. In the first, early or fossil crania are compared to recent (post-Neolithic) crania from Howells's (1989) world sample, supplemented with crania from historic Native American tribes. This approach is de-

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scribed by Owsley and Jantz (1999). In the second, individual fossil crania are compared with one another. Morphometric methods used in this paper have been outlined in Jantz and Owsley (2001) and are similar to those proposed by Van Vark (1995). Briefly, the method is based on Mahalanobis distances calculated between samples and between fossil crania. The pooled within-sample covariance matrix is used to obtain all distances, including those among individual fossil specimens. Principal coordinates are used to scale the distances along orthogonal axes for graphical presentation (Gower 1972). The null hypothesis concerning fossil crania is that they are drawn from the same population. This hypothesis can be tested using the single-population expectation from DeFrise-Gussenhoven (1967).

## Samples

Table 1 presents the circumpacific samples identified as useful for investigating the hypothesis of Pacific affinities of early Americans. We have had an opportunity to examine and measure early California crania from Tulare Lake, La Jolla, Karlo, and La Brea. The Tranquillity crania were extensively reported by Angel (1966), and his measurements are used here. Following is the salient information for each site:

### Tulare Lake

The five burials from this site (TUL-90) have been reported by Warren and McKusick (1959), although no morphological interpretation was presented. The site is located in the southern San Joaquin Valley between Bakersfield and Fresno. Warren and McKusick place the site in the middle Horizon between 1500 and 3500 yr B.P., but no radiocarbon date is available. Tulare Lake is likely the latest site among the test samples used.

### La Jolla

La Jolla refers to a complex of shell midden sites along the coast of southern California and Baja California. La Jolla sites indicate intermittent occupation from 7000 yr B.P. until a few hundred years ago (Shumway et al. 1961). The five burials used in the present analysis are from several sites, only one of which, the Scripps Estate site, has been extensively described (Shumway et al. 1961). Our sample has been assigned to La Jolla II. The crania are mineralized, sometimes markedly so, suggesting considerable antiquity. We believe it is likely that our sample dates from 5000–7000 yr B.P., but additional dating is required. Shumway et al. (1961) present no analysis of the burials, but do comment on the dolichocephaly and prognathism seen in some crania.

### Karlo

The Karlo site (LAS-7) site was described by Riddell (1960). It is located in Secret Valley in northeastern California. The Karlo site apparently dates to about 3000 yr B.P., although the Karlo period extends from 2400–4000 yr B.P. Krantz (1960) described the five Karlo crania, noting their large size, dolichocephaly, large and laterally prominent brow ridges, large faces, alveolar prognathism, low noses, and little chin projection.

### Tranquillity

The Tranquillity site (FRE-48) is in the central San Joaquin Val-

**Table 1.** Sites, sample sizes and dates of crania used in this study.

Specimen	Sample (n)	Date (yr B.P.)	Reference
Tranquillity	6	9000?	Angel 1964; Berger et al. 1971
La Jolla	5	2550? 9000?	Shumway et al. 1961
Karlo	5	2500–4000	Riddell 1960
Tulare Lake	5	1500–3500	Warren and McKusick 1959
La Brea	1	9000	Berger 1975
Buhl	1	10,275	Green et al. 1998
Spirit Cave	1	9000	Tuohy and Dansie 1997
Upper Cave 101	1	26,000–28,000	Weidenreich 1938–39; Chen et al. 1989
Upper Cave 103	1	26,000–28,000	Weidenreich 1938–39; Chen et al. 1989
Liujiang	1	late Pleistocene	see Pope (1992)

ley, about 24 miles west of Fresno. Angel (1966) has described the six Tranquillity skeletons, but there is still a critical issue about their date. Angel was convinced that the crania belonged to a late-Pleistocene or early-Holocene temporal context. Not only were the skeletons associated with extinct fauna (*Camelops*, *Equus*, and *Bison*), the chemical analysis by Heizer and Cook (1952) supported that association. However, a conventional radiocarbon date on two skeletons (burials 4 and 5) in Angel (1966) yielded an age of  $2550 \pm 60$  RCYBP (Berger et al. 1971). Berger et al. argue that the radiocarbon date calls the fluorine date into question. This conflict should be resolved by AMS dating. In the meantime, we are suspicious of the radiocarbon date because of the chemical analysis and because Angel describes the skeletons as heavily mineralized, suggesting antiquity. Angel describes the crania as robust, long, and extremely high, with somewhat pinched foreheads, broad faces, and low-rooted and broad noses. He characterized them as "proto mongoloid."

