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Quantitative Cranio-Morphology at Man Bac

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The aim of this chapter is to quantitatively assess cranial morphology of the Man Bac assemblage and explore any evidence for biological relationships between Man Bac and surrounding populations dating from prehistoric through to more recent times. An assessment of the morphometric affinities presented here addresses the issue of the origin of this group of neolithic people in northern Vietnam.

MATERIALS AND METHODS

Of the human remains excavated from Man Bac between 1999 and 2007, comprehensive sets of cranial and mandibular measurements were available for 17 adult males and 13 females. A maximum of 32 measurements, and five indices, were recorded for each cranium and mandible (a complete set was not always available) based on Martin's definitions (see Bräuer, 1988) and are presented in the Appendix to this chapter. Male skulls representative of the sample are shown in Figure 3.1 and Table 3.1 provides a basic statistical description of the cranial and mandibular series based on these measurements. Note that Table 3.1 provides summary data for two recognised Man Bac male subgroups (this is discussed below) as well as the total male sample and complete (both sexes) sample.

Of the cranial assemblage, 17 male skulls are utilised for craniometric analysis. The craniometric affinities among the comparison samples are assessed using Q-mode correlation coefficients (Sneath and Sokal, 1973). The comparative samples are listed in Table 3.2, which includes both archaeological and modern samples from East/Southeast Asia and the Pacific. To aid interpretation of phenotypic affinities between the samples, un-rooted tree diagrams were generated using the Neighbour Joining method (Saitou and Nei, 1987), applied to the distance (1-r) matrix of Q-mode correlation coefficients (r). This procedure was undertaken using the software package "Splits Tree Version 4.0" provided by Huson and Bryant (2006).

RESULTS

The majority of the Man Bac cranial series can be characterised as having a relatively narrow and flat face with round orbits (Figure 3.1 left). However, some individuals present quite different features, such as a dolichocephalic cranium with a prominent glabella and a low and wide face (Figure 3.1, right). Since such visually clear morphological variation among the Man Bac cranial series implies the

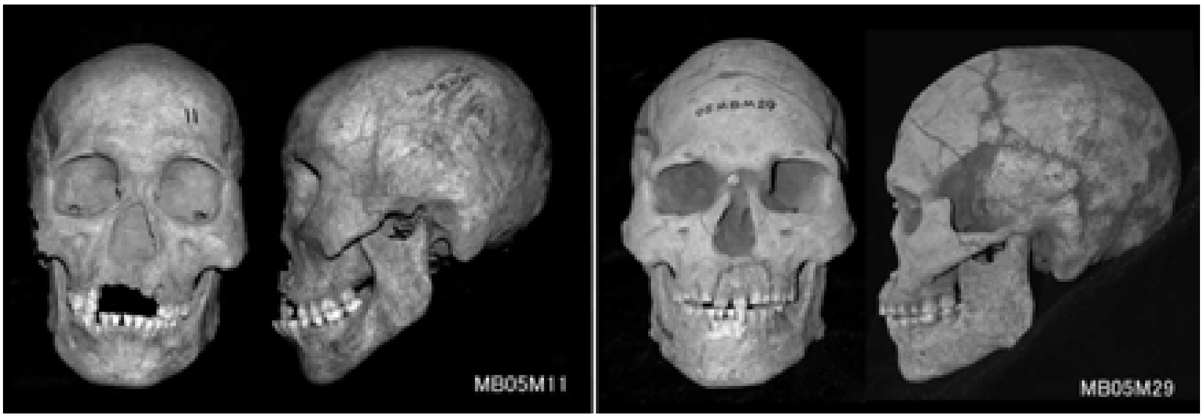

Figure 3.1 Views of representative skulls from the site of Man Bac.

possibility of genetic heterogeneity, multivariate craniometric comparisons were carried out in order to both confirm and assess the degree of phenotypic variation within the Man Bac adult male series.

In order to utilise the greatest number of individual specimens, given differential preservation and consequent availability of measurements, nine cranial measurements (Martin's 1, 8, 9, 45, 48, 51, 52, 54 and 55) were selected for calculating the Q-mode correlation coefficient. A complete data set without any missing values was derived for 14/17 of the Man Bac male adult series. Table 3.3 (upper right triangle) provides the distance matrix (1-r) transformed from the Q-mode correlation coefficients (r) thus computed.

The result of the Neighbour Joining analysis applied to the distance matrix of Q-mode correlation coefficients is presented in Figure 3.2. The non-rooted tree in this figure depicts an apparent divergence into two major clusters. One consists of the majority of Man Bac individuals (n = 9) which have branched from neolithic, Metal Period and modern samples from East and Southeast Asia. In this clustering pattern seven Man Bac specimens are more closely associated with the Metal Period Dong Son Vietnamese among the range of modern Southeast Asian samples. This sub-cluster contains the neolithic and Metal Period sample of Ban Chiang crania from northern Thailand. The modern Vietnamese sample, together with another Man Bac specimen, branches from this sub-cluster. The Hoabinhian, Australian and Melanesian samples form another major cluster, which includes five Man Bac individuals, together with the Jomon.

