THE HOMINID DENTAL REMAINS OF JAVA: A METRICAL STUDY

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The subject of this paper is the hominid teeth from Java (Indonesia). The study comprises all human teeth discovered in the Trinil region (Ngawi, East Java), from the first find of Eugène Dubois in September 1891 to the recent discoveries in 1988 from the region of Sangiran (Central Java). The material comes from several areas and comprises 92 teeth, divided into 81 human teeth, 10 teeth of *Pongo* sp. and a fragment of an indeterminate tooth (Sangiran 36).

The fossiliferous sites belong to the following horizons:

1) The fluvial layers containing a Ngandong fauna, which correspond to the Notopuro Formation of the Upper Pleistocene.
2) The fluvio-volcanic layers containing a Trinil fauna, which correspond to the Kabuh Formation of the Middle Pleistocene.
3) Lacustrine and volcanic layers containing a Jetis fauna, which correspond to the Pucangan Formation of the Lower Pleistocene.

The fossils found in Java belong to the taxon *Pithecanthropus* (*Homo erectus*). Other remains, remarkable for their enormous size, were named *Meganthropus palaeojavanicus* by G.H.R. von Koenigswald (Weidenreich 1945:16). *Meganthropus* has not yet found its place in the human taxonomic sequence of Java and is still being debated. The most recent argument has been put forward by S. Sartono, who has suggested the existence of only one genus of *Homo* in Java, consisting of two species *Homo erectus* and *Homo palaeojavanicus* (Sartono 1982:513).

THE SITES

The only Pleistocene hominid-bearing sites in Java that have yielded hominid dental remains are Kedungbrubus, Trinil, Sangiran and Patiayam.

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Kedungbrubus

This site is in a Middle Pleistocene Kabuh Formation fluviatile deposit situated away from the Solo River to the northeast of Ngawi. The animal fauna comprises *Axis lydekkeri*, *Elephas hysudrindicus* and *Tapirus indicus* (Oakley, Campbell and Molleson 1975:104). Von Koenigswald (1962) suggested, from a potassium-argon date for leucite from the Muria volcano, an age of 500,000 years for the site.

Trinil

This site lies in the Middle Pleistocene Kabuh fluviatile deposit cut by the Solo River, 10 km west of Ngawi. The animal fauna comprises *Axis lydekkeri* and *Bibos palaeosondaicus* (Oakley, Campbell and Molleson 1975:113). Von Koenigswald (1962) also suggested an age of 500,000 years for Trinil.

Sangiran

The Sangiran Dome is situated 12 km north of Surakarta. At the base of the sequence is the Kalibeng Formation from the Upper Pliocene (blue marine clay, coastal limestone), overlain by the Pucangan Formation from the Lower Pleistocene (black clay intercalated with conglomlte and tuffs) (Semah 1982:561). This formation is associated with a Jetis fauna of *Epimachairodus*, *Cervus zwaani* and *Leptobos*. Potassium-argon dating of pumice from a Jetis faunal zone in Mojokerto has given an age of 1.9±0.4 mya (Jacob and Curtis 1971).

Above the Pucangan Formation at Sangiran lies the Kabuh Formation of the Middle Pleistocene, which is well exposed in the Cemoro River near Bapang. This contains a Trinil fauna characterised by *Axis lydekkeri*. Dates proposed for the Kabuh Formation include 500,000 years BP for Trinil, 710,000 years BP for tectites from Sangiran, and 830,000 years BP for pumice from the Kabuh Formation at Tanjung and Pucung.

The Notopuro Formation at Sangiran consists of volcanic breccia and tuff sandstones. It is separated from the Kabuh Formation by a thick layer of limestone conglomerate (Orchiston 1978:2). At the bottom of the Notopuro Formation there is a Trinil fauna. In the Solo Valley, east of Sangiran, the Notopuro Formation contains a Ngandong fauna of Upper Pleistocene date (Bemmelen 1949:566; Bartstra 1976:28-29) characterised by *Sus terhaari*, *Hexaprotodon ngandongensis* and *Cervus javanicus*. According to the chronostratigraphy determined by Jacob and Sartono the age of the Notopuro Formation is 120,000-60,000 years BP (Varcin 1979:83). Dating of Notopuro pumice by the fission-track method (Obradovich and Naeser 1981) has given an age of 250,000-70,000 years.