### La Brea

The La Brea skeleton was recovered along with extinct fauna from the La Brea tar pits in Los Angeles and has been given a conventional radiocarbon date of  $9000 \pm 80$  RCYBP (Berger 1975). Kroeber (1962) assessed the La Brea skull as resembling modern Chumash Indians, and this characterization has been carried through to recent times. The skull was placed in the "narrow-nosed subtype" of the Californian physical type. Our initial evaluation of the La Brea skull shows that it differs markedly from all our recent samples (Jantz and Owsley 1999).

### Buhl

The Buhl skeleton from Idaho is extremely important because of its antiquity and excellent preservation. The loss to science brought about by its reburial is compounded because no comprehensive morphological assessment of the skeleton was performed while it was available. No images other than black-and-white photographs were made. Based on their limited morphological assessment of the skeleton and with no analytical evaluation, Green et al. (1998) concluded that it falls within the range of variation of recent Native Americans. Fenton and Nelson (1998) are more explicit:

It was determined that Buhl registers most closely with the Amerind, or New World samples, practically to the exclusion of the rest of the world. Buhl does not show any affinities with the European samples and indicates only a very tenuous connection with the Ainu. The results of our analysis show the Buhl woman to have been an American Indian. We believe that, in general, she is not morpho-

logically distinct from later North American Indians. It is our contention that the Buhl woman is a representative of an early Paleo-Indian migration that is more closely related to later groups of American Indians than to European or Asian populations.

An even more recent assessment of Buhl's morphometric affinities (Neves and Blum 2000) supporting the Fenton-Nelson interpretation also has some problems. Their two-dimensional principal component plot comparing Buhl with recent world populations shows Buhl to be rather strongly differentiated from recent Native Americans and Siberians in the direction of Polynesians. For whatever reason, they have chosen not to emphasize this aspect of their results.

Lovvorn et al. (1999) classify the Buhl cranium as Ainu using FORDISC 2.0 (Ousley and Jantz 1996). Classification as Ainu suggests the cranium bears little similarity to recent Native Americans. Lovvorn et al. (1999) apparently excluded Polynesians from FORDISC's comparative framework. Lovvorn et al. use 16 measurements, but do not specify which ones. We applied FORDISC using the 16 variables we consider likely candidates for their measurement set and including all of Howells's (1989) female samples. Our results show that the four populations to which Buhl is most similar are the Moriuri, Mokapu, Hawaiians, and Easter Islanders, all Polynesians. The Ainu are the fifth most similar group. Using different measurement subsets did not materially alter the results.

Obviously Buhl is a priority for systematic comparative analysis because of earlier suggestions that it differs little from recent Native Americans. If that is, in fact, its morphological pattern, Buhl would be almost unique among early skeletons, and this would add further complexity to the fossil record.

### Spirit Cave

The now well-known Spirit Cave (Scave) mummy, discovered in 1940, was recently dated to  $9415 \pm 25$  RCYBP (Tuohy and Dansie 1997). Its taphonomy, pathology, and cranial morphometrics have been reported by Jantz and Owsley (1997). The Spirit Cave cranial vault is large, long, and narrow; the face is vertical and not markedly robust.

### Upper Cave 101 and 103

The crania from Upper Cave (UC), or Shandingdong, of Zhoukoudian of northern China have been controversial since Weidenreich's (1938/1939) assessment. Although Weidenreich's characterization of Upper Cave 101 and 103 as "Primitive Mongoloid" and "Eskimoid" respectively was typological, the two crania have recently been shown to be so different from one another that it is unlikely they come from the same population (Cunningham and Wescott 2000). Dates for the Upper Cave crania have variously been considered late Pleistocene-early Holocene (Kamminga and Wright 1988), but more recent AMS dates from animal bones yield a range of 29,000–24,000 RCYBP (Chen et al. 1989).