In the next step of analysis cranial affinities were assessed using group-average measurements for the two identified Man Bac samples, utilising 17 male cranial specimens. As the analysis using the individual dataset yielded a clear dichotomisation of the Man Bac adult male series, five individuals were treated as a separate group designated 'Man Bac 1', while the remaining specimens were combined with other incomplete male crania and labelled 'Man Bac 2'. The descriptive statistics for these two sub-samples is given in Table 3.2. Q-mode correlation coefficients were calculated using the new cranial data set consisting of 16 measurements (Martin's: M1, M8, M9, M17, M43(1), M43c, M45, M46b, M46c, M57, M57a, M48, M51, M52, M54, M55). A distance matrix (1-r) transformed from the Q-mode correlation coefficients thus calculated are given in Table 3.3 (left lower triangle). Figure 3.3 depicts an un-rooted tree using the Neighbour Joining method based on the distance matrix of Q-mode correlation coefficients. 'Man Bac 1' is tightly connected with the early Vietnamese samples including the Hoabinhian, Bac Son and Da But (Con Co Ngua) series. These samples form a mega cluster together with the Australo-Melanesian, Gua Cha (Malaysia) and Jomon (Japan) samples. On the other hand, the 'Man Bac 2' and Dong Son Vietnamese, forming a sub-cluster together with Ban Chiang (Thailand) and modern Vietnamese, are linked closely with another major cluster consisting of the neolithic to modern period samples from East/Southeast Asia, as well as the Neolithic Weidun sample from China.

Table 3.1 Cranial and mandibular measurements (mm) and indices for the Man Bac people.

Martin's No and measurement	Man Bac 1 (males)			Man Bac 2 (males)			Man Bac all (males)			Man Bac all (females)		
	n	M	SD	n	M	SD	n	M	SD	n	M	SD
1 Max. cranial length	5	185.6	4.0	11	179.7	5.7	16	181.6	5.8	12	174.5	6.0
5 Basion-nasion length	5	102.6	4.5	5	99.4	6.7	10	101.0	5.6	5	95.0	4.8
8 Max. cranial breadth	5	143.6	6.8	11	142.4	5.7	16	142.8	5.8	12	134.8	3.3
9 Min. frontal breadth	5	100.4	5.9	11	98.5	4.0	16	99.1	4.6	12	94.0	5.0
10 Max. frontal breadth	5	114.6	9.0	8	118.8	5.8	13	117.2	7.2	10	113.8	4.6
12 Max. occipital breadth	5	113.4	5.9	8	109.4	4.9	13	110.9	5.4	8	108.5	3.9
17 Basion-bregma height	5	143.8	6.3	6	140.0	8.9	11	141.7	7.7	5	134.2	10.7
29 Frontal chord	5	116.4	2.7	8	111.5	3.5	13	113.4	3.9	10	107.3	5.6
30 Parietal chord	5	118.6	3.8	8	114.5	6.7	13	116.1	6.0	10	111.3	7.8
31 Occipital chord	5	105.0	2.8	7	106.0	5.7	12	105.6	4.6	6	100.8	5.8
40 Basion-prosthion length	5	102.2	0.8	5	99.0	2.7	10	100.6	2.5	5	90.8	3.3
43 Upper facial breadth	5	113.0	5.1	11	110.5	5.7	16	111.3	5.5	8	105.5	4.1
45 Bizygomatic breadth	5	142.0	6.2	10	141.6	6.9	15	141.7	6.5	8	132.5	7.1
46 Bimaxillary breadth	5	109.0	4.5	10	108.2	6.1	15	108.5	5.5	6	103.3	4.1
48 Upper facial height	5	68.8	3.1	10	71.0	4.0	15	70.3	3.8	7	68.0	3.4
51 Orbital breadth	5	44.2	1.9	9	41.6	2.1	14	42.5	2.3	8	41.0	1.3
52 Orbital height	5	33.0	2.0	11	35.5	1.8	16	34.7	2.1	9	34.6	1.3
54 Nasal breadth	5	28.8	3.1	11	28.1	1.4	16	28.3	2.0	8	25.9	2.6
55 Nasal height	5	51.0	2.5	10	54.1	3.5	15	53.1	3.5	7	51.6	3.1
60 Upper alveolar length	5	54.2	0.8	10	53.0	3.0	15	53.4	2.5	7	52.4	3.7
61 Upper alveolar breadth	5	66.6	2.1	10	67.0	3.5	15	66.9	3.0	6	63.5	3.5
8:1 Cranial index	5	77.5	5.2	11	79.3	4.2	16	78.7	4.4	10	77.9	4.4
48:45 Upper facial index	5	48.6	4.2	10	45.7	16.3	15	46.6	13.4	6	52.4	1.3
43(1) Frontal chord	5	104.2	5.1	8	103.5	6.6	13	103.8	5.9			
43c Frontal subtense	5	16.3	5.1	8	14.6	3.2	13	15.2	3.9			
57 Simotic chord	5	9.6	1.6	5	10.2	2.6	10	9.9	2.1			
57a Simotic subtense	4	3.2	0.7	5	3.0	1.9	9	3.1	1.4			
46b Zygomaxillary chord	5	107.6	6.1	6	107.0	6.8	11	107.3	6.2			
46c Zygomaxillary subtense	5	22.6	4.1	6	22.5	4.7	11	22.5	4.2			
43c:43(1) Frontal index	5	15.8	5.5	8	14.1	2.8	13	14.7	3.9			
57a:57 Simotic index	4	33.6	1.7	5	26.6	12.4	9	29.7	9.6			
46c:46b Zygomaxillary index	5	21.1	4.2	6	20.9	3.8	11	21.0	3.8			
66 Bigonial breadth	5	104.6	7.5	9	105.9	9.4	14	105.4	8.5	8	96.3	6.3
68 Mandibular length	5	83.2	1.6	9	80.8	4.1	14	81.6	3.5	8	74.5	5.5
69 Symphyseal height	5	33.2	4.1	9	33.3	3.4	14	33.3	3.5	7	32.9	2.3
70 Ramus height	5	68.0	6.3	8	67.6	5.6	13	67.8	5.6	8	59.1	6.8
71 Ramus breadth	5	39.2	1.6	9	37.0	3.2	14	37.8	2.9	8	35.5	1.8