Patiayam

The Patiayam Dome is situated at the foot of the Muria Volcano in Central Java. According to Semah (1986:387) the Patiayam series divides into a marine part at the base, followed by continental deposits which are strongly marked by Gunung Muria volcanic activity. Near Gunung Slumprit, a domed hill, we find cemented boulder volcanic

breccias above which are several metres of sand and fine tuff clay conglomerates. The mammal and reptile fossils exposed in this last sequence have been attributed by Von Koenigswald (1964) to the Trinil fauna. Potassium-argon dating of breccias at the base of the Gunung Slumprit sequence has given an age of 850,000±20,000 years.

THE DENTAL MATERIALS

All of the materials studied are casts conserved in the Musée de L'Homme and the Institut de Paléontologie Humaine (Paris), and in the Laboratoire d'Anthropologie, Faculté de Medicine, Université d'Aix-Marseille II (Marseille). The originals are preserved in Leiden, Frankfurt, Bandung and Yogyakarta.

Patiayam (1), Kedungbrubus (1), Trinil (3), Sangiran (87)

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92 teeth from maxillas, mandibles and isolated teeth

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81 human teeth, 10 *Pongo* teeth, 1 indeterminate tooth

↓

Kedungbrubus	: mandible		: Kedungbrubus 1
Patiayam	: isolated tooth		: Patiayam 1
Trinil	: isolated teeth	upper	: Trinil 1,4
		lower	: Trinil 5
Sangiran	: maxillas		: Sangiran 1a, 4, 15a, 15b, 17, 27
	: mandibles		: Sangiran 1b, 5, 6a, 6b, 8, 9, 21, 22, 33, 37
	: isolated teeth	upper	: Sangiran 7a, 7b, 11a, 11b, 16a, 16b, 24, 35 Ardjuna 1a, 1b, 1c, 12
		lower	: Sangiran 24 Ardjuna 5, 8, 10
		indeterminate	: Sangiran 36

TABLE 1: THE HOMINID DENTAL REMAINS FOUND IN JAVA

The materials are as follows (Tables 1 and 2):

Kedungbrubus 1 (*Pithecanthropus* A, Kabuh Formation, Middle Pleistocene) : a fragment of a mandibular symphysis with the root of P1 (R) and the distal socket of the canine (R).

Trinil 1 (Kabuh Formation, Middle Pleistocene): upper M3 (R) of *Pongo* sp.

Trinil 4 (Kabuh Formation, Middle Pleistocene): upper M2 (L) of *Pongo* sp.

AGE (mya)				KEDUNG BRUBUS	TRINIL	SANGIRAN	PATIAYAM
0.06	PLEISTOCENE	UPPER	NOTO-PURO			Ardjuna 8	
0.12		MIDDLE	KABUH		Trinil (1,4,5)	Sangiran 37	Patiayam 1
0.83				Kedung Brubus 1		Sangiran (7b,8,11, 16,21,24, 33)	
1.0						Sangiran (15a,15b, 17)	
		LOWER	PUCANGAN			Sangiran (1a,1b,4, 5,6a,7a,9, 22,27,36?, Ardjuna 1 (a,b,c),5, 10,12	

TABLE 2: THE CHRONOLOGY OF THE JAVAN HOMINID DENTAL REMAINS

Trinil 5 (*Pithecanthropus erectus*, Kabuh Formation, Middle Pleistocene): lower P1 (L).

Sangiran 1a (*Meganthropus palaeojavanicus*, Upper Pucangan Formation, Lower Pleistocene): a fragment of the left maxilla from the root cavity of M1 to the distal edge of M3. Teeth present are M1 (L), M2 (L, crown broken) and M3 (L).

Sangiran 1b (*Pithecanthropus* B, Upper Pucangan Formation, Lower Pleistocene): right mandible and the mandibular symphysis, stretching from the mesial edge of I2 (R) to the distal edge of M1 (L) and containing P2 (R), M1 (R), M2 (R) and M3 (R).

