

Human cranial variation in South America: Implications for the settlement of the New World

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ABSTRACT

Human diversity in the New World deserves attention because of its paramount importance for the understanding of the peopling of the continent. In recent years, the study of this diversity has been directed to testing the "Three Migration" hypothesis (Turner II, In: *Early Man in the New World*, Sage Publications, 1983; Greenberg *et al.*, *Curr. Anthropol.* 27: 477-497, 1986). Since this approach seems very restrictive, the present work intends to explore the diversity of cranial morphology in South America with no particular model as point of departure. We used uni, bi and multivariate methods to compare craniometric data of 502 individuals sorted out from representative pre-historic and historic collections all over the subcontinent. The results suggest the existence of two distinct morphological patterns, one of which linked to Paleo-Indians and another to archaic and horticulturalist populations. Even if one considers that local evolutionary forces or functional responses of the skull to environmental stresses could have caused the detected differences, the pattern of differentiation in time leads us to suggest the entrance of more than one migratory wave into South America.

INTRODUCTION

The theme of the colonization of New World by its native inhabitants is a polemic matter. There are several points of intense debate for which it is difficult to foresee any simple solution: who were the first colonizers, when did they arrive, where did they come from and how? (See Meltzer, 1989; 1993; Rogers *et al.*, 1992 for reviews.) The main goal underlying these questions is the understanding of present and past human diversity in the Americas.

At first, physical anthropologists and archaeologists were mainly concerned with the ancestry of American Indians. Their comparative studies of morphology and material culture led to the conclusion that human populations in Asia and America were closely related. As new fields of investigation were developed along this century, grounded in an evolutionary framework, new kinds of evidence became available to understand the peopling of the Americas and new inquiries arose (Harper and Laughlin, 1982).

After the publication of a seminal paper by Turner II (1983), Greenberg *et al.* (1986) proposed a model of occupation bringing together data on dental morphology, linguistic and genetic diversity in the New World, coupled with archaeological evidence. The scenario imagined by these workers was one of a recent entry of three different stocks of Mongoloid/Sinodont populations, whose ultimate origins could be situated at Northeastern Asia. According to this hypothesis, all native Americans with the exception of Na-Dene and Eskaleut speakers descend from one single invading human lineage. Accordingly, South America was peopled by relatively homogeneous populations derived from a single migratory event.

Since its publication, the Three-migration Model, as it became to be known, was severely criticized in terms of methodology, nature of data and conclusions (Campbell, 1986; Fox, 1986; Laughlin, 1986; Szathmary, 1986; Weiss and Woolford, 1986; Powell, 1993). Notwithstanding this criticism, it is undeniable that the idea of Greenberg *et al.* was the first formal hypothesis encompassing capital questions like time of entry, ancestral population, possible routes and number of migratory waves. As a result, the model generated an upheaval among scientists interested in human

history in the Americas and, as Rogers *et al.* (1992, p. 292) pointed out: "In some cases identification of the number of migrations became the issue of primacy and patterns of diversity became the tests for migration scenarios".

The aim of the present work is to re-attack the key problem in the study of the peopling of the New World - the diversity of native Americans - without assuming any specific "migration scenario" as a point of departure. Patterns of cranial morphological diversity in South America are investigated and the implications of the results to the understanding of its colonization are further considered.

MATERIAL AND METHODS

In our survey we attempted to bring together the greatest number of South American skeletons possible, both pre-historic and historic, for which cranial measures were available. Our sources were published craniometric data extracted out of the anthropological literature and unpublished data collected by one of us (W.A.N.) or kindly offered by other physical anthropologists.

We have not included collections with reported occurrence of artificial cranial deformation. This strategy led to the exclusion of the majority of Andean collections. The composition of the final data bank was also constrained by the number of craniometric variables that could be compared to those used by Howells (1973), and by sample sizes.

Related samples, *i.e.*, groups showing some biological affinities, were pooled into more inclusive units, to diminish effects from random local variation. Individuals presenting discrepant morphology within their own series were excluded from the study. Thus, the data bank embraces 13 craniometric variables and 502 individuals (285 males and 217 females), from eight South American geographical and chronological units. Table I lists the essential information about the samples and Figure 1 depicts them site by site. Sample sizes, mean values and standard deviations for each variable in the case of males are presented in Table II, while the same information for females is presented in Table III.

Data were scrutinized by means of univariate, bivariate and multivariate analyses.

Univariate analysis

If Bartlett's tests indicated homoscedasticity, differences among all series were assessed by means of parametric analysis of variance followed by Duncan's tests. Non-parametric analysis of variance (Kruskal-Wallis statistic) and Dunn's tests were applied in case of absence of homoscedasticity.

In order to summarize the large amount of information obtained from these pairwise analyses we applied a tree-constructing algorithm (Fitch-Margoliash method 3.0, included in PHYLIP 3.2) on a matrix of relative frequencies of difference between pairs of series. The input order was randomized 20 times to find the best tree. It must be emphasized that we did not intend to imply any

phylogenetic relationship with this approach. The algorithm was used, thus, as a mean of expressing the degree of dissimilarities among the skeletal samples.

Bivariate analysis

Means of four paired variables were used to delineate bivariate graphs in order to investigate the dispersion of the South American series in agreement with two craniofacial indexes commonly used to describe human populations. The pairs of variables and their related indexes are: GOL and XCB for Cranial Index; and ZYB and NPH for Upper Facial Index.

Multivariate analysis

The chosen multivariate method was Principal Components Analysis applied to R and Q-standardized variables. This alternative restricted the original data bank to only seven variables to keep the number of variables smaller than the number of cases. BNL, XFB, AUB, DKB and BRR were excluded in view of frequent occurrence of missing values in the series (Tables II and III); NPH was dismissed because of its redundancy with NLH.

Univariate analysis was performed by means of Statgraphics 6.0 and Instat 2.0, while multivariate analysis was carried out by means of BMDP.



Figure 1 - Approximate geographic location of the South American archaeological sites and ethnographic groups involved in this work. (Botocudos have a wide distribution in Central Brazil. Their location in the map represents the central point of dispersion).

Table I - Summary information about the eight South American series used in the present work, including archaeological sites involved, sample sizes for males and females, brief geographical localization, dating (when available) and data sources.