Man Bac 1 consists of 05M29, 07H1M8, 07H2M27, 07H2M30 and 07H2M32.
Man Bac 2 consists of the other 12 individuals given in Appendix 3.1.

Table 3.2 Comparative prehistoric cranial samples from East/Southeast Asia.

	Period	Data Source	Storage	Remark
Hoabinhian Vietnam	Late Pleistocene - Early Holocene	H.M.	IAH, MHO	Sites of Mai Da Nuoc, Mai Da Dieu, Lang Gao, Lang Bon in northern Vietnam (Cuong, 1986, 2007)
Bac Son	Early Holocene (c. 8,000-7,000 BP)	H.M.	MHO	Sites of Pho Binh Gia, Lang Cuom, Cua Gi, Dong Thuoc in northern Vietnam
Con Co Ngua	Early Neolithic Da But culture (c.5,000 BP)	Cuong, 2003	IAH, MHO	Sites of Con Co Ngua 'Thuy, 1990) and Da But in Than Hoa Prov. northern Vietnam; M43(1),43c,46b,46c,57,57a by H.M.
Dong Son	Early Metal Age (3,000-1,700 BP)	Cuong, 1996, and H.M.	IAH, CSPH	Sites of Vinh Quang, Chau Son, Doi Son, Quy Chu, Thieu Duong, Nui Nap, Dong Mom, Minh Duc, Dong Xa in northern Vietnam
Gua Cha	Hoabinhian (c.8,000-6,000 BP)	H.M.	UCB	Site in Kelantan Prov., Malaysia; specimen No. H12; Sieveking (1954)
Ban Chiang	Neolithic-Bronze Age (c. 3,500-1,800 BP)	Pietrusewsky and Douglas, 2002	UHW, SAC	Site in Udon Thani Prov., Thailand; M51by Hanihara, 1993; M43(1),43c,46b,46c,57,57a by H.M.
Weidun	Neolithic (c.7,000-5,000 BP)	Nakahashi et al., 2002.		Nakahashi and Li, 2002
Anyang	Bronze - Iron Age (c. 3,300 BP)	IHIA 1982; Han and Qi, 1985	AST	M43(1),43c,46b,46c,57,57a by H.M.
Jiangnan	Zhou-Western Han (2,770-1,992 BP)	Nakahashi et al., 2002		Jiangnan Region, Sth China; Nakahashi and Li, 2002
Jomon	Late Jomon (c. 5,000-2,300 BP)	Hanihara, 1993, 2000		Sites in Japan; Yamaguchi, 1982
Yayoi	Early Metal Age (2,800-1,700 BP)	Ishida, 1992; Nakahashi, 1993		
Bunun	Modern	Pietrusewsky and Chang, 2003	NTW	M43(1),43c,45,46b,46c,48,51,55,57,57a by H.M.
Cambodia	Modern	H.M.	MHO	-
Celebes	Modern	Pietrusewsky, 1981; Hanihara, 2000	BMNH	M17,45,48,51 by H.M.
Dayak	Modern	Yokoh, 1940; Hanihara 2000		
Hainan	Modern	Howells, 1989	NTW	M43(1),43c,46b,46c,48,51,55,57,57a by H.M
Java	Modern	Pietrusewsky, 1981; Hanihara, 2000	BMNH	M17,45,48,51 by H.M.
Laos	Modern	Cuong, 1996	MHO	M43(1),43c,46b,46c,57,57a by H.M.
Myanmar	Modern	Pietrusewsky, 1981; Hanihara, 2000	BMNH	M17,45,48,51 by H.M.
North China	Modern	Hanihara, 1993, 2000		
Philippines	Modern	Suzuki et al., 1993	NMP	M43(1),43c,46b,46c,57,57a by H.M.
Sumatra	Modern	Pietrusewsky, 1981; Hanihara, 2000	BMNH	M17,45,48,51 by H.M.
Thai	Modern	Sangvichien, 1971; Hanihara, 2000		
Vietnam	Modern	H.M.	MHO	
Australia	Modern	Hanihara, 1993	BMNH, UCB	M43(1),43c,46b,46c,57,57a by H.M.
Melanesia	Modern	Hanihara, 1993, 2000		
Loyalty	Modern	H.M.	MHO	

In 'Remarks': M=Martin's cranial measurment number, In 'Storage': institutions of materials studied by H.M. (H. Matsumura) AST=Academia Sinica of the Republic of China in Taipei; BMNH=Department of Palaeontology, Natural History Museum, London; CSPH=Center for South East Asian Prehistory, Hanoi; IAH=Department of Anthropology, Institute of Archaeology, Hanoi; MHO=Laboratoire d'Anthropologie Biologique, Musée de l'Homme, Paris; NMP=Department of Archaeology, National Museum of the Philippines, Manila; NTW=Department of Anatomy, National Taiwan University, SAC=Princess Maha Chakri Sirindhorn Anthropology Centre, Bangkok; UCB=Department of Biological Anthropology, University of Cambridge; UHW=Department of Anthropology, University of Hawaii.

