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Preliminary Study of *Homo erectus* Skull IX (Tjg-1993.05) from Sangiran, Central Java, Indonesia

Johan Arif[1], Hisao Baba[2], Made Emmy Suparka[1], Yahdi Zaim[1] and Takeshi Setoguchi[3]

[1] Department of Geology, Institute of Technology Bandung, Indonesia
[2] Department of Anthropology, National Science Museum, Tokyo, Japan
[3] Department of Geology and Mineralogy, Faculty of Science, University of Kyoto, Japan

Abstract A new skull of *Homo erectus* was recovered from Tanjung village, Sangiran, Central Java, Indonesia. The skull was presumed to be derived from the middle part of the Bapang (Kabuh) Formation. Sartono provisionally labeled it as Skull IX. The skull consists of a vault and a maxilla with teeth. Comparative morphological study revealed that the Skull IX possessed characteristic features of Asian *Homo erectus* and that the Skull IX indicated closer similarities to Javanese *Homo erectus* from Early/Middle Pleistocene (specimens from Sangiran and Trinil) than to Chinese *Homo erectus* (Zhoukoudian) and Javanese *Homo erectus* from Late Pleistocene (Ngandong), which was expected from its provenance.
Key words: Skull IX, morphology, *Homo erectus*, Java, fossil.

Introduction

Java Island is one of the most important places for the study of human evolution in Asia. Within this Island, Sangiran in Central Java is the most promising site for early hominid fossils. Since the first find by von Koenigswald in 1936 (Koenigswald 1940), about 100 hominid fossils have been discovered from there.

A new hominid fossil skull was found and picked up by a local inhabitant from the middle part of the Bapang (Kabuh) Formation near Tanjung Village in May of 1993 (Fig. 1). There is no formal specimen number for this skull. But, Sartono and Tyler (1993) announced this find and provisionally labeled it as Skull IX in the "International Conference on Human Paleoecology" held at Jakarta, Indonesia in October of 1993. Larick et al. (2001) also labeled the skull as Tjg-1993.05.

The present paper provides geological setting of the site and basic description of the skull, and discusses its affinities with those of other Asian *Homo erectus*.

Geology of Sangiran Area and Provenance of the Skull IX

Sangiran is one of the villages in Kali Jambe sub-district, regency of Sragen, Central Java. It locates about 14.7 km north of Solo City. The name of Sangiran was

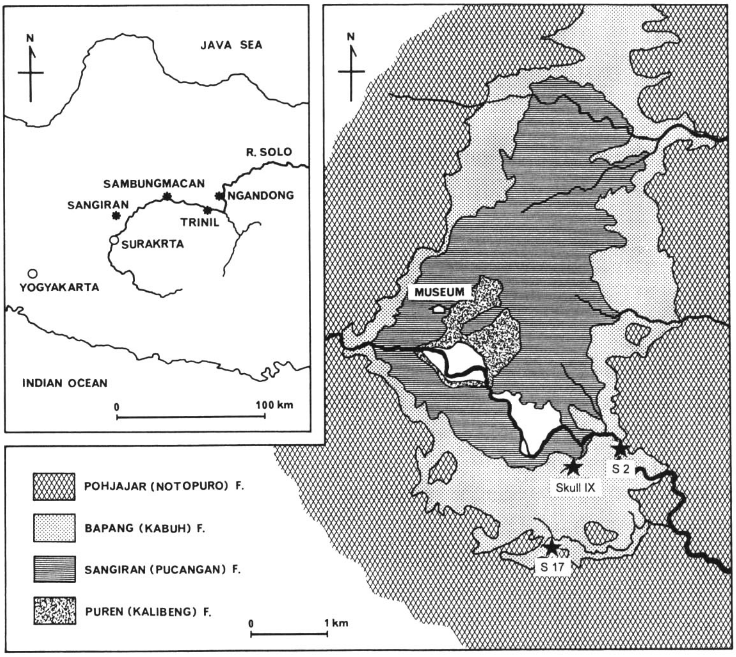

Fig. 1. Location and geology of the Sangiran area. Asterisks near S 2, S 17 and Skull IX indicate the places where each skull was found. The Skull IX was found in Tanjung Village.

chosen as a representative of those villages where a number of vertebrate and hominid fossils were discovered.

Geologically, the sediments of Sangiran area form the structure like a dome. Therefore, the area is commonly called as Sangiran dome. There are four formations identified in this area, in ascending order: Puren (Upper Kalibeng), Sangiran (Pucangan), Bapang (Kabuh) and Poh Jajar (Notopuro) Formations (Ithihara et al., 1985, 1994). Koenigswald (1940) and Sartono (1961, 1970, 1975) assigned the Puren (Upper Kalibeng) Formation to Upper Pliocene, the Sangiran (Pucangan) Formation to Lower Pleistocene, the Bapang (Kabuh) and Poh Jajar (Notopuro) Formation to Middle Pleistocene.

The Puren (Kalibeng) Formation is divided into four layers, bluish gray clay & silty clay (six thin tuff layers are recognized here), silt sand (Turitella beds), balanus limestone, and clay & silt (Corbicula beds).