Morphometric relationships have been extensively considered, but little agreement has emerged. Howells has emphasized their Amerindian character (Howells 1983; 1995). Kamminga and Wright (1988) emphasized their Australian affinities. Van Vark and Dijkema (1988) and Cornell (1998) emphasize the unique-

ness of Upper Cave compared with recent *Homo sapiens*, although both identify Pacific affinities in the skulls. There is substantial agreement that the Upper Cave crania have little in common with recent Chinese crania.

### Liujiang

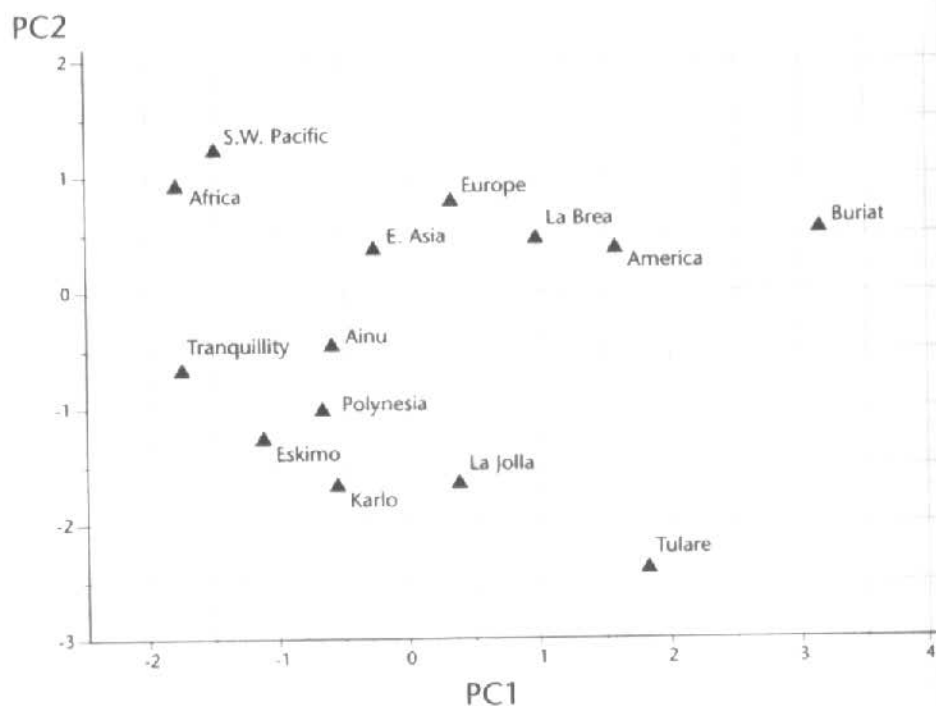
Howells (1983) describes the Liujiang skull of southeastern China as "definitely of a generalized Mongoloid character" and "somewhat un-Chinese" in appearance, particularly in the short face and low orbital openings (p. 298). Howells later (1995) identifies European affinities in the skull. Unlike the Upper Cave crania, the Liujiang skull falls easily within the range of variation of recent *Homo sapiens* skulls. The date of this cranium remains indefinite. Woo (cited in Coon 1963, p. 467) considered it upper Pleistocene geologically, although a uranium date puts it at 67,000 years (Yuan et al. 1986). Its similarity to recent populations makes the early date suspect (Pope 1992).