Sangiran 4 (*Pithecanthropus* IV/*robustus* Weidenreich, Upper Pucangan Formation, Lower Pleistocene): maxilla (L) and (R) (palatines). The palate is complete. The right maxilla extends from the mesial side of I1 to the distal side of M3. It joins the left maxilla, which extends from the mesial side of I1 to the distal side of M1. The teeth are canine (R), P1 (R), P2 (R), M1 (R), M2 (R), M3 (R), canine (L), P1 (L), P2 (L), M1 (L), and the sockets of I1 (R), I2 (R), I1 (L), and I2 (L).

Sangiran 5 (*Pithecanthropus dubius*, Upper Pucangan Formation, Lower Pleistocene): fragment of a right mandible, from the mesial side of P1 to the distal side of M2. Teeth present are M1 (R) and M2 (R).

Sangiran 6a (*Meganthropus* A, Upper Pucangan Formation, Lower Pleistocene): fragment of a right mandible, from the symphysis region to the distal side of M2. Teeth preserved are P1 (R), P2 (R) and M1 (R).

Sangiran 6b (*Meganthropus* II, Upper Pucangan Formation, Lower Pleistocene): a fragment of left mandible (part of gonion) from the mesial side of M1 to the distal side of M3. Teeth present are M2 (L) and M3 (L).

Sangiran 7a (Pucangan Formation, Lower Pleistocene): isolated human tooth crown.

Sangiran 7b (Kabuh Formation, Middle Pleistocene): 3 isolated *Pongo* sp. tooth crowns.

Sangiran 8 (*Meganthropus* B, Kabuh Formation, Middle Pleistocene): mandible (right and left) and symphysis region, extending from the distal side of M3 (R) (which corresponds to the anterior part of the ramus) to the distal side of M1 (L). It retains M3 (R), M1 (R, crown is broken), roots of canine (R), P1 (R) and P2 (R). On the left side of the mandible is the root of P1 (L), P2(L) and a piece of M1 (L).

Sangiran 9 (*Pithecanthropus* C/*dubius*, Upper Pucangan Formation, Lower Pleistocene); right mandible and symphysis region extending from the distal side of M3 (R) to the mesial side of the socket of I2 (L). Teeth conserved are canine (R), P1 (R), P2 (R), M2 (R) and M3 (R).

Sangiran 11a and 11b (Kabuh Formation, Middle Pleistocene): isolated teeth comprising an upper I1 (R) and an upper M3 (L).

Sangiran 15a (*Pithecanthropus* D, either Kabuh Formation or Pucangan Formation): fragment of a left maxilla, from the distal side of the socket of I2 to the mesial side of M1. Teeth present are P1 (L) and P2 (L).

Sangiran 15b (Kabuh Formation/Grenzbank, Middle Pleistocene): fragment of a right maxilla from the mesial side of I2 to the mesial side of M1. Only P1 (R) is preserved.

Sangiran 16 a/b (Kabuh Formation, Middle Pleistocene): isolated teeth, comprising an upper P1 (L) and an upper M2 (R) of *Pongo* sp.

Sangiran 17 (*Pithecanthropus* VIII, Lower Kabuh Formation, Middle Pleistocene): maxilla (intact) connected to the face and skull cap. Teeth preserved are canine (R), M1 (R), M2 (R), M3 (R) and P1 (L).

Sangiran 21 (*Pithecanthropus* E, Kabuh Formation, Middle Pleistocene): right mandible and ramus with M3 (R).

Sangiran 22 (*Pithecanthropus* F, Upper Pucangan Formation, Lower Pleistocene): right and left mandibles and entire symphysis region. Teeth preserved are canine (R), P1 (R), P2 (R), M1 (R), M2 (R), I2 (L), canine (L), P1 (L) and P2 (L).

Sangiran 24: isolated teeth comprising lower M2 (L), lower M3 (R, 2 teeth), lower M3 (L), upper M1 (L), upper M1 (R), upper M3 (L), and lower P2 (R, of *Pongo* sp.)

Sangiran 27 (*Pithecanthropus*, Upper Pucangan Formation, Lower Pleistocene): face with right and left maxilla (palatines). The palate is nearly complete and extends from orale to the posterior part of the pyramidal process tuberosity. Teeth preserved are P1 (R), P2 (R), M1 (R), M2 (R), P2 (L), M1 (L) and M2 (L).