The Sangiran (Pucangan) Formation is divided into the basal Lower Lahar and the Black Clay as the main remaining part (Koenigswald, 1940; Sartono, 1970, 1975). The Lower Lahar discordantly overlies the Puren (Kalibeng) Formation and consists of light gray unstratified andesitic tuff, fragments of tuff, pumice, calcareous nodules, mollusca and corals. The Black Clay includes bluish gray clay and silty clay containing intercalations of silt, sand, molluscan shell enclosure, foraminiferal sand, diatomite, peat and tuff. According to Itihara et al. (1985), the Black Clay contains more than forty tuff layers. Among them only twelve tuff layers (T0-T11) are useful for stratigraphical markers.

The Bapang (Kabuh) Formation consists mainly of clay, silt, sand, iron sand and gravel of fresh-water origin. It also contains intercalations of conglomeratic sandstone known as Grenzbank and tuffs. The Grenzbank occurs only in the basal part. In the Bapang formation, three distinct tuff layers are frequently found, namely the Lower, Middle and Upper Tuff layers. Based on these three Tuff layers, the Bapang (Kabuh) Formation is subdivided into four parts, namely the Lowermost part, Lower part, Middle part, and Upper part.

The Poh Jajar (Notopuro) Formation discordantly overlies the Bapang (Kabuh) Formation and distributed in the hilly land surrounding the Sangiran dome. It consists of gravel, sand, silt and clay of fresh water origin. It also contains intercalation of lahar, pumice and tuff. Three marker beds are recognized, namely the Upper lahar, the Uppermost lahar and the Upper Pumice beds. Based on these marker beds, the Poh Jajar (Notopuro) Formation is subdivided into the Lower, Middle and Upper parts.

Hominid fossils mainly come from the uppermost part of the Sangiran (Pucangan) Formation (e.g., Sangiran 22) and the lower and middle parts of the Bapang (Kabuh) Formation (e.g., Sangiran 17). Sartono and Tyler (1993) once declared that the Skull IX derived from the level of Upper Tuff of the Bapang Formation. Recently they (Tyler and Sartono, 2001) changed their opinion and suggested the skull was derived from the Middle Sangiran (Pucangan) Formation. The texture and fossilization of the skull suggest strongly that its provenance is not the Sangiran (Pucangan) but the Bapang (Kabuh) Formation.

Preservation and Reconstruction of the Skull IX

The Skull IX is the second best *Homo erectus* cranium ever found in Java (Figs. 2–4). At present, the skull consists of three separated parts, namely, the vault, most part of the maxilla, and the right temporal bone. The vault consists of the nearly complete frontal, parietal, occipital, and temporal bones and a part of the greater wing of the sphenoid bone. The outer surface is rather well preserved and most of the surface morphological characters and anatomical landmarks can be discerned without much difficulties. The maxilla consists of seven crowns, namely, complete right upper first, second and third molars, a lingual half of the right upper forth premolar, a disto-lingual quarter of the right upper third premolar, a distal half of the left upper second molar, and lingual two thirds of the left upper third molar.

The Skull IX was reconstructed after the discovery, using the glue mixed with epoxy resin and sand. But the reconstructed skull is distorted, especially on the left