Figure 3.2 An un-rooted tree of neighbour joining analysis applied to the distances of Q-mode correlation coefficients between the Man Bac individuals and comparative samples (based on 9 male cranial measurements).

Figure 3.3 An un-rooted tree of neighbour joining analysis applied to the distances of Q-mode correlation coefficients between the two groups of Man Bac individuals and comparative samples (based on 16 male cranial measurements).

DISCUSSION

Archaeological and linguistic research has linked the dispersal of Austronesian and Austroasiatic language families with the demographic expansion of rice cultivating people during the Neolithic period, and have sought the ultimate homeland of these language and population dispersals in southern China and Taiwan (Renfrew, 1987, 1989, 1992; Bellwood, 1991, 1993, 1996, 1997; Bellwood et al, 1992; Blust, 1996a, b; Glover and Higham, 1996; Higham, 1998, 2001; Bellwood and Renfrew, 2003; Diamond and Bellwood, 2003). With respect to analyses of human skeletal data, the 'Two Layer' model, is instrumental in understanding the population history of mainland Southeast Asia (e.g. Callenfels, 1936; Mijsberg, 1940; Von Koenigswald, 1952; Coon, 1962; Jacob, 1967; Brace et al, 1991, Matsumura and Hudson, 2005; Matsumura, 2006). This model hypothesises that Southeast Asia was initially occupied by indigenous populations, akin to modern Australo-Melanesians, that later exchanged genes with immigrants from North and/or East Asia, leading to the formation of present day Southeast Asian populations. However, some recent cranial and dental studies question this model, alternatively advocating regional continuity or local evolutionary scenarios in order to account for the region's population history (e.g. Turner, 1990; Hanihara, 1994; 2006; Pietrusewsky, 1994, 2005, 2006, 2008). The question arises as to whether these opposing models address the timing and scale of the population dispersal under debate with regard to the expansion of Austroasiatic and Austronesian languages and rice farming cultures, and whether there was a resultant mixture with replacement of extant populations.

Table 3.3 Distance (1-r) matrices of Q-mode correlation coefficients (r), based on 9 cranial measurements (upper right triangle), and on 16 cranial measurements (lower left triangle).

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	MB99M3	0.86	1.50	1.40	0.77	1.32	1.15	1.18	1.65	1.56	0.93	0.80	1.21	1.08	1.72	0.98	1.09
2	MB01M5		0.55	0.43	1.12	0.78	0.37	1.28	1.08	1.32	0.49	0.90	0.86	1.12	1.07	0.98	1.43
3	MB01M9			0.47	0.75	1.13	0.47	0.75	0.62	0.69	0.65	1.59	0.61	0.80	0.67	0.96	1.37
4	MB01M10				1.15	0.83	0.45	1.30	0.55	0.73	0.55	1.22	0.64	1.09	0.88	1.18	1.17
5	MB05M11					1.92	1.00	1.23	1.27	0.80	0.87	1.55	1.30	1.36	1.25	1.31	1.23
6	MB05M29						0.97	0.96	0.60	1.36	1.30	0.47	0.67	0.63	0.55	0.49	0.65
7	MB05M31							1.07	0.67	0.65	0.83	1.49	0.56	0.91	0.83	1.36	1.11
8	MB07H1M5								0.95	0.76	0.96	1.21	0.69	0.40	0.92	0.84	1.16
9	MB07H1M8									0.73	1.40	1.48	0.21	0.44	0.50	0.77	0.53
10	MB07H2M1										0.86	1.56	0.97	1.16	0.77	1.68	1.08
11	MB07H2M10											0.93	1.25	1.44	1.52	1.46	1.92
12	MB07H2M27												1.53	1.34	1.08	0.78	1.05
13	MB07H2M30													0.15	0.83	0.64	0.68
14	MB07H2M32														0.78	0.37	0.59
15	Hoabinhian Mai Da Dieu 16															0.66	0.48
16	Hoabinhian Mai Da Nuoc																0.56
17	Hoabinhian Lang Bon																

Table 3.3 (Continued).