Series	Sites	n		Country	Radiometric dates (y.B.P)	Data Sources
		males	females			
Lowlands Paleoindians ¹ (PILL)	Cerca Grande	4	4	Brazil	9720 ± 130	Neves (unpublished)
	Sumidouro	8	8	Brazil	-----	Neves (1989)
	Confins	2	2	Brazil	-----	Neves (unpublished)
	Caetano	1	1	Brazil	-----	Neves (unpublished)
	Amoreira	1		Brazil	-----	Neves (unpublished)
	Lapa d'Água		1	Brazil	-----	Neves (unpublished)
	Lapa Vermelha		1	Brazil	11680 ± 500	Neves (unpublished)
Highlands Paleoindians ¹ (PIHL)	Sueva		1	Colombia	10090 ± 90	Correal (1979)
	Tequendama	5	4	Colombia	9740 ± 135	Correal and Van der Hammen (1977)
	Chia III		2	Colombia	5040 ± 100	Ardila (1984)
	Aguazuque	22	28	Colombia	5030 ± 40	Correal (1990)
Lowlands Archaics (ARLL)	Congonhas	3	4	Brazil	3270 ± 200	Neves (1982) Neves (unpublished)
	Caiera	2	2	Brazil	3350 ± 110	Neves (1982) Neves (unpublished)
	Carnaça	3		Brazil	3370 ± 150	Neves (unpublished)
	Cabeçuda	28	16	Brazil	4120 ± 220	Mello e Alvim <i>et al.</i> (1975)
	Guaraguaçu A	9	8	Brazil	4220 ± 200	Neves (unpublished)
	Matinhos	4	7	Brazil	-----	Neves (unpublished)
	Piaçaguera	17	5	Brazil	4930 ± 110	Mello e Alvim and Uchôa (1976)
	Buracão	7	3	Brazil		Mello e Alvim (1978)
	Tapera ²	29	29	Brazil	1525 ± 70	Silva (unpublished)
Base aérea ²	13	12	Brazil	1150 ± 70	Silva and Neves (unpublished)	
Highlands Archaics (ARHL)	Camarones 14	4	6	Chile	7420 ± 225	Quevedo (1984)
Lowlands Horticulturalists (HOLL)						Neves (1982)
	Enseada	11	8	Brazil	-----	Neves (unpublished)
	Laranjeiras II	17	17	Brazil	-----	Aguiar (1986)
	Forte Marechal Luz	13	5	Brazil	1070 ± 100	Mello e Alvim (1978)
Highlands Horticulturalists (HOHL)	Quitor 6	6	4	Chile	1010 ± 70	Costa (1988)
Ethnographic Groups of Tierra del Fuego (EGTF)	Selknam	26	9	Chile/Argentina	XX century	Gusinde (1989)
	Yamana	23	11	Chile	XX century	Gusinde (1989)
	Alacaluf	4	4	Chile	XX century	Gusinde (1989)
Ethnographic Groups of Central Brazil (EGCB)	Botocudos	23	9	Brazil	XIX century	Mello e Alvim (1963)

Notes: 1 - Paleoindian is used here to refer to Southamerican prehistoric populations dated from 12000 to 8000 y.B.P and/or later populations demonstrated to be their direct descendants. 2 - Although these sites are chronologically placed in the Horticultural period, Neves (1988) demonstrated a close affinity between their inhabitants and archaic shell-mound builders.

Table II - Craniometric variables, sample sizes, means and standard deviations for the South American series used in the work (males).

Series	Variables ¹																				
	GOL		BNL		XCB		XFB		ZYB		AUB		NPH								
	N	Means	SD	N	Means	SD	N	Means	SD	N	Means	SD	N	Means	SD						
PILL	13	186.1	5.9	7	102.1	4.3	13	130.3	5.0	13	111.6	4.5	2	127.0	1.4	13	118.4	5.2	6	63.3	3.6
PHL	18	186.5	7.2	10	103.5	7.7	15	130.0	5.0	17	105.4	6.0	10	134.3	5.1	18	125.4	4.0	71	74.1	5.3
ARLL	95	183.0	5.7	45	101.0	5.8	92	142.7	5.3	91	117.4	5.1	61	140.1	6.4	49	106.3	1.7	4	70.5	3.1
ARHL	4	182.0	2.4	3	97.7	4.9	4	140.0	4.8	3	117.0	3.5	3	131.3	3.5	20	133.9	6.1	11	120.1	4.4
HOLL	33	180.9	5.6	19	100.4	4.4	33	137.7	3.7	28	116.3	5.4	6	133.3	4.8	51	127.5	5.1	53	74.4	4.3
HOHL	6	168.5	4.7				6	136.7	4.5	22	112.5	5.8	20	135.5	5.9	19	116.3	3.3	7	116.3	3.3
EGTF	52	189.0	6.3	52	103.5	3.7	52	141.8	4.3	51	117.1	4.7	52	142.6	5.2	51	127.5	5.1	53	74.4	4.3
EGCB	22	184.4	7.0	20	102.6	4.2	23	135.3	4.2	22	112.5	5.8	20	135.5	5.9	23	118.5	6.0	23	118.5	6.0

Variables

Series	Variables																	
	NLH		OBH		OBB		NLB		DKB		BRR							
	N	Means	SD	N	Means	SD	N	Means	SD	N	Means	SD						
PILL	9	48.8	2.8	11	33.0	1.6	11	40.1	1.4	9	24.2	1.9	13	23.0	2.4	7	116.3	3.3
PHL	19	52.8	3.5	16	33.3	1.9	15	37.3	2.3	18	25.1	1.8	20	23.3	1.3	20	119.0	10.2
ARLL	78	53.2	3.1	89	35.6	2.0	87	40.1	1.8	87	25.6	2.0	91	22.6	2.4	88	116.0	4.9
ARHL	4	49.5	1.3	4	34.0	1.4	4	39.5	1.7	4	24.3	2.1	3	21.3	1.5	4	113.5	1.0
HOLL	31	52.5	4.1	31	35.2	1.6	30	39.2	2.5	27	24.0	2.0	32	22.8	2.0	33	121.6	6.6
HOHL	6	49.7	2.0	6	35.2	1.3	6	39.7	2.4	6	24.2	2.4						
EGTF	51	53.5	2.9	53	35.5	2.1	53	43.5	2.2	53	24.6	1.7						
EGCB	19	52.2	3.0	20	32.6	1.9	20	40.6	1.9	19	24.9	1.4	21	21.4	1.8	23	118.5	6.0

¹ GOL glabella - occipital length; BNL basion - nasion length; XCB maximum cranial breadth; XFB maximum frontal breadth; ZYB bizygomatic breadth AUB biauricular breadth; NPH nasion - prosthion height; NLH nasal height; OBH orbit height, left; OBB orbit breadth, left; NLB nasal breadth; DKB interorbital breadth; BRR bregma radius.

Table III - Craniometric variables, sample sizes, means and standard deviations for the South American series used in the work (females).