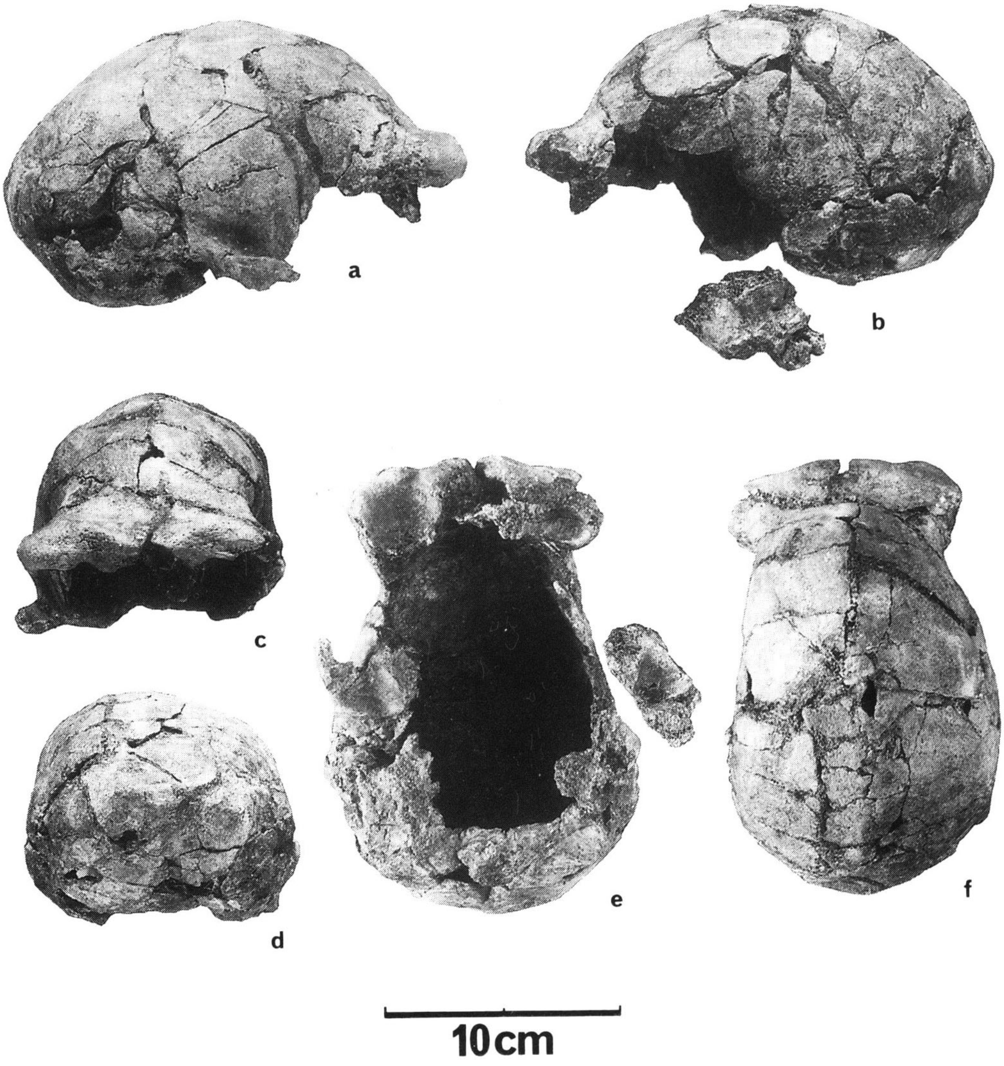

Fig. 2. Skull vault of the Skull IX (original). Someone reconstructed the skull inadequately, especially in the left part of the vault. a: right lateral aspect, b: left lateral aspect with a temporal fragment, c: frontal aspect, d: occipital aspect, e: basal aspect with a temporal fragment, f: superior aspect.

side of the vault. Moreover, some of the teeth are glued in wrong positions. The left upper third molar was moved to the position between the left upper forth premolar and the left upper first molar. In the occulusal aspect, the left upper third molar was turned clock wise about 90 degrees and the left upper second molar was also turned anti-clock wise about 90 degrees.

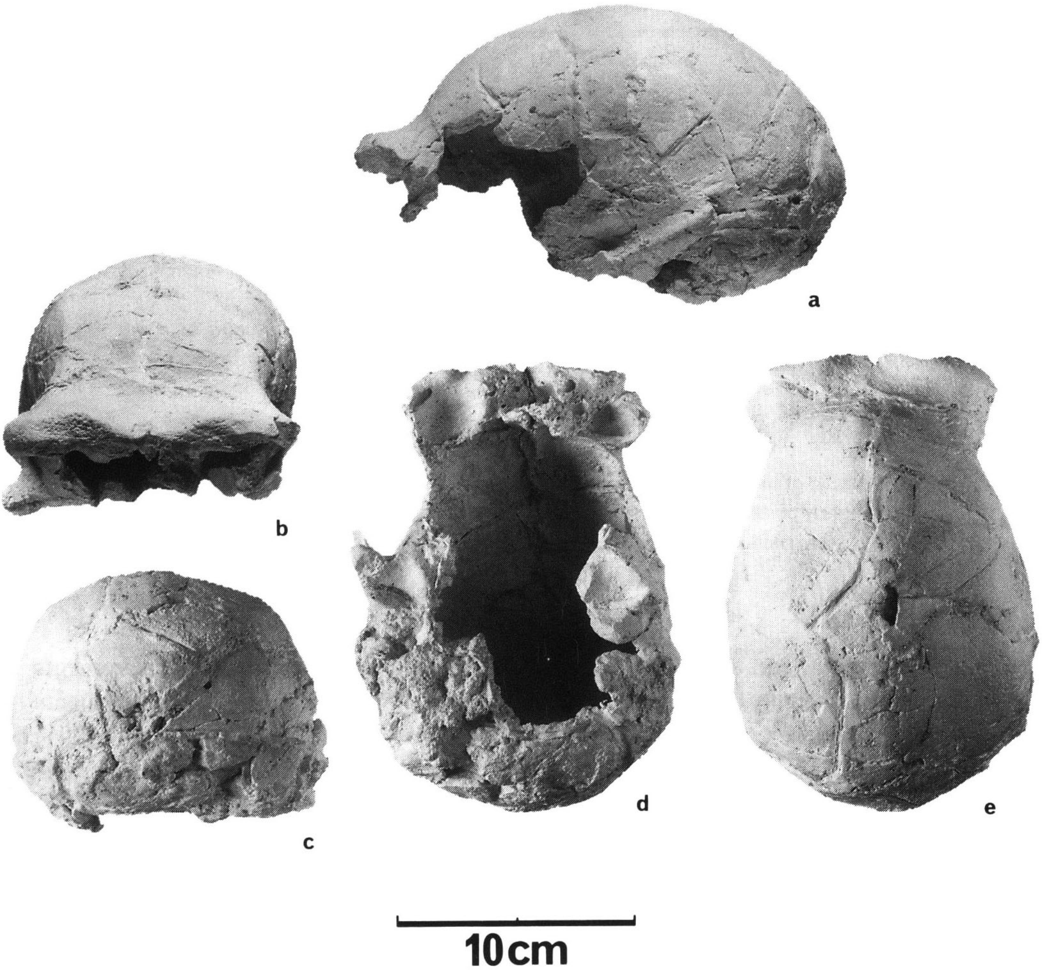

Fig. 3. Partly re-reconstructed cast of the Skull IX. The left part of the vault was arranged. a: left lateral aspect, b: frontal aspect, c: occipital aspect, d: basal aspect, e: superior aspect.