		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
1	MB99M3			1.01	0.89	1.27	0.88	0.91	0.69	0.87	1.26	0.76	1.03	1.13	0.64	1.23	1.04	0.96	1.50	0.80	1.31	0.74	0.82	0.93	1.08	0.36	0.67	1.15	0.20	1.44
2	MB01M5			0.75	1.39	1.22	0.85	1.00	1.00	0.97	1.08	1.08	0.20	0.70	0.60	1.13	1.14	1.00	1.16	1.18	1.33	1.48	0.91	1.28	0.74	0.89	0.85	0.78	0.79	1.02
3	MB01M9			1.20	1.26	1.05	1.12	1.39	0.83	1.05	0.88	0.55	0.41	0.74	0.93	1.21	1.01	0.83	0.92	1.03	1.17	1.56	1.18	1.39	0.52	1.68	0.96	0.35	1.34	1.16
4	MB01M10			1.11	1.50	0.92	0.76	0.92	1.19	1.09	0.77	1.27	0.54	0.78	1.27	0.94	0.92	1.39	0.66	1.06	1.06	1.31	0.96	1.17	0.68	0.98	1.14	0.65	1.47	1.04
5	MB05M11			1.32	1.25	1.15	1.09	0.74	0.76	1.03	1.08	0.25	0.91	1.20	0.76	1.35	0.99	0.56	1.64	0.89	1.05	1.08	1.02	0.84	1.18	0.93	0.77	0.45	1.06	1.37
6	MB05M29			0.71	0.72	0.60	1.00	1.10	1.40	1.28	0.69	1.67	0.92	0.49	1.30	0.43	1.37	1.50	0.38	1.39	0.76	0.89	1.26	1.39	1.00	1.17	1.42	1.63	1.04	0.67
7	MB05M31			0.68	1.80	1.32	1.23	1.11	0.48	0.67	1.34	0.94	0.80	0.87	0.64	1.21	0.80	0.77	0.81	0.58	1.70	1.84	0.70	1.35	0.43	1.16	0.41	0.34	0.86	0.90
8	MB07H1M5			1.07	0.65	1.29	1.18	1.91	0.53	0.58	1.26	0.73	1.21	1.21	0.90	1.34	0.60	0.75	0.72	0.59	1.33	1.19	0.90	1.08	0.39	1.67	0.77	0.83	0.80	1.01
9	MB07H1M8			1.34	1.05	0.49	1.05	1.18	0.99	1.38	0.43	1.12	1.16	0.49	1.65	0.59	1.25	1.50	0.15	0.96	0.89	1.10	1.31	1.63	0.85	1.52	1.31	0.94	1.42	0.97
10	MB07H2M1			0.90	1.59	1.31	1.21	1.09	0.69	0.50	1.39	0.96	1.38	1.50	0.99	1.32	0.31	0.62	0.80	0.45	1.30	1.50	0.59	0.65	0.61	1.27	0.59	0.31	1.46	0.71
11	MB07H2M10			1.07	1.30	1.66	0.43	1.18	0.99	0.52	1.28	1.07	0.44	1.51	0.61	1.71	0.46	0.77	1.39	0.90	1.29	1.38	0.46	0.53	0.78	0.80	0.81	0.55	1.02	0.89
12	MB07H2M27			0.59	0.62	0.95	0.76	0.71	1.63	1.07	1.02	1.66	0.85	1.05	0.91	0.74	1.17	1.16	1.20	1.54	0.59	0.61	1.00	0.64	1.45	0.56	1.35	1.77	0.89	0.63
13	MB07H2M30			1.41	0.95	0.72	1.03	1.55	0.60	1.19	0.60	0.87	1.07	0.48	1.44	0.83	1.17	1.50	0.21	0.70	1.29	1.13	1.21	1.81	0.49	1.47	1.05	0.86	0.91	1.31
14	MB07H2M32			1.34	0.55	0.67	1.22	1.71	0.61	1.21	0.67	0.74	1.19	0.49	1.38	0.76	1.26	1.39	0.32	0.79	1.16	0.90	1.38	1.78	0.52	1.60	1.10	1.13	0.74	1.39
15	Hoabin. Mai Da Dieu 16			0.64	1.02	0.45	1.69	0.92	1.30	1.38	0.83	1.04	0.97	0.47	1.25	0.36	1.37	1.03	0.61	1.38	0.65	1.10	1.58	1.37	0.87	1.61	1.25	1.10	1.54	0.86
16	Hoabin. Mai Da Nuoc			1.25	0.22	0.28	1.19	1.22	1.32	1.74	0.36	0.83	0.75	0.20	1.45	0.35	1.80	1.54	0.73	1.58	0.51	0.44	1.85	1.69	1.07	1.36	1.63	1.64	0.96	1.47
17	Hoabin. Lang Bon			0.95	0.79	0.24	1.54	0.73	1.12	1.54	0.66	1.07	1.53	0.44	1.59	0.17	1.50	1.48	0.47	1.11	0.67	0.53	1.56	1.46	1.11	1.04	1.26	1.46	1.11	1.24
18	Man Bac 1																													
19	Man Bac 2	0.78																												
20	Anyang	0.97	1.12		1.42	1.28	1.51	0.75	1.01	0.61	1.69	1.35	1.03	1.13	0.42	0.92	0.82	0.53	1.18	1.01	1.25	1.40	0.76	0.74	0.85	0.86	0.55	1.04	0.83	0.51
21	Australia	1.51	0.94	1.54		0.54	0.87	1.30	1.34	1.47	0.48	0.92	1.03	0.72	1.42	0.67	1.45	1.40	0.89	1.44	0.44	0.25	1.54	1.20	1.28	1.22	1.64	1.71	0.93	1.28
22	Bac Son	1.00	0.59	1.30	0.78		1.25	0.69	1.56	1.93	0.20	1.02	1.00	0.20	1.80	0.08	1.81	1.71	0.58	1.62	0.25	0.35	1.89	1.55	1.32	1.17	1.77	1.57	1.46	1.37
23	Ban Chiang	0.44	0.73	0.78	1.42	0.98		1.04	1.21	0.92	0.69	1.39	0.80	1.31	1.12	1.40	0.83	1.29	1.03	1.04	0.92	0.88	0.60	0.72	1.37	0.64	1.29	1.10	0.99	0.78
24	Bunun	1.52	1.66	0.81	0.91	1.07	1.37		1.54	1.36	0.90	1.28	0.99	0.94	1.07	0.60	1.30	1.08	1.35	1.43	0.55	0.74	1.12	0.71	1.67	0.36	1.21	1.24	1.32	0.88