Series	Variables ¹																							
	GOL		BNL		XCB		XFB		ZYB		AUB		NPH											
	N	Means	SD	N	Means	SD	N	Means	SD	N	Means	SD	N	Means	SD									
PILL	15	178.8	6.0	8	96.5	3.3	15	129.2	3.8	13	107.7	5.0	1	123.0		12	114.3	4.4	3	58.7	5.9			
PIHL	31	184.2	7.4	22	98.4	5.2	29	127.8	4.0	30	104.4	3.5	19	124.5	7.8		28	65.8	5.3	28	65.8	5.3		
ARLL	71	174.6	5.2	41	95.8	3.9	70	137.4	4.5	68	114.1	5.1	44	131.1	3.6	46	118.9	4.3	59	70.1	4.2	59	70.1	4.2
ARHL	3	169.7	9.5	2	88.5	12.0	3	130.7	6.0	4	105.5	2.6	1	125.0					3	66.0	5.3	3	66.0	5.3
HOLL	22	175.3	7.5	10	95.9	3.3	21	134.7	5.0	15	109.8	6.3	8	128.8	4.9	6	110.3	9.0	14	68.6	5.0	14	68.6	5.0
HOHL	4	160.0	1.8				4	138.5	6.4				4	123.8	4.6				4	64.3	3.8	4	64.3	3.8
EGTF	24	180.4	9.2	23	99.8	6.2	24	138.0	3.8	24	111.6	3.9	22	133.8	7.9	23	121.3	6.5	23	70.2	7.0	23	70.2	7.0
EGCB	10	175.0	3.9	10	97.3	4.8	10	131.4	4.1	10	110.3	4.1	10	127.3	3.1				8	66.5	4.6	8	66.5	4.6

Series	Variables																							
	NLH		OBH		OBB		NLB		DKB		BRR													
	N	Means	SD	N	Means	SD	N	Means	SD	N	Means	SD	N	Means	SD									
PILL	5	43.3	2.7	5	33.2	0.8	5	37.8	1.3	3	25.0	1.0	10	21.5	1.7	6	110.8	4.9						
PIHL	26	51.0	3.7	29	33.4	1.5	28	37.1	1.6	27	25.5	2.5	31	22.8	1.9	28	115.0	8.2						
ARLL	61	50.3	3.6	63	35.7	2.5	64	39.1	2.1	62	24.9	1.7	66	22.0	2.2	65	110.9	4.2						
ARHL	3	46.0	3.0	3	34.0	0.0	3	37.3	1.2	4	21.5	1.9	2	20.5	0.7	2	104.5	9.2						
HOLL	14	48.8	1.8	17	33.9	2.2	17	37.8	2.6	13	23.5	1.3	18	22.8	1.8	17	120.2	8.4						
HOHL	4	46.8	2.1	4	34.8	1.3	4	39.0	1.8	4	23.5	0.6												
EGTF	23	51.0	4.2	23	34.5	1.5	23	41.5	2.3	23	24.2	1.9												
EGCB	9	48.6	2.9	10	32.3	1.8	10	38.7	2.4	9	24.4	1.4	10	20.8	1.2	10	112.3	4.5						

¹ See Table II.

RESULTS

Univariate analysis

Analysis of variance revealed significant differences among the eight South American series in the majority of variables (Table IV). BNL, in the case of males, and DKB for both sexes were the only exceptions.

The results from multiple comparisons' tests are summarized in Tables V and VI. The tests failed to find inter-group differences ($p < 0.01$) for NPH in the case of females and NLB in the case of males, although the previous analysis of variance would suggest the opposite.

Table VII exhibits a matrix for each sex, listing absolute and relative frequencies of differences between pairs of series, based on the results from multiple comparisons' tests. The Fitch-Margoliash algorithm applied to these data matrices generated unrooted trees, shown in Figure 2.

The topologies of the two trees indicate that PILL is a highly differentiated group. PIHL is also quite distinct but in different degrees in accordance with sex. Other series highly differentiated from the rest are HOLL in the case of males and ARHL in the case of females. In both sexes EGTF and ARLL differ little in relation to each other and these two series are less distinct from HOHL than the remaining ones. The group formed by them is close to ARHL and EGCB in the case of males, while in the case of females it is less different from HOLL and subsequently from EGCB.

Bivariate analysis

As can be seen in Figure 3, the eight series present a similar dispersion pattern with respect to Cranial Index,

Table IV - F-ratios and Kruskal-Wallis statistics obtained for each of the 13 craniometric variables used as anthropological markers.

Craniometric variables	F-ratios ¹ /KW statistics ²	
	Males	Females
GOL	13.076 ^{1*}	53.238 ^{2*}
BNL	2.088 ¹	3.148 ^{1*}
XCB	27.129 ^{1*}	20.932 ^{1*}
XFB	16.169 ^{1*}	16.779 ^{1*}
ZYB	10.136 ^{1*}	28.811 ^{2*}
AUB	30.221 ^{1*}	9.077 ^{1*}
NPH	7.064 ^{1*}	24.702 ^{2*}
NLH	4.150 ^{1*}	4.716 ^{1*}
OBH	9.859 ^{1*}	35.126 ^{2*}
OBB	23.274 ^{1*}	9.458 ^{1*}
NLB	3.278 ^{1*}	3.851 ^{1*}
DKB	2.091 ¹	2.590 ¹
BRR	24.587 ^{2*}	22.398 ^{2*}

* $p < 0.01$.

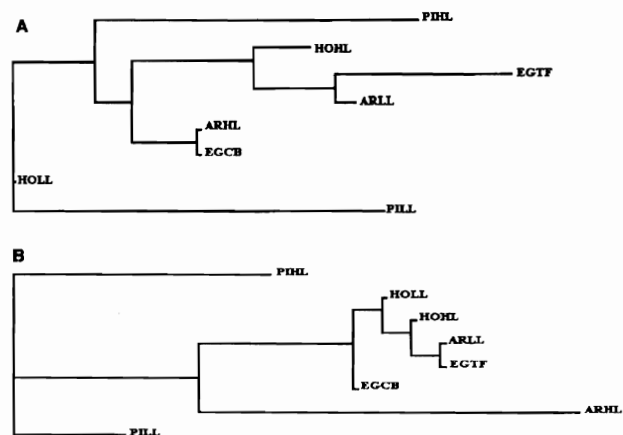


Figure 2 - Unrooted trees based on relative frequencies of significant differences between pairs of series generated by Fitch-Margoliash algorithm. A) males (sum of squares: 4.26). B) females (sum of squares: 19.28).

independent of sex. Paleo-Indian groups are distinguishable from the others in cranial morphology, being dolichocranic, while almost all the remaining ones are mesocranic. HOHL is the only brachycranic group. EGCB always occupy an intermediate position between the Paleo-Indians and the other series. In the case of males this ethnographic group is dolichocranic but in the case of females it is placed exactly on the boundary between dolichocranii and mesocranii.