Since the bones are fragile and the glue is too tough to remove from the bones, it is, at present, hard to decompose and re-reconstruct the skull. Consequently, the distortion was corrected using high-quality casts. That is, we prepared precise plaster casts of the Skull IX at the Department of Geology, Institute of Technology Bandung (ITB), Indonesia in March 1997. Then the cast of the vault was cut into 16 pieces and they were joined together in appropriate positions in order to adjust distortion of the original (Fig. 3).

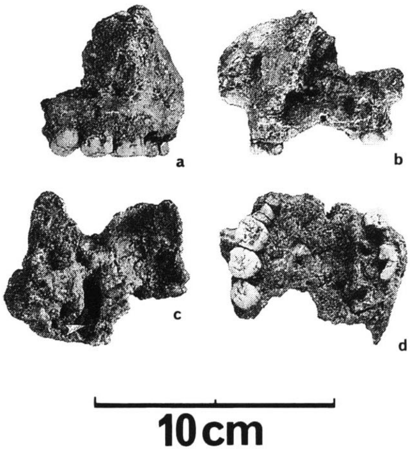

Fig. 4. Maxilla of the Skull IX (original). a: right lateral aspect, b: frontal aspect, c: superior aspect (slightly posterior), d: inferior aspect. In the superior aspect, a wide lacrimal canal (arrow head) is seen, running from the orbital margin to the nasal cavity.

Material and Methods

The original and cast of the Skull IX were used for description, measurements and comparison with other Asian *Homo erectus* specimens. Cranial measurements and indices were selected from Martin (1928), Weidenreich (1943) and Wood (1991) (Table 1). The results of the measurements were listed in Table 2. Non-metrical morphological characters, including ectocranial super-structures such as the sagittal keel, angular torus, etc. were compared. The metric and non-metrical data were taken from the casts of comparative specimens as well as published descriptions.

Comparative specimens consist of the other Indonesian Pleistocene hominid fossils, namely the Sangiran, Trinil, Ngandong, and Sambungmacan specimens and hominid fossils from Zhoukoudian, China. All the comparative specimens are casts, except for Sangiran 12 and17. Trinil 2 was lumped together with the Sangiran specimens, since the differences in morphological features and geological age between Trinil 2 and Sangiran 2 are small (Weidenreich, 1943: Santa Luca, 1980). Sambungmacan 1 was also lumped with the Ngandong specimens. But, the metrical data of Sambungmacan 1 were not included.

Sex and Age of the Skull IX

Relatively small overall vault size, rounded frontal squama and slight projection of the occipital torus suggest that the specimen was of a female individual. But strong development of the supraorbital torus and robust maxilla suggest this individual was a male. Taken together, the sex of this individual is unknown.

Table 1. Definitions and instruments used for the measurements.

No.	Items	Definition	Instrument	Cited number in Martin (1928)	Cited number in Wood (1991)	Cited number in Weidenreich (1943)
1	G-opc L	Glabella-opisthocranion length	SC	1	1	1
2	Post cranial L	Most posterior point of ext. auditory meatus to opc	SQP		3	
3	B pos. to g-opc	Bregma position from glabella projected to g-opc	SQP			11
4	L pos. to g-opc	Lambda position from glabella projected to g-opc	SQP			12
5	Postorb. con. to g-opc	Postorbital constriction from glabella projected to g-opc	SQP			
6	Ast-opc to g-opc	Asterion-opisthocranion projected to g-opc	SQP			
7	Ft-ft B	Minimum frontal (frontotempolare) breadth	SC	9		
8	Postorbital B	Postorbital breadth	SC	9(1)	8	
9	Co-co B	Maximum frontal (coronale) breadth	SC	10		
10	Squam. sut. B	Temporoparietal (squamosal surure) breadth	SC	8c		
11	Au-au B	Biauricular breadth	SC	11		
12	Max B	Bisupramastoid breadth	SC	8	12	
13	Ast-ast B	Biasterionic breadth	SC	12	14	
14	Po-b H	Porion-bregma height	SQP	20		36
15	B over g-o	Bregma height over glabella-opisthion line	SQP			40
16	L over g-o	Lambda height over glabella-opisthion line	SQP			
17	Opc over g-o	Opisthocranion height over glabella-opisthion line	SQP			
18	N-b subs.	Nasion-bregma subtense	SQP	29b		
19	N-b chord	Nasion-bregma chord	VC	29		56
20	G-b chord	Glabella-bregma chord	SC		17	57
21	G-b arc	Glabella-bregma arc	T		18	55
22	Sg-b chord	Supraglabellare-bregma chord	VC	29(2)	19	65
23	Sg-b arc	Supraglabellare-bregma arc	T	26(2)	20	64
24	B-l chord	Bregma-lambda chord	SC	30	25	59
25	B-l arc	Bregma-lambda arc	T	27	26	58
26	L-ast chord	Lambda-asterion chord	SC	30(3)	31	69
27	L-ast arc	Lambda-asterion arc	T	27(3)	32	68
28	L-opc chord	Lambda-opisthocranion chord*	SC	31(1)	35	71
29	L-opc arc	Lambda-opisthocranion arc*	T	28(1)	36	70

Table 1. (continued)