Sangiran 33 (Kabuh Formation, Middle Pleistocene): a fragment of a right mandible with M1 (R, crown broken) and M2 (R).

Sangiran 35: an isolated upper M2 (R).

Sangiran 36: isolated tooth, indeterminate.

Sangiran 37: (*Pithecanthropus* G, Kabuh Formation, Middle Pleistocene): right mandible, from the mesial side of P1 to the distal side of M3, containing P2 (R), M1 (R) and M3 (R).

Ardjuna la, b, c (Pucangan Formation, Lower Pleistocene): isolated *Pongo* sp. teeth comprising upper M2 (R), upper M2 (L) and upper M1 (R).

Ardjuna 5: an isolated lower M3 (R).

Ardjuna 8 (Notopuro Formation, Upper Pleistocene): an isolated lower M2 (R).

Ardjuna 10 (Upper Pucangan Formation, Lower Pleistocene): an isolated lower M2 (L).

Ardjuna 12 (Upper Pucangan Formation, Lower Pleistocene): an isolated upper M2 (L).

Patiayam 1 (Kabuh Formation, Middle Pleistocene): an isolated lower P1 (L).

Inventory	Nature of teeth	Dimensions			Index of robustness	Notes
		M-D*	B-L*	Height		
Kedungbrubus 1	low. M3 R					root
Trinil 1	up. M3 R	12.0	15.6	(6.4)	187.2	Pongo sp.
Trinil 4	up. M2 L	12.6	13.5	(6.5)	170.1	Pongo sp.
Trinil 5	low. P1 L	7.1	8.2	(6.5)	58.2	isolated
Sangiran 1 a	up. M1 L	-	-	-	-	broken
	up. M2 L	-	-	-	-	crown
	up. M3 L	12.1	14.9	(5.8)	180.2	
Sangiran 1 b	low. P2 R	9.0	10.5	(6.5)	94.5	
	low. M1 R	12.0	12.8	(5.7)	156.1	
	low. M2 R	13.1	12.8	(6.7)	170.3	
	low. M3 R	13.6	12.2	(6.3)	165.9	
Sangiran 4	up. C R	9.5	11.7	(12.5)	111.1	
	up. P1 R	8.2	12.4	(8.4)	101.6	
	up. P2 R	8.1	12.1	(7.5)	98.0	
	up. C L	9.5	11.9	(13.1)	113.0	
	up. P1 L	8.5	12.4	(8.7)	105.4	
	up. P2 L	8.5	12.3	(8.5)	104.5	
	up. M1 L	12.3	13.6	(7.0)	167.2	
Sangiran 5	low. M1 R	13.0	13.0	(5.0)	169.0	
	low. M2 R	14.1	14.3	(6.0)	201.6	
Sangiran 6 a	low. P1 R	9.1	11.4	(8.3)	103.7	
	low. P2 R	9.4	11.9	(7.1)	111.8	
	low. M1 R	14.3	12.6	(6.3)	180.1	
Sangiran 6 b	low. M2 L	14.4	13.2	(5.3)	190.0	
	low. M3 L	13.7	13.5	(5.3)	184.9	
Sangiran 7 a/b	up. M3 L	12.4	14.8	(7.1)	183.5	isolated
	up. M1 L	13.9	14.9	(9.9)	207.1	Pongo sp.
	up. M1 L	14.2	(14.2)	(10.8)	(201.6)	Pongo sp.
	low. M3 R	13.4	10.1	(7.1)	135.3	Pongo sp
Sangiran 8	low. M1 R	(11.8)	(10.8)	-	(127.4)	
	low. M3 R	14.3	12.6	(5.3)	180.1	
Sangiran 9	low. C R	6.2	8.5	(5.6)	52.7	
	low. P1 R	8.6	11.0	(5.4)	94.6	
	low. P2 R	8.0	11.1	(5.3)	88.8	
	low. M2 R	13.1	12.3	(5.1)	161.1	
	low. M3 R	12.2	12.3	(4.6)	150.0	
Sangiran 11 a	up. I1 R	7.3	6.6	(9.9)	48.1	isolated
11 b	up. M3 L	9.4	12.8	(7.3)	120.3	isolated
Sangiran 15 a	up. P1 L	7.5	11.5	(5.8)	86.2	
	up. P2 L	7.5	11.1	(7.3)	83.2	
Sangiran 15 b	up. P1 R	7.2	10.0	(5.9)	72.0	
Sangiran 16 a	up. M2 R	14.9	16.1	(5.7)	239.8	Pongo sp.
16 b	up. P1 L	7.0	9.7	(7.5)	67.9	isolated
Sangiran 17	up. C R	8.8	8.4	(10.9)	73.9	
	up. M1 R	10.1	12.3	(6.0)	124.2	
	up. M2 R	10.7	12.0	(5.5)	128.4	
	up. M3 R	8.5	12.5	(5.9)	106.2	
	up. P1 L	6.3	10.4	(6.5)	65.5	
Sangiran 21	low. M3 R	12.0	10.8	(5.9)	129.6	
Sangiran 22	low. C R	7.4	9.1	(5.7)	67.3	
	low. P1 R	8.6	10.1	(5.4)	86.8	
	low. P2 R	8.0	10.2	(4.4)	81.6	
	low. M1 R	11.8	12.4	(4.8)	146.3	
	low. M2 R	12.5	12.6	(5.4)	157.5	
	low. I2 L	4.9	6.9	(5.3)	33.8	