25	Cambodia	0.99	1.01	1.19	1.14	1.34	1.37	1.30		0.40	1.53	0.51	1.34	1.28	0.57	1.58	0.54	0.57	0.95	0.11	1.89	1.53	0.53	1.18	0.39	1.18	0.17	0.38	0.37	1.16
26	Celebes	1.23	1.46	0.69	1.25	1.75	1.25	0.76	0.52		1.87	1.10	1.26	1.82	0.34	1.80	0.08	0.35	1.17	0.25	1.77	1.63	0.10	0.45	0.55	0.91	0.19	0.47	0.61	0.56
27	Da But	0.74	0.49	1.47	0.85	0.20	0.62	1.33	1.35	1.81		1.03	0.79	0.34	1.80	0.43	1.71	1.78	0.60	1.58	0.30	0.43	1.69	1.52	1.42	1.18	1.88	1.45	1.43	1.31
28	Dayak	1.29	1.38	1.18	0.85	1.04	1.52	0.81	0.52	0.78	1.29		0.87	0.87	0.82	1.23	1.14	0.66	1.36	0.82	1.20	1.06	1.30	1.30	0.73	1.37	0.75	0.53	0.82	1.67
29	Dong Son	0.62	0.87	1.09	1.12	1.05	0.89	1.14	1.15	0.96	0.98	1.11		0.65	0.78	1.05	1.33	1.02	1.35	1.57	0.86	1.19	1.26	1.20	0.97	1.10	1.26	0.90	1.13	1.16
30	Gua Cha	1.00	0.51	1.21	0.61	0.51	1.26	1.01	1.18	1.65	0.68	0.89	0.91		1.45	0.23	1.88	1.57	0.62	1.54	0.64	0.74	1.84	1.88	1.01	1.30	1.51	1.37	1.11	1.43
31	Hainan	1.34	1.56	0.71	1.13	1.55	1.50	0.69	0.54	0.29	1.68	0.50	0.93	1.34		1.64	0.62	0.15	1.66	0.73	1.61	1.65	0.45	0.67	0.84	0.89	0.25	0.59	0.46	0.69
32	Hoabinhian	1.13	0.63	0.99	0.76	0.15	1.11	0.85	1.44	1.61	0.54	1.09	1.07	0.36	1.48		1.75	1.63	0.59	1.61	0.34	0.44	1.79	1.47	1.26	1.04	1.63	1.66	1.35	1.20
33	Java	1.22	1.46	0.95	1.18	1.61	1.30	0.88	0.51	0.13	1.63	0.79	1.14	1.70	0.44	1.62		0.52	1.06	0.27	1.60	1.48	0.15	0.34	0.56	0.90	0.36	0.44	0.92	0.64
34	Jiangnan	1.11	1.65	0.56	1.33	1.47	1.21	0.74	0.65	0.34	1.54	0.59	1.10	1.60	0.21	1.50	0.48		1.61	0.67	1.46	1.63	0.53	0.55	0.87	1.15	0.30	0.45	0.78	0.63
35	Jomon	1.09	0.43	1.28	0.68	0.89	1.19	1.07	0.99	1.12	0.88	1.34	1.06	0.58	1.46	0.78	1.05	1.57		0.83	0.99	0.96	1.17	1.51	0.67	1.39	1.25	1.16	1.22	0.94
36	Laos	1.00	1.14	1.29	0.94	1.34	1.37	1.03	0.37	0.57	1.27	1.01	1.22	1.23	0.85	1.35	0.55	0.85	0.69		1.84	1.46	0.31	0.87	0.44	0.98	0.20	0.40	0.56	0.98
37	Loyalty	1.55	1.07	1.30	0.42	0.59	1.42	0.70	1.45	1.42	0.79	0.79	1.20	0.55	1.12	0.52	1.24	1.29	0.96	1.34		0.28	1.68	0.97	1.67	1.00	1.91	1.65	1.64	1.05
38	Melanesia	1.72	1.18	1.42	0.26	0.67	1.53	0.61	1.15	1.24	0.89	0.66	1.44	0.69	1.01	0.66	1.04	1.26	0.90	1.07	0.22		1.55	1.01	1.49	0.70	1.70	1.76	1.12	1.43
39	Myanmar	1.41	1.43	0.90	1.14	1.72	1.36	0.72	0.54	0.15	1.74	0.76	1.06	1.49	0.29	1.60	0.15	0.55	1.06	0.66	1.12	0.97		0.39	0.83	0.64	0.32	0.55	0.66	0.46
40	North China	1.43	1.65	0.77	1.09	1.44	1.11	0.60	1.08	0.46	1.49	0.85	1.16	1.66	0.50	1.43	0.32	0.51	1.39	1.18	0.87	0.77	0.35		1.26	0.52	0.79	0.91	1.14	0.54
41	Philippines	0.93	1.11	0.90	0.94	1.37	1.36	0.84	0.64	0.52	1.47	0.81	1.05	0.95	0.81	1.18	0.65	0.83	0.61	0.40	1.31	1.11	0.79	1.20		1.40	0.48	0.47	0.80	1.26
42	Sumatra	1.60	1.47	1.16	0.83	1.16	1.57	0.40	0.86	0.53	1.39	0.73	0.81	1.16	0.46	1.06	0.55	0.85	1.08	0.85	0.79	0.58	0.37	0.51	0.97		0.91	1.24	0.74	1.01
43	Thai	1.05	1.43	0.57	1.45	1.69	1.26	0.85	0.30	0.22	1.76	0.66	1.21	1.46	0.29	1.58	0.37	0.28	1.23	0.50	1.56	1.32	0.36	0.71	0.51	0.79		0.35	0.44	0.87
44	Vietnam	0.39	1.06	1.03	1.63	1.29	0.86	1.32	0.55	0.63	1.18	0.89	0.47	1.36	0.83	1.44	0.66	0.70	1.15	0.74	1.62	1.75	0.81	1.06	0.83	1.04	0.62		1.05	1.03
45	Weidun	0.98	0.94	0.56	1.42	1.16	0.65	1.13	0.74	0.64	1.24	0.80	0.82	1.27	0.72	1.08	0.95	0.72	1.43	1.18	1.46	1.40	0.83	0.99	1.04	0.95	0.63	0.74		1.15
46	Yayoi	0.80	0.86	0.63	1.48	0.94	0.44	1.20	1.17	0.93	0.80	1.39	0.88	1.48	1.00	1.12	0.91	0.77	1.21	1.44	1.40	1.46	1.02	0.68	1.50	1.19	1.04	0.79	0.73	