No.	Items	Definition	Instrument	Cited number in Martin (1928)	Wood (1991)	Weidenreich (1943)
30	Opc-o chord	Opisthocranion-opisthion chord*	SC	31(2)	37	71
31	Opc-o arc	Opisthocranion-opisthion arc*	T	28(2)	38	70
32	L-o chord	Lambda-opisthion chord	SC	31	39	61
33	L-o arc	Lambda-opisthion arc	T	28	40	60
34	Frontal sq. angle	Frontal squama angle to FH	SQP		29	
35	B-g-opc angle	Bregma-glabella-opisthocranion angle*	SQP	32(2)		3
36	Occp. plane angle	Occipital plane angle	SQP		130	
37	L-opc-g angle	Lambda-opisthocranion-glabella angle*	SQP	33(1b)		8
38	L-opc-o angle	Lambda-opisthocranion-opisthion angle*	SQP	33(4)		10

* The point of measurement is not at opisthocranion but at inion in Martin (1928) and Wood (1991).
T: Flexible tape calibrated in millimeters
VC: Vernier caliper
SC: Spreading caliper
SQP: Squared paper

In the Skull IX, sutures of the vault are mostly closed or obscure but still open in the posterior part of the sagittal suture. The lingual cusps of the right first molar are worn and a dentine island is exposed. The third molars had already erupted and were worn moderately. These features suggest that this individual was a young adult at the age of death.

Overall Size and Shape of the Skull IX

The vault size of the Skull IX is a little larger than that of Sangiran 2, almost equivalent to those of the Zhoukoudian specimens and smaller than those of Sangiran 17 and Ngandong-Sambungmacan specimens. Compared with *Homo sapiens* vaults, the vault of the Skull IX is long and low, as in other *Homo erectus* vaults. But it is very narrow and a little high as a *Homo erectus* vault (Table 2, Figs. 2, 3). The endocranial volume was tentatively reported by Sartono and Tyler (1993) as about 800 ml, but after re-reconstruction using the cast, it was measured as about 840 ml, which is considerably smaller than those of the comparative specimens.

In the lateral view, the supraorbital region of the Skull IX is long and projected but the occipital region is short and more or less rounded, because the occipital torus

Table 2. Metrical data of the Skull IX and comparative specimens.

No.	Item	Skull IX		Sangiran-Trinil		Zhoukoudian		Ngandong	
		original	cast	Mean	N	Mean	N	Mean	N
1	G-opc L	(195)	(198)	189	3	194	5	202	6
2	Post cranial L	(84)	(85)	75	3	86	4	91	4
3	B pos. to g-opc	(91)	(91)	74	3	76	4	76	6
4	L pos. to g-opc	(172)	(183)	170	3	170	4	176	6
5	Postorb. con. g-opc	—	(51)	21	1	35	3	44	2
6	Ast-opc	—	29	32	3	42	4	40	4
7	Ft-ft B	78	77	84	3	86	4	104	6
8	Postorbital B	(83)	(88)	89	4	92	3	98	3
9	Co-co B	(102)	(108)	106	3	105	3	118	4
10	Squam. sut. B	(127)	(132)	133	3	136	3	145	4
11	Au-au B	(127)	(130)	136	4	145	4	148	5
12	Max B	(133)	(146)	148	4	146	4	152	3
13	Ast-ast B	(114)	(109)	125	5	112	4	126	6
14	Po-b H	99	104	96	2	100	4	109	6
15	B over g-o	(66)	(66)	68	3	72	4	78	6
16	L over g-o	—	(83)	67	3	82	4	82	4
17	Opc over g-o	—	(62)	34	3	45	4	39	4
	11/1	(65)	(66)	73	3	75	4	73	5
	15/1	(34)	(33)	36	3	37	4	38	6
	14/1	(78)	(80)	70	3	68	4	75	5
	2/1	(43)	(43)	42	2	45	4	44	4
	3/1	(46)	(46)	39	3	39	4	37	6
	6/1	—	(15)	17	3	22	4	19	4
	5/1	—	(26)	21	1	18	3	21	2
	7/8	(94)	(87)	92	3	93	3	107	3
	8/12	(62)	(60)	63	3	64	4	63.5	2
	9/12	(77)	(74)	74	2	72	3	77	3
	10/11	(100)	(99)	97	3	93	4	99	4
	6/13	—	(27)	28	3	37	4	31	3
	17/16	—	(75)	52	3	54	4	47	4
18	N-b subtense	—	(17)	17	2	20	4	19	6
19	N-b chord	—	(118)	99	3	110	5	117	6
	18/19	—	(14)	15	2	18	4	17	6
20	G-b chord	(115)	(111)	100	3	107	5	109	6
21	G-b arc	(117)	(115)	102	3	113	5	114	6
	20/21	(98)	(96.5)	98	3	94	5	96	6
22	Sg-b chord	97	84	83	3	87	5	86	4
23	Sg-b arc	102	87	85	3	93	5	89	4
	22/23	95	96.5	98	3	94	5	99	4
24	B-l chord	90	98	91	7	96	5	102	6
25	B-l arc	92	102	95	7	104	5	108	6
	24/25	98	96	96	7	93	5	95	6

Table 2. (continued)