TABLE 3: CROWN DIMENSIONS AND INDICES OF ROBUSTNESS OF JAVAN HOMINID TEETH

(continued next page)

Inventory	Nature of teeth	Dimensions			Index of robustness	Notes
		M-D*	B-L*	Height		
	low. C L	7.5	8.9	(8.0)	66.7	
	low. P1 L	8.2	10.5	(5.1)	86.1	
	low. P2 L	8.2	10.3	(4.7)	84.4	
Sangiran 24	low. M2 L	12.5	11.2	(6.8)	140.0	isolated
	up. M1 L	11.7	11.5	(7.1)	134.5	isolated
	up. M1 R	10.1	11.0	(6.3)	111.1	isolated
	up. M3 L	10.6	13.0	(6.3)	137.8	isolated
	up. M3 L	8.3	10.8	(6.2)	89.6	isolated
	low. M3 L	11.7	11.2	(8.7)	131.04	isolated
	low. M3 R	11.6	10.4	(6.7)	117.1	isolated
	low. M3 R	10.6	9.2	(4.4)	97.5	isolated
	low. P2 R	10.6	11.6	(8.1)	122.9	Pongo sp.
	low. P2 R	11.0	11.3	(7.0)	124.3	Pongo sp.
Sangiran 27	up. P1 R	8.4	(12.1)	(6.2)	(101.6)	
	up. P2 R	(7.2)	12.2	(5.8)	(87.8)	
	up. M1 R	11.5	14.5	(7.3)	166.7	
	up. M2 R	12.7	15.0	(5.9)	190.5	
	up. P2 L	(6.7)	(11.9)	(5.2)	(79.7)	
	up. M1 L	(11.1)	12.8	(6.6)	(142.0)	
	up. M2 L	(12.2)	13.5	(6.8)	(164.7)	
Sangiran 33	low. M2 R	14.4	13.5	(8.7)	191.7	
Sangiran 35	up. M2 R	11.3	12.6	(5.6)	142.3	isolated
Sangiran 36	?	-	-	-	-	indeterm.
Sangiran 37	low. P2 R	7.6	10.5	(5.8)	79.8	
	low. M1 R	12.2	11.6	(6.0)	141.5	
	low. M2 R	12.3	11.7	(7.1)	143.9	
	low. M3 R	10.6	11.1	(5.7)	117.6	
Ardjuna 1 a	up. M2 R	13.5	13.4	-	180.9	Pongo sp.
1 b	up. M2 L	14.2	15.3	-	217.2	Pongo sp.
1 c	up. M1 R	14.8	12.0	-	177.6	Pongo sp.
Ardjuna 5	low. M3 R	11.6	11.4	-	132.2	isolated
Ardjuna 8	low. M2 R	11.7	10.1	-	118.1	isolated
Ardjuna 10	low. M2 L	-	11.1	-	-	isolated
Ardjuna 12	up. M2 L	12.5	13.0	-	162.5	isolated
Patiayam 1	low. P1 L	7.5	9.2	(6.3)	69	isolated