Figure 4 shows the results for Upper Facial Index. In both sexes PILL is euryene and all others are mesene.

Multivariate analysis

Table VIII shows the amount of original information synthesized by each principal component while Tables IX and X list the correlations between the PCs and the original craniometric variables. Figures 5 and 6 show the distribution of the South American series, for the first two PCs since they comprise 70 to 76% of the initial variability.

The four Principal Components Analyses carried out in the present work - size and shape and shape information alone, for both sexes - revealed the singularity of Paleo-Indian cranial morphology in relation to more recent groups. When R-standardized variables (size and shape) are considered, it is possible, both in males and females, to see that a diagonal line separates PILL and PIHL from the Archaic, Horticulturalist and Tierra del Fuego groups, while EGCB occupies an intermediate position (Figure 5). Notwithstanding, no recurrent distribution pattern between sexes could be detected for ARLL, ARHL, HOLL, HOHL and EGTF.

Similar results were obtained with R and Q-standardized variables (shape information alone) although the general aspect of the graphs is clearly different (Figure

Table V - Summary results of multiple comparisons tests (males). Vertical bars link the series between which no significant ($p < 0.01$) differences were found. Means and medians for parametric and non-parametric tests, respectively.

Series	Variables							
	GOL	BNL	XCB	XFB	ZYB	AUB	NPH	
PILL	Means 186.1	Means * 102.1	Means 130.3	Means 111.6	Means 127.0	Means 118.4	Means 63.3	
PIHL	186.5	103.5	130.0	105.4	134.3	125.4	71.6	
ARLL	183.0	101.0	142.7	117.4	140.1	106.3	74.1	
ARHL	182.0	97.7	140.0	117.0	131.3	120.1	70.5	
HOLL	180.9	100.4	137.7	116.3	133.9	127.5	73.5	
HOHL	168.5		136.7		133.3		72.2	
EGTF	189.0	103.5	141.8	117.1	142.6		74.4	
EGCB	184.4	102.6	135.3	112.5	135.5		69.1	

Series	Variables						
	NLH	OBH	OBB	NLB	DKB	BRR	
PILL	Means 48.8	Means 33.0	Means 40.1	Means 24.2	Means * 23.0	Medians 118.0	
PIHL	52.8	33.3	37.3	25.1	23.3	119.5	
ARLL	53.2	35.6	40.1	25.6	22.6	116.0	
ARHL	49.5	34.0	39.5	24.3	21.3	114.0	
HOLL	52.5	35.2	39.2	24.0	22.8	121.0	
HOHL	49.7	35.2	39.7	24.2			
EGTF	53.5	35.5	43.5	24.6			
EGCB	52.2	32.6	40.6	24.9	21.4	119.0	

* in these cases even the previous analyses of variance did not point to significant differences.

Table VI - Summary results of multiple comparisons tests (females). Vertical bars link the series between which no significant ($p < 0.01$) differences were found. Means and medians for parametric and non-parametric tests, respectively.

Series	Variables													
	GOL		BNL		XCB		XFB		ZYB		AUB		NPH	
	Medians	Means	Medians	Means	Medians	Means	Medians	Means	Medians	Means	Medians	Means	Medians	Means
PILL	181.0	96.5	129.2	107.7	123.0	114.3	123.0	114.3	123.0	114.3	61.0	114.3	61.0	114.3
PIHL	184.0	98.4	127.8	104.4	123.0	118.9	123.0	118.9	123.0	118.9	66.3	118.9	66.3	118.9
ARLL	174.0	95.8	137.4	114.1	131.0	110.3	131.0	110.3	131.0	110.3	70.0	110.3	70.0	110.3
ARHL	170.0	88.5	130.7	105.5	125.0	110.3	125.0	110.3	125.0	110.3	68.0	110.3	68.0	110.3
HOLL	176.0	95.9	134.7	109.8	129.0	110.3	129.0	110.3	129.0	110.3	68.0	110.3	68.0	110.3
HOHL	160.0	99.8	138.5	111.6	123.0	121.3	123.0	121.3	123.0	121.3	65.5	121.3	65.5	121.3
EGTF	179.0	97.3	138.0	110.3	133.5	121.3	133.5	121.3	133.5	121.3	69.0	121.3	69.0	121.3
EGCB	173.5	97.3	131.4	110.3	126.0	110.3	126.0	110.3	126.0	110.3	66.5	110.3	66.5	110.3

Series	Variables											
	NLH		OBH		OBB		NLB		DKB		BRR	
	Means	Medians	Means	Medians	Means	Medians	Means	Medians	Means *	Medians	Means	Medians
PILL	43.3	33.0	37.8	37.8	25.0	21.5	21.5	112.5	21.5	112.5	112.5	112.5
PIHL	51.0	34.0	37.1	37.1	25.5	22.8	22.8	116.5	22.8	116.5	116.5	116.5
ARLL	50.3	36.0	39.1	39.1	24.9	22.0	22.0	112.0	22.0	112.0	112.0	112.0
ARHL	46.0	34.0	37.3	37.3	21.5	20.5	20.5	104.5	20.5	104.5	104.5	104.5
HOLL	48.8	34.0	37.8	37.8	23.5	22.8	22.8	122.0	22.8	122.0	122.0	122.0
HOHL	46.8	35.0	39.0	39.0	23.5	22.8	22.8	122.0	22.8	122.0	122.0	122.0
EGTF	51.0	34.0	41.5	41.5	24.2	20.8	20.8	112.0	20.8	112.0	112.0	112.0
EGCB	48.6	32.0	38.7	38.7	24.4	20.8	20.8	112.0	20.8	112.0	112.0	112.0

* in these cases even the previous analyses of variance did not point to significant differences.

Table VII - Absolute (bold numbers) and relative frequencies of significant differences between pairs of series (above diagonal: males; below diagonal: females).