No.	Item	Skull IX		Sangiran-Trinil		Zhoukoudian		Ngandong	
		original	cast	Mean	N	Mean	N	Mean	N
26	L-ast chord	(r 67, l 70)	(r 66, l 73)	79	6	84	4	—	—
27	L-ast arc	(r 75, l 76)	(r 70, l 79)	88	6	93	4	—	—
	26/27	(r 89, l 92)	(r 94, l 92)	90	6	90	4	—	—
28	L-opc chord	42	33	46	5	49	4	8	6
29	L-opc arc	46	33	49	5	51	4	61	6
	28/29	91	100	94	5	96	4	96	6
30	Opc-o chord	—	68	54	4	60	2	55	6
31	Opc-o arc	—	7	56	4	63	2	57	6
	30/31	—	88	95	4	94	2	96	6
	28/30	—	48	85	4	84	3	108	6
	29/31	—	43	87	4	83	3	107	6
32	L-o chord	—	82	80	5	86	2	86	6
33	L-o arc	—	110	109	4	118	2	118	6
	32/33	—	4	75	4	73	2	72	6
	24/32	—	119	113	5	103	2	119	6
	25/33	—	93	88	5	83	2	91	6
34	Frontal sq. angle	(41)	(54)	48	2	64	4	48	4
35	B-g-opc angle	(35)	(36)	42	3	42	4	46	6
36	Occp. plane angle	(55)	(58)	72	3	72	4	79	4
37	L-opc-g angle	(56)	(57)	65	3	63	4	63	6
38	L-opc-o angle	—	104	104	4	102	4	101	4
	Cranial vol. (ml)	800	840	930	6	1043	5	1151	5

is located high and slightly projected. Although the development of the occipital torus is poor, the opisthocranion coincides with the tip of the torus (inion).

In the superior view, the outline of the vault is narrow. The supraorbital torus is moderately wide with strong postorbital constriction. The vault is wider posteriorly and the occipital outline is not projected but rounded, as in other Javanese specimens.

In the occipital view, the vault outline of the Skull IX is less gabled and a little more rounded than those of the other Asian *Homo erectus*. The maximum breadth corresponds to the bi-supramastoid breadth, which is common in the other *Homo erectus* specimens.

Individual bones of the Skull IX

1. *Frontal bone*

The supraorbital torus of the Skull IX is robust, thick and projected anteriorly (Figs. 2, 3). General architecture of the torus of the Skull IX resembles that of Sangiran 17, although the former is wider and more straight than the latter (Rightmire, 1990; Aziz et al., 1996). It shows no lateral thickening, as is often seen in Ngandong-Sambungmacan specimens.

In most *Homo erectus* and archaic *Homo*, the supraorbital torus was divided into three portions, that is the central glabellar swelling, medial arches between the glabellar swelling and the supraorbital groove, and lateral prominence between the supraorbital groove and the zygomatic process of the frontal bone. The latter two divisions correspond to the superciliary arch and the supraorbital trigone, respectively (Santa Luca, 1980). These three divisions are clearly identified in the Skull IX, although the middle part of the glabellar swelling was lost.

In the Skull IX, the supraorbital torus begins from the glabellar swelling, curves upward far above the level of the glabella, forming a distinct superciliary arch, and extends to the supraorbital groove. After crossing the groove, the torus turns downward and forms a wide supraorbital trigone. The torus reduces its thickness laterally. The supraorbital notch exists as a wide and deep hollow (8 mm wide). Laterally, there is a bony projection so-called a supraorbital process (Weidenreich, 1943).

In the superior view, the lateral part of the supraorbital torus of the Skull IX is wide and flared posteriorly, as in the Zhoukoudian specimens. The postorbital constriction is marked, showing strong development of the anterior part of the temporalis muscle.

The supratoral sulcus of the Skull IX is shallow and wide on both lateral parts (Figs. 2, 3). There is a slight ophrionic depression on the midline just behind the glabella. The frontal sinus is partly broken but were estimated as 14 mm long and 27 mm wide. Internally, the frontal crest is low and broad at the base. It extends about 35 mm, and disappears superiorly.

The frontal squama is narrow and moderately long, having a slight bump structure at its central part. The metopic keel can be discerned on the squama as a moderate ridge about 40 mm long. The keel is clear on the middle part of the squama and becomes weak before reaching to the bregmatic eminence.

2. *Parietal bone*

The absolute size of the parietal bone of the Skull IX is more or less large, although the vault is narrow (Figs. 2, 3). The parietal bone is not angulated at the temporal line as in Sangiran 17 and Ngandong specimens but rounded as in Sangiran 2 and Sambungmacan 1. The sagittal keel is weak and discerned only on the anterior part of the parietal bone. Consequently, the parasagittal depression is developed only on the anterior part as a slight hollow.

3. *Temporal Bone*

The temporal squama of the Skull IX is long and low (Figs. 2, 3). The anterior border (sphenotemporal suture) is nearly vertical and about 40 mm long. The parietal border (squamous suture) is straight, 40 mm long, and declines steeply posteriorly. There is a clear sign of *striae parietalis* on the adjacent part of the parietal bone.

The zygomatic process of the temporal bone is thick, continues to the strong supramastoid crest. The process is located laterally away from the squama by a concave and wide channel called *sulcus processus zygomatici* (Weidenreich, 1943), indicating the ample development of the temporalis muscle.

The glenoid fossa of the Skull IX is well preserved as a shallow depression. Its anterior border is formed not by a projected articular eminence but by a flat *planum preglenoidale*. Although both entoglenoid processes are partly eroded, the width of the glenoid fossa (between the ectoglenoid and entoglenoid processes) is estimated as 30 mm. The transverse axis of the glenoid fossa, as defined by the line that connects above two processes, makes an angle of about 110 degrees to the sagittal plane.

4. *Occipital Bone*

The occipital bone is moderately flexed at the occipital torus, which is located at a high position. The occipital plane is much shorter longitudinally than the nuchal plane. While the occipital plane is flat and inclines anteriorly, the nuchal plane is strongly curved and faces rather posteriorly.