With regard to qualitative cranial morphology, the late Pleistocene/early Holocene Hoabinhian and Bac Son samples, in addition to the mid-Holocene Da But individuals, share dolichocephalic calvaria, large zygomatic bones, a remarkably prominent glabella, a concave nasal root and a low and wide face with prominent prognathism. On the other hand, the majority of Metal Period Dong Son individuals tend to possess an array of distinctive cranial features represented by relatively narrow and long faces, flat glabella and nasal roots, and round orbits. Such a remarkable discontinuity in cranial morphology between the pre- and early historic populations suggests that the neolithic period may be regarded as a turning point in terms of the micro-evolutionary history of northern Vietnam, at least. Multivariate analysis using the data set of the craniomorphometric dataset supports the view that Bac Son and Da But populations are direct descendants of Hoabinhian settlers, while much later Dong Son populations owe a significant proportion of their genetic heritage to immigrant populations from the northern peripheral areas of Vietnam, including southern China. In the current analysis it can be seen that the neolithic Man Bac sample is not a genetically homogeneous group. Many Man Bac individuals display cranial features common in the later Dong Son sample, whereas some individuals exhibit characteristics possibly inherited or retained from earlier mid-Holocene and even late Pleistocene Hoabinhian populations. This suggests an initial appearance of immigrants during the Phung Nguyen culture phase currently best characterised, in terms of human biology, by Man Bac, and the coexistence of different population lineages in a single site. The Man Bac specimens lend strong support to the 'Two Layer' model.