## Morphometric Relationships of the California Samples

To better illustrate relationships, the world reference populations were grouped into major geographical regions: Europe, sub-Saharan Africa, East Asia, Southwest Pacific, Polynesia, and America. Populations especially relevant to New World origins that do not easily group into major geographic categories are retained as separate samples. These include the Ainu (Japan), Buriats (Siberia), and Eskimos (New World Arctic). Measurement sets available for the individual crania differ in the number of variables because of the degree of preservation or the source of the data, which limit the number of variables that can be used in comparing crania. The most limiting set is for the Tranquillity crania, followed closely by the set available for the Buhl skull. We have therefore carried out two analyses, one that focuses on the California samples and another more extensive analysis that omits Tranquillity, but includes the other samples. Figure 1 shows a two-dimensional plot portraying the distances among the modern samples and the early California samples.

The first axis can be seen as a major dimension on which modern populations are arrayed. On one end of the axis with low scores are African and Southwest Pacific populations. On the opposite end with high scores are the Siberian Buriats and American Indians. East Asia, Europe, and Polynesia are more centrally located on the graph, although Polynesia tends toward the Africa-Southwest Pacific end and Europe and East Asia tend toward the American Indian-Siberian end of the axis. The early California samples exhibit almost as much variation along the first axis as do modern populations.

Measurement contributions to these two axes permit description of the major metric features responsible for the observed differentiation. Variables contributing to the first axis are vault breadth and face height. Populations with high scores, such as Native Americans and the extreme Buriats, have wide vaults and high faces. Those on the opposite end, Southwest Pacific and Africa, have long, narrow vaults and low faces. Among early Californians, the Tranquillity crania are characterized by narrow



**Figure 1.** Two-dimensional principal coordinates plot showing relationships of recent human populations and early Californians (including Tranquillity).

vaults and low faces. Tulare Lake, on the other hand, is characterized by wider vaults and higher faces.

The second axis primarily expresses the distinctiveness of the California samples, except for La Brea, from most recent samples. The recent Polynesians, Eskimos, and to a slightly lesser extent Ainu are also differentiated on the second axis. Tulare Lake has a first-axis score approximately the same as recent Native Americans, but is differentiated from them on the second axis. Tranquillity has a first-axis score corresponding to Africa and Southwest Pacific, but is likewise differentiated from them on the second axis. Karlo and La Jolla assume positions very close to Polynesians and Eskimos. Nearly all variables contribute in the same direction to the second axis, making it a reflection of general size. Variables defining facial forwardness and vault height contribute most prominently to this axis. Groups with low scores on this axis can therefore be characterized as generally large, but with more pronounced facial forwardness and high vaults. These features are seen in modern Polynesians, Ainu, and Eskimos and are a consistent description of the early Californians, with the exception of La Brea.

The La Brea skull is not distinctive on these first two axes, where it assumes a position in the vicinity of Native Americans. This skull is distinctive on the third axis (not shown), which to a considerable extent reflects the small size of the face. We deal with the La Brea skull in greater detail in the next section.

### Morphometric Relationships of Early Californians, Americans, and Asians

In this analysis all samples presented in Table 1 except Tranquillity are used. Omitting Tranquillity allows use of a larger, but still limited variable set.