The occipital torus of the Skull IX appears as a moderate bulge (Figs. 2, 3). The torus is clear on the left side but almost obscure on the right side (c. f., Ascenzi et al., 1996). The cause of this asymmetry is not known. The torus crosses the left half of the occipital bone a little obliquely from right upper to left lower direction. It is relatively well developed on the central part as a rounded bulge and is weakened laterally. The continuum of the occipital torus to the lateral side is obscure (especially to the right lateral side) due to some cracks and damage on the angular torus, mastoid region and nuchal plane.

The superior toral surface does not project sharply away from the occipital plane. Laterally, the superior toral surface disappears or coalesces with the occipital plane. The inferior toral surface slopes gradually to the nuchal plane.

5. *Maxilla*

In the Skull IX, most part of the maxilla is preserved but distorted considerably (Fig. 4). The inferior orbital margin of the Skull IX slopes downwards to the lateral side. Medially, there is a wide lacrimal canal, continuing to the nasal cavity, of which medio-lateral diameter is 8 mm.

The zygomatic process of the maxilla is preserved only on the right side. The process is thick and its inferior margin is located very low, about 10 mm to the alveolar margin. Consequently, the process is very high, its minimum height is about 36 mm and the orbito-alveolar height is about 45 mm. The base of the process is situated above the upper first molar.

There is a big infraorbital foramen in the center of the right zygomatic process of the maxilla, about 13 mm below to the inferior orbital margin. The entrance of the foramen of Skull IX is narrow transversely.

The palate is shallow. The right alveolar arch is relatively straight from the upper third premolar to the upper second molar. The length of right upper molars (from the mesial surface of the upper first molar to the distal surface of the upper third molar) of Skull IX is about 33 mm.

6. *Teeth*

The mesio-distal and bucco-lingual diameters of the right upper first molar of Skull IX are 11.3 mm and 11 mm respectively. The crown of the right upper first molar has four cusps (Fig. 4). The lingual cusps (protocone and hypocone) were worn almost flat, while the buccal cusps (paracone and metacone) still maintain some relief. There is a dentine exposure on the protocone of the right upper first molar. A marked buccal groove is seen, extending bucco-lingually.

The mesio-distal and bucco-lingual diameters of the right upper second molar are 10.6 mm and 10.9 mm respectively. The condition of the occulusal wear is almost same as in the first molar, but no dentine exposure is seen. The mesio-distal and bucco-lingual diameters of the right upper third molar are 8.9 mm and 10.4 mm. The occulusal wear is more advanced on the buccal half than on the lingual half in which some relief was remain.

Ectocranial Superstructures of the Skull IX

Weidenreich (1943) noted that the massiveness of vault could be reflected in the development of ectocranial superstructures which constitute a general reinforcement system. The superstructures comprise the supraorbital torus, temporal line, sagittal keel (including metopic keel), bregmatic eminence, coronal keel, occipital torus, angular torus, supramastoid crest, and so on. Since the supraorbital and occipital tori and metopic keel have already been mentioned above, we describe here other ectocranial superstructures.

Anteriorly, the temporal lines of the Skull IX begin just posterior to the supraorbital torus. From the point of departure, there are two lines corresponding to the superior and inferior temporal lines. The latter does not extend far away from its point of departure. The superior line goes posterior, reaches high on the parietal bones, and bifurcates into anterior and posterior temporal lines. The anterior line turns down toward the anterior part of the angular torus and coalesces with the supramastoid crest. The posterior line goes toward the posterior part of the angular torus.

The bregmatic eminence appears as a low but distinct mound. Its right lateral arm extends 28 mm laterally without developing a coronal ridge. Although there are some cracks on the parietal bones particularly just behind the bregma, a weak extension of the posterior arm of the bregmatic eminence can be discerned, continuing to the weak sagittal keel.

The angular torus of the Skull IX is moderately preserved on the left and right sides as an elongated bulge, occupying the posterior part of the mastoid angle of the parietal bone. This torus was confined by the anterior and posterior temporal lines, as in other comparative specimens.

The supramastoid crest is remarkably developed forming a thick round eminence. The crest begins from the root of the zygomatic process, curves upwards, crosses the parietomastoid suture and connects with the anterior temporal line. These features resemble those of the Ngandong and Sambungmacan specimens.

Affinities of the Skull IX with Asian *Homo erectus*

Morphologically, the Skull IX has some unique characters which differ from the comparative specimens. Nevertheless, there are many similarities between the Skull IX and the comparative specimens.

1. *Unique features of the Skull IX are pointed out as follows*:

a. The vault shape of the Skull IX is more slender in the vertical view and more rounded in the occipital view than those of the comparative specimens, since the vault is narrow in proportion to its length and height (Figs. 2, 3; Table 2).

b. The frontal bone of the Skull IX is much elongated, especially in the anterior part, which is caused by the anterior projection of the supraorbital torus.

c. In the Skull IX, the degree of inclination of the frontal squama relative to the Frankfurt Horizontal plane is intermediate between those of the Zhoukoudian specimens and the Sangiran-Trinil and Ngandong-Sambungmacan specimens (Table 2). It is caused by relatively rapid raising of the frontal squama just posterior to the supratoral sulcus and the presence of a bump-like structure on the anterior half of the frontal squama, which is not identical to the paired bumps of the Zhoukoudian cranial specimens (Figs. 2, 3).

d. The deepest part of the temporal fossa of the Skull IX is located more posterior than those of the comparative specimens (Figs. 2, 3; Table 2).

e. The Skull IX has the shortest occipital plane and the longest nuchal plane among the comparative specimens (Figs. 2, 3; Table 2).