SUMMARY

This chapter has described the quantitative morphology of the cranial series from the Man Bac site. Multivariate comparisons using craniometric data demonstrates that the Man Bac series is clearly not a monophyletic group. Some individuals closely resemble the earlier pre-neolithic settlers of the region, while others show a close affinity to the later Dong Son, or Metal Period, inhabitants. This remarkable intra-group variation in cranial morphology suggests an initial appearance of immigrants at Man Bac with a genetic heritage located in the northern peripheral region of Vietnam, which includes the area currently encompassed by southern China.

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Appendix 3.1 Cranial and mandibular measurements (mm) and indices for the Man Bac specimens (Sex M=male, F=female).

Sample No.	99 M3	01 M5	01 M9	01 M10	05 M11	05 M20	05 M29	05 M31	07H1 M5	07H1 M8	07H1 M9	07H2 M1	07H2 M10	07H2 M19	07H2 M27
Martin's No. / Sex	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
1 Max. cranial length	180	185	174	184	173	180	186	175	177	185	192	176	181		192
5 Basion-nasion length	99	93		104	93		96			105			108		105
8 Max. cranial breadth	139	143	137	145	136	140	138	155	140	147	140	150	141		135
9 Min. frontal breadth	96	103	98	102	93	98	95	101	96	101	97	94	106		94
10 Max. frontal breadth	118				116	113	110	130	117	123	117	125	114		120
12 Max. occipital breadth	104				104	110	105	107	116	110	109	108	117		115
17 Basion-bregma height	142	134		138	128		136			147		154	144		138
29 Frontal chord	117				111	113	115	110	107	116	113	114	107		114
30 Parietal chord	115				102	116	120	112	118	119	126	112	115		114
31 Occipital chord	101				108		102	98	104	104	115	110	106		108
40 Basion-prosthion length	96	100		99	97		103			102			103		102
43 Upper facial breadth	102	118	110	110	106	107	109	111	115	114	104	113	120		107
45 Bizygomatic breadth	128	142	147	144	130		138	146	142	146	144	147	146		133
46 Bimaxillary breadth	102	108	109	102	113		111	100	110	105		109	121	108	107
48 Upper facial height	70	75	67	68	70	66	67	74	70	69		71	79		74
51 Orbital breadth	42	40	40	41	40		42	39	45	44		44	43		43
52 Orbital height	34	34	35	35	39	37	30	34	34	35	34	37	37		32
54 Nasal breadth	28	29	28	26	28	28	26	29	29	28		26	27	31	26
55 Nasal height	53	56	52	54	50	52	49	53	54	49		54	63		55
60 Upper alveolar length	49	57		50	54	50	54	53	55	53	52	52	58		55
61 Upper alveolar breadth	62	67		66	71	62	68	66	67	64	72	71		66	65
8:1 Cranial index	77.2	77.3	78.7	78.8	78.6	77.8	74.2	88.6	79.1	79.5	72.9	85.2	77.9		70.3
48:45 Upper facial index	54.7	52.8	45.6	47.2	53.8		48.6	50.7	49.3	47.3	0.0	48.3	54.1		55.6
43(1) Frontal chord		109	110		95		101	100	107	107	94	103	110		97
43c Frontal subtense		18	16		12		17	10	14	8	16	12	19		23
57 Simotic chord		11.4			6.5		10.1		8.6	7.6		11.7	12.9		9.5
57a Simotic subtense		2.8			0.8				1.5	2.6		4.3	5.4		3.3
46b Zygomaxillary chord		109	112				110	95	108	100		104	114		104
46c Zygomaxillary subtense		23	25				22	19	30	18		16	23		28
43c:43(1) Frontal index		16.5	14.9		12.2		16.6	10.1	13.3	7.9	17.5	11.2	16.9		23.3
57a:57 Simotic index		24.1			12.5				17.9	33.8		36.5	42.0		34.6
46c:46b Zygomaxillary index		20.8	21.9				20.2	19.5	27.3	18.0		15.6	20.6		26.8
66 Bigonial breadth	94				103	112	106	113	108	106	95	115	118	95	93
68 Mandibular length	83				75	82	82	74	78	81	85	82	84	84	85
69 Symphyseal height	32				38	31	38	36	27	34	36	32	36	32	36
70 Ramus height	63				56	70	69	71	69	66		69	69	74	66
71 Ramus breadth	39				32	39	40	34	35	37	41	41	35	37	40

Sample No.	07H2 M30	07H2 M32	99 M2	99 M5b	05 M9	05 M15	05 M16	05 M34	07H1 M4	07H1 M10	07H1 M11	07H2 M5	07H2 M12	07H2 M22	07H2 M24
Martin's No. / Sex	M	M	F	F	F	F	F	F	F	F	F	F	F	F	F
1 Max. cranial length	181	184	176	169	169	183	163	174	171	177	180		180	171	181
5 Basion-nasion length	100	107	91	94	90	100								100	
8 Max. cranial breadth	151	147	137	131	136	129	137		139	137	137	135	130	137	133
9 Min. frontal breadth	108	104	93	91	93	101	85	97	99	96	97		85	95	96
10 Max. frontal breadth	119	101	106	114	119		107	119	115		113		111	116	118
12 Max. occipital breadth	118	119	112	107	105	109					107		103	115	110
17 Basion-bregma height	150	148	121	132	128	147								143	
29 Frontal chord	116	121	99	102	100	116	110	106			106		111	111	112
30 Parietal chord	124	116	108	123	105	121	97	108			109		113	111	118
31 Occipital chord	108	103	103	90	107	100								102	103
40 Basion-prosthion length	101	103	92	93	85	92								92	
43 Upper facial breadth	120	115	99	106	107	109	108				109		99	107	
45 Bizygomatic breadth	147	146	120	128	133	133	144		137		136			129	
46 Bimaxillary breadth	116	106	97		103	109	106						101	104	
48 Upper facial height	66	68	62	65	69	71					71		68	70	
51 Orbital breadth	45	47	41		39	40	43		42		41		40	42	
52 Orbital height	34	34	33	35	35	37	34		34		33		34	36	
54 Nasal breadth	31	33	22	25	25	27	28				27		30	23	
55 Nasal height	50	52	47	53	49	56					52		54	50	
60 Upper alveolar length	55	54	51	55	46	53				57	55			50	
61 Upper alveolar breadth	67	69	60	60	65	69				65				62	
8:1 Cranial index	83.4	79.9	77.8	77.5	80.5	70.5	85.6		81.3	77.4	76.1		72.2	80.1	
48:45 Upper facial index	44.9	46.6	51.7	50.8	51.9	53.4					52.2			54.3	
43(1) Frontal chord	110	105													
43c Frontal subtense	17	16													
57 Simotic chord	11.9	9.0													
57a Simotic subtense	4.1	2.8													
46b Zygomaxillary chord	116	107													
46c Zygomaxillary subtense	19	26													
43c:43(1) Frontal index	15.7	15.2													
57a:57 Simotic index	34.7	31.1													
46c:46b Zygomaxillary index	16.5	23.9													
66 Bigonial breadth	114	104	86	90	94	104				102	94		101	99	
68 Mandibular length	84	84	67	69	75	71				83	75		75	81	
69 Symphyseal height	29	29	37	30	34	32				33	31			33	30
70 Ramus height	78	61	46	58	56	55				65	64		63	66	
71 Ramus breadth	41	38	35	35	35	37				36	38		36	32	