	PILL	PIHL	ARLL	ARHL	HOLL	HOHL	EGTF	EGCB	Mean % of difference
PILL	-	4/67	6/71	3/71	2/71	3/56	7/66	2/67	
	-	6.0	8.5	4.2	2.8	5.4	10.6	3.0	5.8
PIHL	1/78	-	3/67	2/67	2/67	2/56	3/66	3/67	
	1.3	-	4.5	3.0	3.0	3.6	4.6	4.5	4.2
ARLL	3/81	4/78	-	1/71	2/71	2/56	1/66	2/67	
	3.7	5.1	-	1.4	2.8	3.6	1.5	3.0	3.6
ARHL	2/78	2/78	4/78	-	1/71	1/56	4/66	0/67	
	2.6	2.6	5.1	-	1.4	1.8	6.1	0.0	2.6
HOLL	1/81	3/78	2/81	1/78	-	1/56	3/66	1/67	
	1.2	3.9	2.5	1.3	-	1.8	4.6	1.5	2.6
HOHL	1/56	2/56	0/56	1/56	0/56	-	3/56	2/56	
	1.8	3.6	0.0	1.8	0.0	-	1.8	3.6	3.3
EGTF	4/71	4/71	0/71	4/71	2/71	1/56	-	3/66	
	5.6	5.6	0.0	5.6	2.8	1.8	-	4.6	5.3
EGCB	1/58	1/78	2/78	2/78	0/78	1/56	1/71	-	
	1.3	1.3	2.6	2.6	0.0	1.8	1.4	-	2.8
Mean % of difference	2.5	3.3	2.9	3.1	1.7	1.5	3.3	1.6	

Table VIII - Initial variation explained by the principal components based on the R-standardized variables (size and shape) and R and Q-standardized variables (shape alone).

	PC	Males	Females
Size and shape	1	0.4791	0.4562
	2	0.7357	0.7627
	3	0.8815	0.8532
	4	0.9380	0.9381
Shape alone	1	0.3908	0.5355
	2	0.6952	0.7324
	3	0.8447	0.8570
	4	0.9446	0.9710

Table X - Correlations between the R and Q-standardized variables and the principal components generated (males and females).

Variables	Males		Females		
	PC1	PC2	Variables	PC1	PC2
GOL	-0.959	0.000	GOL	-0.934	0.000
XCB	0.896	0.000	XCB	0.918	-0.291
OBH	0.839	0.000	ZYB	0.750	0.473
NLH	0.000	0.902	NLB	-0.730	-0.454
OBB	0.000	-0.829	OBB	0.699	0.000
ZYB	0.475	0.605	OBH	0.666	-0.475
NLB	0.000	0.421	NLH	0.000	0.793

Table IX - Correlations between the R-standardized variables and the principal components generated (males and females).

Variables	Males		Females		
	PC1	PC2	Variables	PC1	PC2
ZYB	0.973	0.000	XCB	0.877	-0.411
NLH	0.811	0.409	ZYB	0.877	0.286
XCB	0.784	-0.476	OBB	0.854	0.000
OBH	0.657	-0.624	OBH	0.711	-0.365
GOL	0.272	0.749	NLH	0.644	0.532
NLB	0.522	0.625	GOL	0.000	0.939
OBB	0.595	0.000	NLB	0.000	0.771

6). In the case of males the first PC is completely responsible for the major distinction among the series, as described above, and the second PC differentiates each series individually. In the case of females the same pattern is observable but this time the separation between Paleo-Indians and the others again follows a diagonal line.

Considering the correlation between the original variables and the first two PCs one can perceive that for size and shape analyses PC1 is highly related to XCB, ZYB and OBB while GOL is primarily correlated to PC2 (Table IX). Alternatively, in shape analyses the first principal component is preferably associated to neurocranial variables and the second one is more influenced by facial variables (Table X).

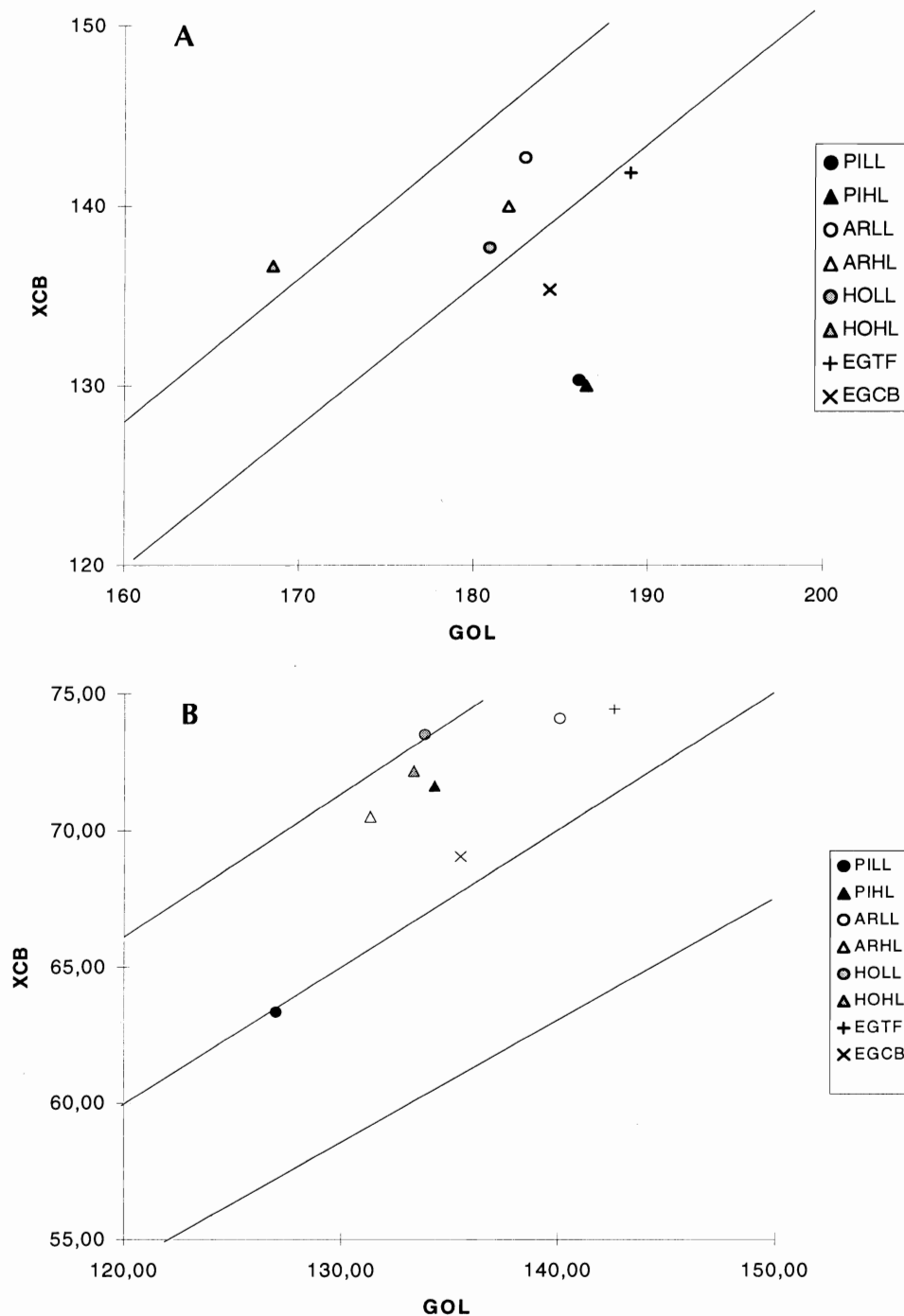


Figure 3 - Mean cranial length (GOL) *versus* mean maximum cranial breadth (XCB) for historic and pre-historic South American populations. Lines separate brachycranial, mesocranial and dolichocephalic groups. A) males and B) females.