* Mesial-distal diameter (mm)
**Buccal-lingual diameter (mm)

TABLE 3 (CONTINUED)

Nature	Mandible			Maxilla		
	Min.	Max.	Aver.	Min.	Max.	Aver.
I 1	-	-	-	48.1	-	48.1
I 2	33.8	-	33.8	-	-	-
C	52.7	67.3	60.0	73.9	113.0	93.4
P 1	86.1	103.7	94.9	65.5	105.4	85.4
P 2	79.8	118.8	99.3	83.2	104.5	93.8
M 1	141.5	180.1	168.8	111.1	167.2	139.1
M 2	140.0	201.6	170.8	128.4	210.8	169.6
M 3	97.5	184.9	141.2	89.6	180.1	134.8

Notes: Min: Minimum index of robustness
Max: Maximum index of robustness
Aver: Average value of the index of robustness

TABLE 4: AVERAGE INDICES OF ROBUSTNESS FOR JAVAN HOMINID TEETH

Nature	Dimensions M-D*	B-L**	Index of robustness
Low. I1	5.4	6.0	32.4
Up. I1	9.0	7.0	63.0
Low. I2	5.9	6.4	37.8
Up. I2	6.4	6.0	38.4
Low. C	6.9	7.9	54.5
Up. C	7.6	8.0	60.8
Low. P1	8.0	8.0	64.0
Up. P1	7.2	9.0	64.8
Low. P2	7.1	8.0	56.8
Up. P2	6.8	8.8	59.8
Low. M1	11.2	10.3	115.3
Up. M1	10.7	11.8	126.2
Low. M2	10.7	10.1	108.0
Up. M2	9.2	11.5	105.8
Low. M3	10.7	9.8	104.8
Up. M3	8.6	10.6	91.2

* Mesial-distal diameter (mm)
** Buccal-lingual diameter (mm)

TABLE 5: AVERAGE CROWN DIMENSIONS AND INDICES OF ROBUSTNESS FOR MODERN HUMANS

RESULTS OF THE MEASUREMENTS

Robustness of the Upper Teeth

The indices of robustness for the Sangiran teeth are detailed in Tables 3 and 4. These values are clearly greater than the averages for modern humans (Table 5). The overall average values for the Sangiran teeth occupy an intermediate position between the Sangiran extreme values and the averages of modern humans.

A diagrammatic comparison of the indices of robustness of Javan hominids and modern humans is presented in Fig. 1. In this the lines for Sangiran 4 (right and left) can be seen to drop from canine to second premolar (C > P1 > P2), showing almost the same trend as the lines for Sangiran 27 (right and left). However, the line for modern man shows an increase in robustness from the canine to the first premolar, before dropping to the second premolar, which almost reaches the same value as the canine (P2 < C < P1). Sangiran 4 (right and left) has the most robust canines, whereas Sangiran 17 (right and left) has the smallest. Sangiran 27 (right and left), Sangiran 15a and Sangiran 15b occupy intermediate positions. The overall sequence of robustness is thus Sangiran 4 > Sangiran 27 (right and left) > Sangiran 15a > Sangiran 15b > Sangiran 17 (right and left) > modern man. If we look at the material in relation to chronology we find that Sangiran 4 and Sangiran 27 belong to the Pucangan Formation of the Lower Pleistocene, and Sangiran 15a, Sangiran 15b and Sangiran 17 belong to the Kabuh Formation of the