2. *Similarities between the Skull IX and Sangiran-Trinil and Ngandong-Sambungmacan are as follows*:

a. The occipital vault length (ast-opc to g-opc) is shorter in relative to the biasterionic breadth in the Skull IX, Sangiran-Trinil and Ngandong-Sambungmacan specimens than in the Zhoukoudian specimens (Table 2). As a consequence, the occipital horizontal outline is rounded in the formers but ellipsoidal and projected in the latter.

b. Anteriorly, the supratoral sulcus of the Skull IX, Sangiran-Trinil and Ngandong-Sambungmacan specimens are relatively wider and flatter than those of the Zhoukoudian specimens (Figs. 2, 3).
c. The frontal sinus is wider in the Skull IX, Sangiran-Trinil and Ngandong-Sambungmacan specimens than in the Zhoukoudian specimens.

3. *Similarities between the Skull IX and Sangiran-Trinil and Zhoukoudian are as follows*:
a. The parasagittal depression is developed both on the frontal and parietal bones in the Skull IX, Sangiran-Trinil and Zhoukoudian specimens (Figs. 2, 3). Such depression does not exist in the Ngandong-Sambungmacan specimens.
b. The Skull IX, Sangiran-Trinil and Zhoukoudian specimens have the planum preglenoidale instead of the true articular eminence, whereas the Ngandong-Sambungmacan specimens have the true articular eminence in which the anterior wall of the glenoid fossa is vertical.
c. The minimum frontal breadth is narrower than the postorbital breadth in the Skull IX, Sangiran-Trinil and Zhoukoudian specimens but almost equal in Ngandong-Sambungmacan specimens (Table 2).

In addition to the features above mentioned, the development of the ophrionic depression is moderate in the Skull IX and Sangiran-Trinil specimens, marked in the Zhoukoudian specimens, and none in the Ngandong-Sambungmacan specimens. So far the incomplete maxillary specimens suggest, the mid-face of the Skull IX is as large as in Sangiran17 and much larger than those of Zhoukoudian specimens.

All in all, the Skull IX shows much closer similarities to the Sangiran-Trinil specimens than to Zhoukoudian and Ngandong-Sambungmacan specimens.

Discussion and Conclusion

Within the Sangiran-Trinil specimens, only Sangiran17 preserves the face. The face of Sangiran17 is robust and flat with extremely bulged zygomatic bones (Rightmire, 1990; Habgood, 1992; Baba, 1995). In the Skull IX, so far as the incomplete right maxilla is concerned, the zygomatic process is massive and high, suggesting the strong development of the masseter muscle, as in Sangiran17.

According to Baba (1995), the masseter muscle of Sangiran17 might be thick and situated anteriorly, close to the palate, so that the bite force acting on the teeth was presumably very strong. This structure is similar to that of robust Australopithecines to some extent. Moreover, compared with the position of the alveolar plane, the masseter muscle was set low in Sangiran17, unlike the Neanderthals in which the masseter muscle was set very high. In these features, the Skull IX resembles Sangiran 17.

In the Skull IX, the postorbital constriction is marked and the most constricted part of the frontal bone is located more posterior than those of the other Asian *Homo erectus* specimens. It means that, the Skull IX had bigger temporalis muscles especially in the anterior part than in the other Asian *Homo erectus* specimens.

In the Skull IX, the nuchal plane is narrow but very long, resulting a wide area almost equal to that of Sangiran 17. In the case of a large robust male such as Sangiran17, it is reasonable that he should have had very thick nuchal muscles. In the case of a small to medium sized individual as Skull IX, it is somewhat strange that he/she might have had thick nuchal muscles.

As a whole, the Skull IX indicates a numerous characters shared with Asian *Homo erectus* specimens which were pointed out by many authors (Weidenreich, 1943; Jacob, 1972; Santa Luca, 1980; Rightmire, 1990). Consequently, it can be deduced without doubt that the Skull IX is assigned to Asian *Homo erectus*.

The Skull IX shows a unique combination of the characters, such as narrowness of the vault, elongation of the supraorbital region, bump structure of the frontal squama, and strong development of the masticatory and nuchal muscles. It does not, however, mean that the Skull IX can be separated from the other Asian *Homo erectus*, because those characters, except the narrowness, are also possessed by some of the comparative Asian *Homo erectus* specimens individually.

The Skull IX exhibits mosaic features in the affinity within Asian *Homo erectus*. For example, the Skull IX is somewhat close to the Sangiran-Trinil specimens in the occipital bone characters, and intermediate between the Sangiran-Trinil and Zhoukoudian specimens in the frontal bone characters, but far from the Ngandong-Sambungmacan specimens in most characters. Thus, at present, it is reasonable to regard the individual of the Skull IX as one of the variable examples of the Sangiran-Trinil hominids.

In terms of evolutionary perspective of *Homo erectus*, the Skull IX also shows mosaic of primitive and advanced features. The primitive ones are the small cranial capacity, well-developed supraorbital torus, strong postorbital constriction, and marked development of the nuchal plane. On the contrary, high vault and small teeth are regarded as advanced features.

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