DISCUSSION AND CONCLUSIONS

Our results suggest that the early inhabitants of South America were very different in cranial morphology from the later occupants of the continent. Overall cranial shape seems to be the predominant factor of difference since

more recent samples are mesocranial or brachycranial while PILL and PIHL are basically dolichocephalic. Actually, these two series do not present much longer skulls than the others, but they are narrower (Figure 3).

Multivariate analysis supports these observations. In most Principal Components Analyses the main separation is influenced by the two first components, and in these cases,

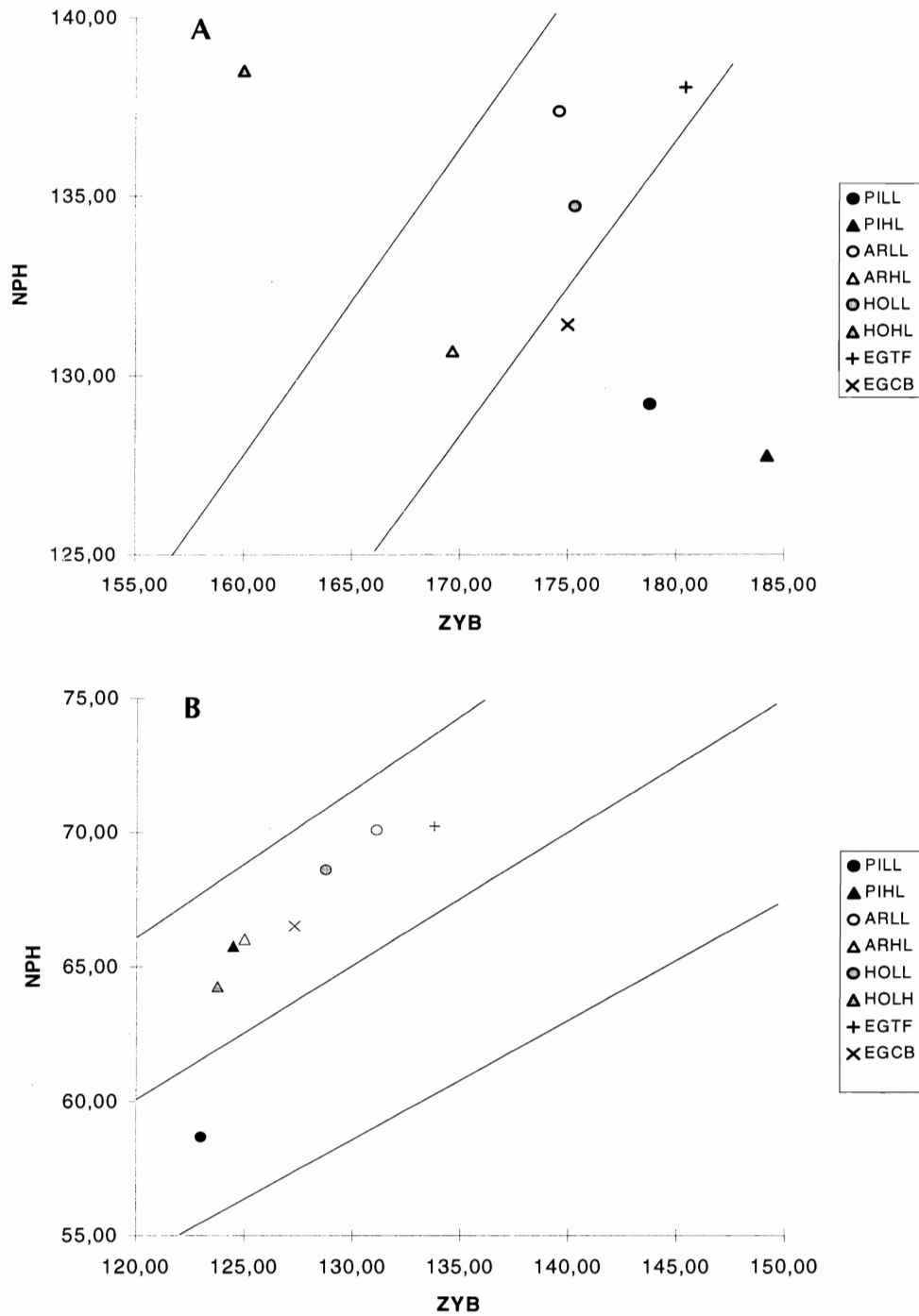


Figure 4 - Mean bitygomatic breadth (ZYB) *versus* mean upper facial height (NPH) for historic and prehistoric South American populations. Lines separate leptene, mesene, euryene and hipereuryene groups. A) males and B) females.

GOL and XCB are better represented by PC1 and PC2 respectively. The only case where PC1 is responsible for the differentiation of PILL and PIHL (Figure 6A) this complex variable concentrates the information from both GOL and XCB.