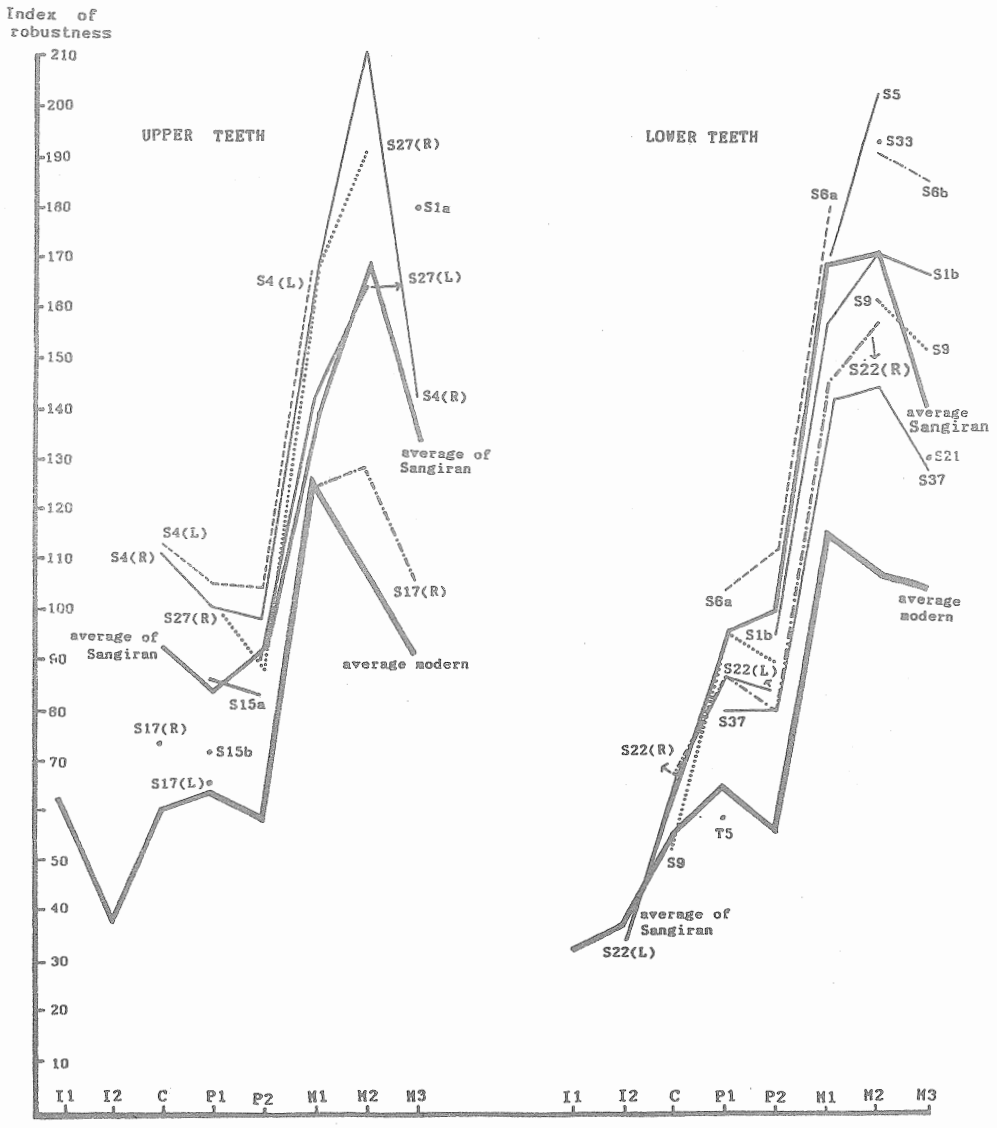

FIGURE 1: COMPARISON OF THE INDICES OF ROBUSTNESS FOR JAVAN HOMINID TEETH

Middle Pleistocene. There is thus a significant decrease in the robustness of the canine from Lower to Middle Pleistocene to Recent.

For molars we have Sangiran 4 (right), Sangiran 27 (right and left), Sangiran 17 (right and left) and the M3 of Sangiran 1a. Sangiran 4 (right) is again more robust than Sangiran 27 (right and left) and Sangiran 17 (right and left). The average Sangiran values roughly follow those of Sangiran 27 (left). The index of robustness of the M3 of Sangiran la is greater than that of the M3 of Sangiran 4 (180.2 to 142.8). So the direction of decreasing molar size runs as follows: Sangiran 1a > Sangiran 4 > Sangiran 27 (right and left) > Sangiran 17 (right and left) > modern humans. The results show the same age trend as the canines, with a decrease in molar robustness from the Lower Pleistocene onwards.