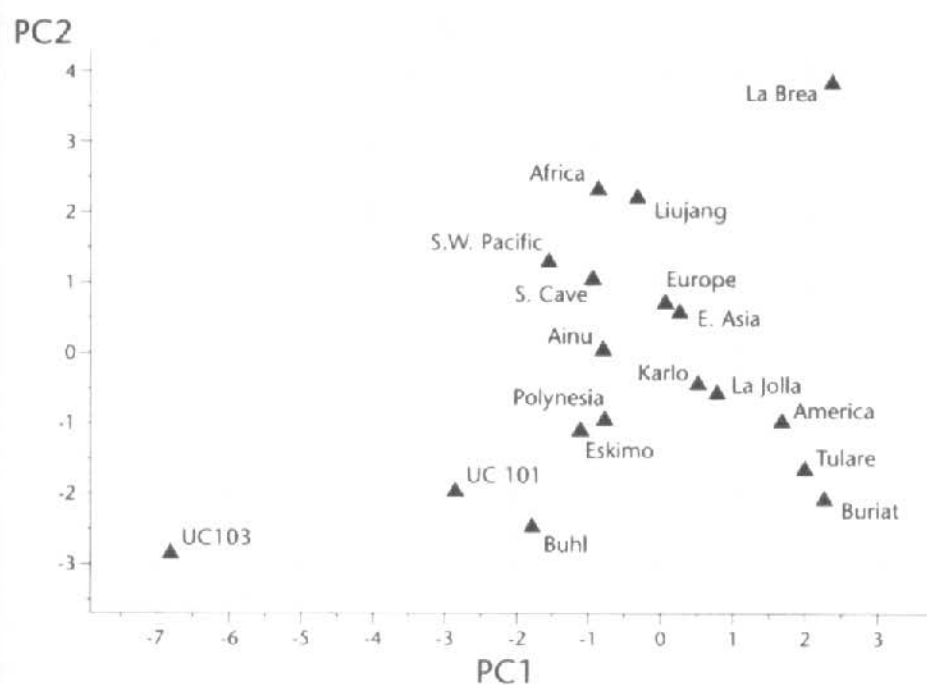
### General Analysis

Figure 2 is the two-dimensional plot of these samples in relation to recent human populations. The axes are dominated by the fossil crania, which occupy the low and high positions on both axes. Their inclusion has the effect of compressing the modern populations to the center, which reflects their similarity to one another and the distinctiveness of some of the fossils. On the first axis La Brea occupies an extreme positive position and Upper Cave 103 an extreme negative. The extreme position of Upper Cave 103 distorts some of the interesting population arrangements on the first axis. Somewhat more moderate negative scores are associated with the recent populations of the Pacific rim: Polynesians, Eskimos, Ainu, and Southwest Pacific populations. Upper Cave 101, Buhl, and Spirit Cave share this general location to varying degrees. On the second axis La Brea is the positive extreme and Buhl and Upper Cave 103 are the extreme negative values.

The morphological pattern expressed by axis 1 relates to vault length, especially the parietal contribution to length, vault breadth, and face height. The crania of Upper Cave 103, and to a lesser extent Upper Cave 101 and Buhl, can be characterized as long and narrow with short faces. Buriats, Native Americans, and La Brea represent the opposite condition. Axis 2 reflects to some extent general size, but emphasizes upper facial forwardness, vault breadth, especially at the base, and nose height. Low-scoring populations on axis 2 can first be characterized as generally large, and more subtly as upper facially forward with vaults wide at the base compared with the maximum cranial breadth, and high noses relative to facial height.

La Brea is clearly a metric anomaly, bearing little resemblance to any modern human population or any other fossil. The other fossil crania can generally be described as large, but the La Brea cranium is small with a high face height relative to size. This





**Figure 2.** Two-dimensional principal coordinate plot showing relationships of recent human populations, early Californians (excluding Tranquillity), and individual fossil crania.

cranium would be an atypical member of any population examined here.

#### Relationships of Early Groups to Recent Populations

Figure 2 gives an overall summary of intergroup relationships, but fails to account for important details. Table 2 presents the full Mahalanobis squared distance of each early group from the modern regional populations, with distances arranged in descending order. Decreasing similarity to Native Americans is seen in three California samples, Tulare Lake, La Jolla, and Karlo, where Native Americans are in first, second, and third positions respectively. The California samples are also similar to East Asia, Ainu, and Polynesia, in marked contrast to the early fossil crania, where the Native American rank ranges from fifth (La Brea) to eighth

(UC103 and Spirit Cave). The three groups most similar to the early fossils are overwhelmingly Pacific Rim populations, although Europe is most similar to Spirit Cave and Liujang.

#### Relationships among Early Fossils

The Mahalanobis distance ( $D^2$ ) matrix giving the distance between crania in each pair is presented in Table 3. Significance levels designate whether each pairwise distance is greater than would be expected if the two crania were drawn from a single population. The single-population criterion used here is the pooled-within-sample covariance matrix from Howells's (1989) world samples with Native American additions as described in Jantz and Owsley (2001). These samples are local populations, so this test will be conservative in permitting the conclusion that two crania are from the same population.