However, although PILL and PIHL are clearly distinct from the remaining series, they are also distinct from each other. Bivariate graphs (Figure 4) indicate that

Paleo-Indians from South America Lowlands have shorter and narrower faces than Highlands inhabitants of the same period. Again, Figure 6A strengthens this view: PC2 evidently separates PILL from PIHL and this component is strongly related to facial variables (Table X). At first, this distinction could be interpreted as the result of diverse adaptation to Highlands and Lowlands environments. Nevertheless, as this pattern of differentiation is not detected

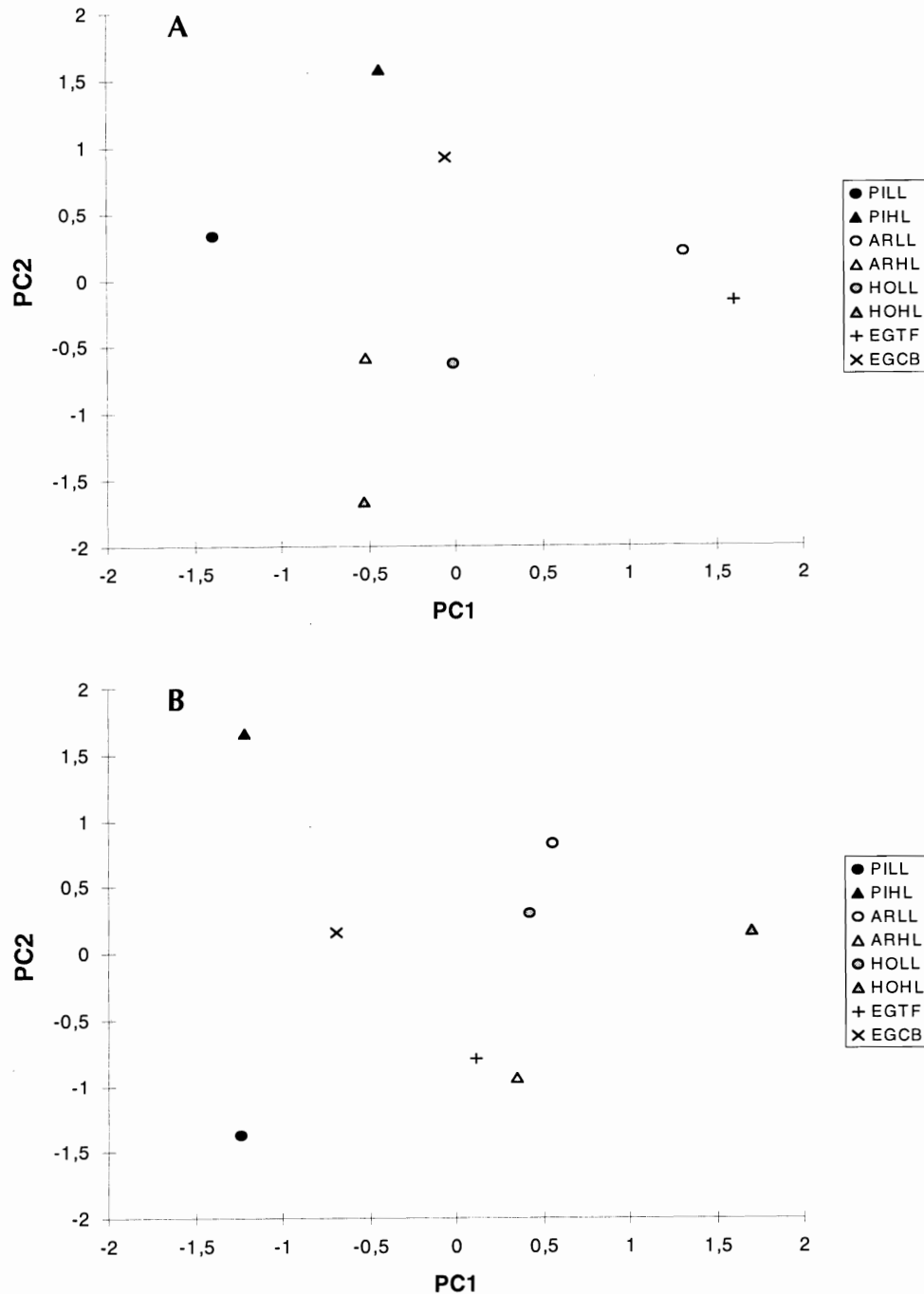


Figure 5 - Plots of the 8 South American skeletal samples along the first and second principal components (R standardized variables). A) males and b) females.

in the other series, under similar conditions, we do prefer not to assume such a simple explanation.

Previous studies on cranial morphology have detected the uniqueness of Paleo-Indians not only in South America (Neves and Pucciarelli, 1989, 1990, 1991) but also in North America (Steele and Powell, 1992a, 1992b; Neves *et al.*, 1993). Differences are not restricted to cranial morphometrics: Powell (1993, p. 814) in a re-analysis of Turner's data on dental variation pointed out that "the position of

Paleo-Indians indicates that they are biologically distinct from their later descendants".

This dissimilarity cannot be easily explained. We envision at least two different interpretations: 1) only one migratory event is involved (in agreement with Greenberg *et al.*, 1986) and differentiation occurred *in situ*; 2) two migratory events occurred during the colonization of South America and Paleo-Indians are not the ancestors of all later Amerindians.