The largest of the Sangiran 4 molars is the M2 and the smallest is M3 (M2 > M1 > M3). The same trend is shown by Sangiran 27 (right and left) and Sangiran 17 (right and left). On the contrary, we find that M1 > M2 > M3 in modern humans. Therefore, we can conclude that M2 is the largest tooth in the hominid series of Pleistocene Java, whereas M1 is largest in modern humans.

Robustness of the Lower Teeth

The robustness of the lower teeth, as indicated by Sangiran 22 (left), shows an increase from the second incisor to the first premolar. There is then a decline from the first premolar to the second premolar. This phenomenon occurs also in Sangiran 22 (right) and Sangiran 9, while Sangiran 37 of the Middle Pleistocene has equal-sized first and second premolars. Sangiran 6a shows the opposite trend: a clear increase from the first to the second premolar.

The only isolated tooth from Trinil (Trinil 5, a lower left P1) is smaller than all other P1 teeth, even modern ones. The average values for Javan hominid upper teeth show the same pattern as Sangiran 6a, with a larger second premolar. However, excepting Sangiran 6a the first premolar is the most robust in the canine group, and the canine is the weakest (C < P2 < P1).

In the case of modern humans there is an increase of robustness from the first incisor to the first premolar and then a decrease from the first to the second premolar. The strongest tooth in the canine group is the first premolar (average value 64.0), and the weakest is the canine (average value 54.5) (C < P2 < P1).

For the molars there is an increase from M1 to M2 followed by a reduction from M2 to M3. Among the first molars that of Sangiran 6a is the largest, while the smallest is that of Sangiran 37. The overall order of first molar size is Sangiran 5 > Sangiran 1b > Sangiran 22 (right) > Sangiran 37 (right). The first four come from the Pucangan Formation and only Sangiran 37 comes from Kabuh Formation of the Middle Pleistocene.

M1 is still the most robust tooth in modern populations and M3 is the smallest (M1 > M2 > M3). For the lower molars, therefore, there is again a regular reduction in robustness from Lower to Middle Pleistocene and, of course, to Recent. We cannot yet

speak about the teeth of the Upper Pleistocene since we only have an isolated tooth (a lower right M2) which comes from the Notopuro Formation (Ardjuna 8).

CONCLUSIONS

This Sangiran material allows us in some way to understand dental evolution during the Pleistocene Period, especially during the Lower and Middle Pleistocene. It is a great pity that finds are still insufficient to study the last stage of the Pleistocene. Furthermore, little can be said about the specimens from Kedungbrubus and Trinil (both Middle Pleistocene). We only have a lower right root of P1 connected with the symphysis region of the Kedungbrubus mandible. Furthermore, it is risky to use the Trinil material since it shows very strong *Pongo* characteristics (Trinil 1 and Trinil 4 have big sizes, very ridged occlusals and divergent roots).

After having examined the index of robustness we come to the following conclusions:

a. Upper teeth:

Canine group:	C > P1 > P2	(Java hominids)
	P2 < C < P1	(modern humans)
Molar group:	M2 > M1 > M3	(Java hominids)
	M1 > M2 > M3	(modern humans)

b. Lower teeth:

Canine group:	C < P2 < P1	(Java hominids)
	C < P2 < P1	(modern humans)
Molar group:	M1 < M2 > M3	(Java hominids)
	M1 > M2 > M3	(modern humans)

The canine group of the upper teeth shows a diminution of robustness of the canine and an augmentation of P2:

C (Java hominids) ⟶ relative diminution ⟶ C (modern)

P2 (Java hominids) ⟶ relative augmentation ⟶ P2 (modern)

In the case of the canine group of the lower teeth *there has been no change* in the dimensional succession from Pleistocene to modern. This means that there has been no evolution of the lower canine group from Lower Pleistocene to Recent.

Both the upper and lower molar groups show the same pattern of evolution: a reduction of the second molar (M2) and an augmentation of the first molar (M1) from Pleistocene to Recent.

M2 (Java hominids) ⟶ relatively more gracile ⟶ M2 (modern man)

M1 (Java hominids) ——→ relatively more robust ——→ M1 (modern man)

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