**Table 2.** Mahalanobis distances ( $D^2$ ) between early samples and recent regional populations.

	Amerindian	Polynesian	Ainu	E. Asia	Buriat	European	S.W. Pacific	African	Eskimo
Tulare	5.67	20.90	22.02	23.32	24.21	24.62	34.05	34.19	34.23
Karlo	Ainu	E. Asia	Amerindian	European	Polynesian	Eskimo	S.W. Pacific	Buriat	African
	26.41	27.43	27.59	28.75	29.45	30.22	36.07	39.43	41.84
La Jolla	E. Asia	Amerindian	European	Polynesian	Ainu	S.W. Pacific	Eskimo	Buriat	African
	15.94	18.42	19.38	21.33	22.39	25.84	28.06	30.04	32.18
La Brea	E. Asia	European	African	Ainu	Amerindian	S.W. Pacific	Polynesian	Eskimo	Buriat
	46.10	47.03	52.68	53.63	55.59	57.81	66.85	69.84	76.23
UC103	Eskimo	S.W. Pacific	Polynesian	Ainu	European	E. Asia	African	Amerindian	Buriat
	63.71	65.77	65.82	70.80	79.62	80.71	86.81	92.68	108.78
UC101	Ainu	Polynesian	European	Buriat	S.W. Pacific	Amerindian	E. Asia	African	Eskimo
	37.99	42.37	45.71	50.00	51.02	51.77	53.64	54.89	57.40
Buhl	Polynesian	S.W. Pacific	European	E. Asia	Ainu	Amerindian	Eskimo	African	Buriat
	33.44	40.35	40.64	42.28	43.68	45.19	51.15	51.85	56.45
Sp. Cave	European	Ainu	E. Asia	Polynesian	Eskimo	S.W. Pacific	African	Amerindian	Buriat
	22.52	25.89	26.79	27.82	30.66	30.72	31.66	33.57	54.17
Liujang	European	African	S.W. Pacific	E. Asia	Ainu	Amerindian	Polynesian	Buriat	Eskimo
	23.44	28.36	33.27	33.59	34.18	38.60	41.45	54.21	55.73

**Table 3.** Distances (D) between individual fossil specimens.

	La Brea	Buhl	Sp. Cave	UC101	Liujiang	UC103
La Brea	0.000					
Buhl	10.617 <sup>▲</sup>	0.000				
Sp. Cave	6.768	8.318 <sup>■</sup>	0.000			
UC 101	10.896 <sup>▲</sup>	9.054 <sup>▲</sup>	6.802	0.000		
Liujiang	7.877 <sup>■</sup>	9.074 <sup>▲</sup>	5.498	7.368	0.000	
UC 103	12.150 <sup>▲</sup>	8.594 <sup>▲</sup>	9.357 <sup>▲</sup>	8.965 <sup>▲</sup>	10.254 <sup>▲</sup>	0.000

■  $p < 0.05$     ▲  $p < 0.01$

The extreme position of Upper Cave 103 is evident in its high distances from all other crania and low probability that it could have been drawn from the same population as any of the others. Buhl's relationship to other crania is almost as distinctive. Spirit Cave, by contrast, is the most centrally located skull, differing only from Upper Cave 103 and Buhl. Spirit Cave, Upper Cave 101, and Liujiang are all similar enough to each other to have been drawn from the same population.

## Size

The foregoing analyses have shown that early Californians exhibit a great deal of variation over the 5000–6000 years represented. A common feature is the large size of the cranial vault. It is useful to examine size variation explicitly in relation to world variation. We limit size to cranial vault size, quantified as the geometric mean of cranial length, width, and height. Cranial length and breadth have the usual definitions, but vault height is defined as vertex radius. This procedure allows use of crania with the bregma measurement missing, as is often the case in the California series. Size data were centered on world sex-specific averages and expressed as standard scores.