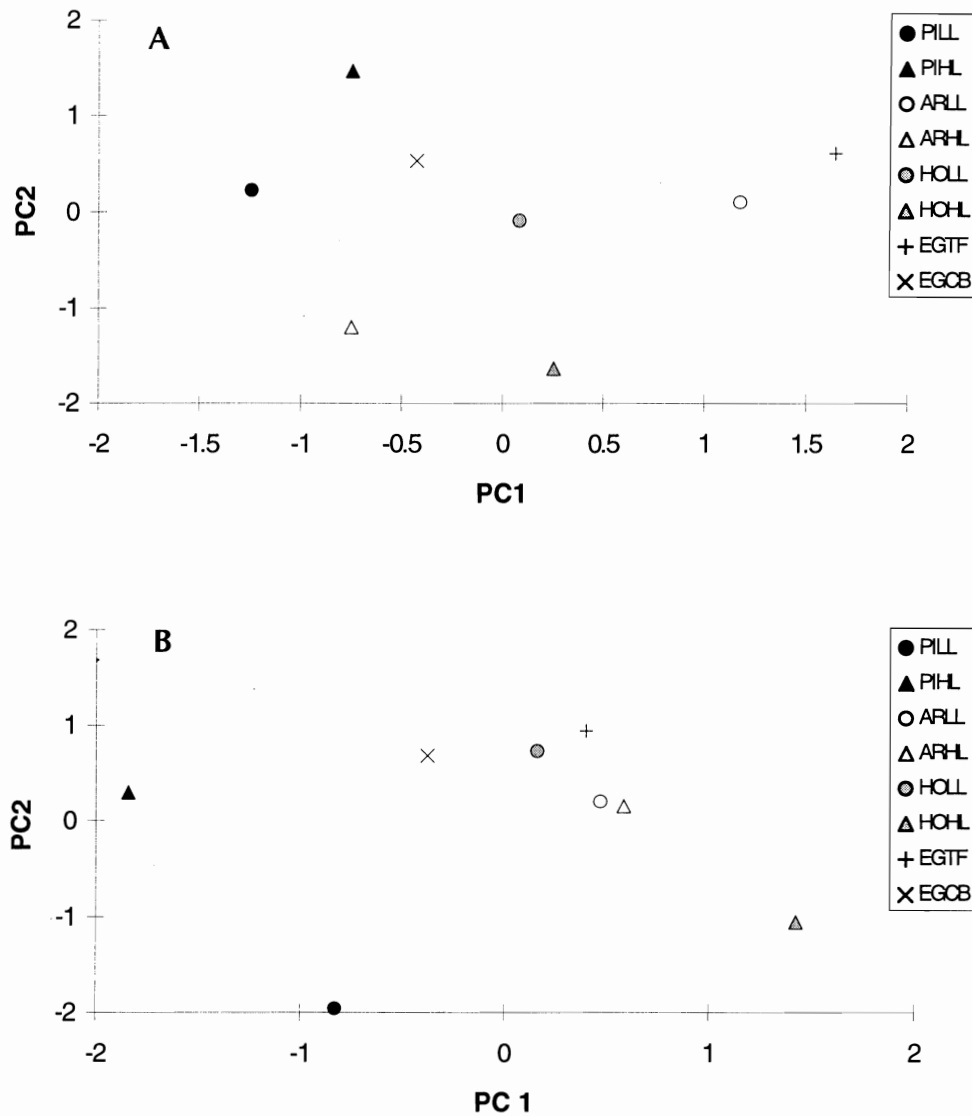


Figure 6 - Plots of the 8 South American skeletal samples along the first and second principal components (R and Q standardized variables). A) males and B) females.

If the first alternative holds true, the differentiation of the more recent groups could be due to local processes, like adaptation and/or developmental responses to environmental stresses. Kasai *et al.* (1993) carried out a comparative study on craniofacial morphology in Japanese and Australian aboriginal populations. They found out that differences in morphology could be attributed to the distinct forms of subsistence of each group. Since Australian hunter-gatherers commonly submit their masticatory apparatuses to intense

forces (abrasive food items and manufacturing) they have larger facial dimensions and smaller cranial dimensions than Japanese horticulturalists. Assuming the idea of Kasai *et al.* (1993) and considering the hard diet and accentuated dental wear of South American shell mound populations (ARLI and ARHL) one would expect these Archaic coastal inhabitants to be similar to the Paleo-Indians in relation to cranial and facial morphology. As shown in Figures 3 and 4 our results do not fit this expectation.

Steele and Powell (1992a), in their analysis of North American Indians, reported a trend to brachycephalization along time. This seems to be a ubiquitous phenomenon in human evolution and could be responsible for the patterns of differentiation detected in the present work. However, it must be noticed that we were unable to reveal a gradual shift to a more brachycranic condition from Paleo-Indians to Archaics and from these latter to the more recent series. Interestingly, both in bivariate (Figure 3) and multivariate analysis (Figure 5 and 6), a historic population (EGCB) and not an archaic sample remains in an intermediate position between PILL/PIHL and the others.

Thus, our results seem to favor the alternative interpretation of an early migratory wave into South America anterior to the entry of Amerind ancestors. This idea has already been defended by Neves and Pucciarelli (1989, 1990, 1991), Neves *et al.* (1993, in press) and Lahr (in press), relying upon metric and non-metric cranial variation. Multivariate analysis comparing South American Paleo-Indians with modern populations (Neves and Pucciarelli, 1989) and Old World hominids of Pleistocene antiquity (Neves and Pucciarelli, 1990, 1991) revealed that these ancient Americans shared a similar cranial morphology with South Pacific aboriginal and pre-historic populations. These results led these authors to argue against the Three-Migration model and to propose an earlier migratory wave into New World, whose point of departure should be found somewhere within the range of distribution of a possible common ancestor to Americans and Australians (Central Asia).

Lahr (in press) explained early Amerindian roots in the broader context of modern human origins. She elegantly reasoned that a generalized kind of *Homo sapiens*, probably a newcomer from Africa, lived in a vast area of continental Asia much before the appearance of the more specialized morphology that characterizes current Northeastern Asian populations. Since Lahr found out that even in the case of relatively recent South American populations, like the inhabitants of Tierra del Fuego and Patagonia, one could discern a non specialized morphology, she concluded that "it is not possible to derive all the South American aboriginal population from a single 'Amerind' wave of people". However, in contrast to Neves and Pucciarelli (1989, 1990, 1991), she does not favor the idea of a common ancestor shared by early Americans and Australians. In her opinion, the peopling of New World must be seen as part of the process of dispersion of modern humans, the similarities between these populations being due to retention of plesiomorphic characteristics.

Genetic evidence seems to support the hypothesis of two major and distinct migratory waves entering South America in pre-historic times. Schanfield (1992), using immunoglobulin allotypes, found that the distribution of GM haplotypes in South American Indians can be explained only if two migrations are assumed to have occurred, ruling out the diversification effects of selection or drift. Studies on mtDNA (Torrioni *et al.*, 1993a, 1993b) also claim for an unsuspected genetic diversity of Amerindians, advocating at least four distinct founding lineages. However, we should be

cautious about using this kind of evidence to infer phylogenetic histories, as remarked by Szathmary (1993).

In sum, the morphological uniqueness of ancient populations in South America suggests a complex process of occupation. In our opinion it is difficult to account for the subtle shift in cranial morphology from Paleo-Indians to their presumed descendants, without assuming at least two migrations of different nature. It is possible that following the first colonizers, represented by non-specialized Paleo-Indians, a new kind of people walked into the New World and, to some extent, replaced their predecessors.

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RESUMO

A diversidade humana no Novo Mundo merece muita atenção por ser de extrema importância para o entendimento do processo de povoamento do continente. Nos últimos anos, o estudo dessa diversidade esteve vinculado ao propósito de testar a hipótese das "Três Migrações" (Turner II, In: *Early Man in the New World*, Sage Publications, 1983; Greenberg *et al.*, *Curr. Anthropol.* 27: 477-497, 1986). Uma vez que essa abordagem parece-nos muito restritiva, o presente trabalho procura interpretar a diversidade da morfologia craniana na América do Sul ao longo do tempo sem necessariamente adotar um modelo de migração como ponto de partida. Para tanto, comparamos dados craniométricos de 502 indivíduos de coleções pré-históricas e históricas de várias localidades da América do Sul através de métodos uni, bi e multivariados. Os resultados apontam a existência de dois padrões morfológicos distintos, um ligado aos grupos de antiguidade Paleo-Índia, outro às populações arcaicas e horticultoras. Mesmo considerando que fenômenos evolutivos locais ou respostas funcionais do crânio a estresses ambientais poderiam ser as causas das diferenças observadas, parece-nos mais coerente com os resultados admitir a entrada de mais de uma corrente migratória na América do Sul.

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