Table 4 shows the distribution of cranial vault size in world-wide samples, arranged from largest to smallest. These are generally presented in broad regional groupings, although Buriats, Eskimos, and Ainu were retained as separate samples either because they represent the only sample from a general region (Siberia for the Buriats and the Arctic for the Eskimos) or because the group is generally considered different from the majority population of its region (Ainu in Asia). North American Indian populations were grouped into smaller, culture-area regions in order to deter-

**Table 4.** Cranial vault size (in standard units) of recent human populations.

group	n	X	S.D.
Buriat	109	1.037	0.860
Ainu	86	0.844	0.741
Polynesia	371	0.816	0.810
Europe	317	0.261	0.749
Eskimo	108	0.225	0.741
E. Asia	400	-0.111	0.807
Historic Plains	213	-0.196	0.754
California (Santa Cruz)	102	-0.447	0.737
S.W. Pacific	298	-0.520	0.856
Numic	22	-0.604	0.521
Africa	373	-0.752	0.985
Southwest U.S. (Pueblo)	43	-0.800	0.706

mine whether significant variation exists among regions.

The largest vaults belong to Buriats, followed closely by the Ainu and Polynesians. These three groups have vault sizes considerably larger than the other groups: more than 0.8 standard deviations above the world mean, with a marked difference relative to the next largest groups, Europeans and Eskimos. All other groups have vault sizes less than the world mean. Amerindians are uniformly below the world mean, ranging from only slightly below (historic Plains), to markedly small (Santa Cruz, Great Basin, and Southwest). Human populations are strongly differentiated on vault size: the minimum  $F_{st}$  among five regions (Europe, Africa, East Asia, Polynesia, and S. W. Pacific) is 0.179, which is greater than the  $F_{st}$  for the average cranial measurement (Relethford 1994).

Table 5 presents vault-size data for individual fossil crania, their mean, and the mean of the early Californians. The largest cranial vaults belong to Upper Cave, particularly Upper Cave 101. Except for La Brea, the early American crania are considerably larger than the world average. Taken as a group, vault sizes of the American and Asian fossil crania are well above the world average and are similar to the Ainu and Polynesians. The early Californians are also very large.

## Discussion

An unanswered question at this point is the taxonomic relevance of cranial size. Size is often regarded as a nuisance variable to be removed. Various removal techniques are available (Jungers et al. 1995), but in cranial morphometrics Darroch and Mosimann shape variables (Darroch and Mosimann 1985) or C-scores (Howells 1989) are commonly used. Many of the recent morphometric analyses of early American crania have attempted to eliminate size (e.g., Neves and Blum 2000; Powell and Neves 1999; Powell and Rose 1999) because size is considered less relevant

**Table 5.** Cranial vault size (in standard units) of early American and Asian crania.

Group/site	n	X	S.D.
Upper Cave 101	1	2.003	—
Upper Cave 103	1	1.013	—
Spirit Cave	1	0.980	—
Buhl	1	0.941	—
Liujiang	1	0.863	—
La Brea	1	-0.183	—
Fossil mean	6	0.936	0.693
Early Californians	26	1.000	0.980

than shape. However, size is patterned in time and space and may reflect as much of a genetic component of variation as shape does.

Howells's (1989) analysis of his world cranial database using PENSIZ clearly demonstrates the patterning in size. Although PENSIZ, as used by Howells, reflects the contributions all variables make to overall size, as opposed to vault size as used here, his size patterning is much the same as we observe. The distribution of large cranial vaults in recent populations includes Polynesians (including the Micronesian Guam sample in Howells's database),

Ainu, and Buriats. Except for Buriats, this is a Pacific distribution. We now see that this characteristic includes early-Holocene Americans from the western United States and early Californians as late as the Middle Horizon, perhaps 1500 B.C. No recent Native American sample can be characterized as large-vaulted; Table 4 shows all are below the world mean, some well below.

The meaning of vault-size variation is poorly understood and has not been subjected to systematic investigation. In most parts of the world, cranial capacity, which will be closely related to size as defined here, has become smaller since the end of the Pleistocene (Henneberg 1988; Henneberg and Steyn 1993). Henneberg (1988) ascribes the change in cranial capacity to generalized structural reduction or gracilization, perhaps driven by hormonal changes (Henneberg and Steyn 1995). Lahr and Wright (1996) have argued that size variation may cloud phylogenetic relationships because of its relationship to robusticity. Vault size as defined here, however, seems to have only a weak relationship to robusticity. The robust Southwest Pacific populations and the more gracile sub-Saharan Africans are small-vaulted, while the large-vaulted Polynesians are robust, but less so than Southwest Pacific populations. Beals et al. (1984) found a strong correlation between climate and cranial capacity, putting it into the framework of adaptation. In the present data, the climate model fits only loosely. Buriats and Eskimos both qualify as cold-climate populations, but differ considerably in vault size. Although Houghton (1990) has argued that Polynesian physique in general is cold-adapted, it is hard to imagine cold stress sufficient to explain their markedly large vaults.

The large vault size seen in early-Holocene Americans and early Californians must unfortunately be left unexplained, but may in part be traced to the original founding populations. What is required at this point is a model that would explain the distribution of vault size in recent human populations that also accounts for the change in vault size in western North Americans. Models from which we might choose would presumably include the possibility that vault-size variation reflects an important component of genetic variation.

The primary question addressed in this paper is whether morphometric relationships support hypotheses that early populations came to America via a coastal route. If early populations came via this route, they presumably came out of coastally adapted populations along the western Pacific rim. There is not much evidence to illustrate what these early populations might have looked like, although those who have examined early Asian crania describe them as unspecialized with sundadont dental features (Lahr 1995). They are typically large and low-faced and lack the facial flatness associated with recent East Asians. Using modern populations as a comparative framework, the early Asians in our analysis (UC101, UC103, Liujiang) generally align with Pacific populations, although Liujiang is most similar to Europe and Africa. A similar result for this skull was obtained by Howells (1995). These early Asian crania would generally be atypical members of modern populations.

Another early-Holocene skeleton from Malaysia has been judged similar to Australian Aborigines, and to Mesolithic populations

from Malaysia and Flores (Matsumura and Zurlina 1999). Although we have not used the Minatogawa crania from Japan, they too have been characterized as possessing low faces and orbits and are metrically similar to Liujiang (Suzuki 1982). Evidence from cranial morphology supports the idea that this generalized S. E. Asian population represents the morphological background of Polynesians and the Jomon-Ainu lineage in Japan (Hanihara 1992). A Southeast Asian or South Chinese origin for Polynesians is seen in both mtDNA (Melton et al. 1995) and Y chromosome data (Bing et al. 2000). A convincing argument can therefore be made that the early western Pacific Rim populations were generalized in cranial morphology, features still seen in such modern groups as Polynesians and Ainu, and also characterizing early-Holocene American crania from western North America.

The California samples, Tranquillity, La Jolla, Karlo, and Tulare Lake, are highly variable, but to some varying degree also show evidence of having been derived from these generalized Asian circumpacific populations. Tranquillity, which we are considering the earliest pending a reliable AMS date, is the most distinctive and bears the least resemblance to recent Native American populations. Our results provide quantitative support to earlier investigators who observed the absence of Amerindian morphology in both Tranquillity (Angel 1966) and Karlo (Krantz 1960) and who mention "Protomongoloid" or "Australoid" morphology. The metric expression of these observations in the present analysis does not align any of them with modern aboriginal Australians, although Tranquillity comes closest. Rather, early California samples are removed from modern samples, including Amerindians, by virtue of longer, narrower cranial vaults, greater upper facial forwardness, and lower facial height. The California sample with the most recent date, Tulare Lake, exhibits the greatest morphometric similarity to recent Amerindians, but, like the other California samples, has greater vault size than recent Native Americans.

The similarity of early crania from California and the western U.S. to early crania from circumpacific East Asia and to contemporary Pacific populations is most parsimoniously explained by a circumpacific movement of people responsible for at least a part of the early population of America. A finding of more intense expression of the generalized circumpacific Asian morphology in California than further inland would provide further support for a coastal route. The present evidence is probably too limited to allow that conclusion, but future research should be directed at that question.

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