

# Physical Cranial Characters of Wajak Man

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## ABSTRACT

Human fossils from Wajak, or better known as Wajak Man which is noted as Wajak 1, have been discovered by von Rietschoten in 1888 during exploration prospecting activities at the marble mine area in Tulungagung. The Wajak 1 found in cave sediments during disorganized excavation, therefore the stratigraphic position of the fossil was uncertain.

Until this time, since the discovery of the fossil, not many study and publications have been performed on the fossil of Wajak 1. For this reason, this research attempted to compare Wajak 1 with *Homo erectus* fossils from Ngandong, Sambungmacan, and Sangiran to understand the presence of a linearity pattern based on anatomy of the physical cranial characters. The research was conducted through qualitative analysis by comparing the anatomy of all samples, and quantitative analysis by measuring some biometric parameters of cranium which then processed by statistical methods.

Based on PCA analysis, the fossils of Ng 9, Ng 10, Ng 11, Sm 1, Sm 3, Sm 4, Sn 17, Ngawi 1, and Wajak 1 have some kinship based on two principal components as a variable that mostly contributed. Particularly, the specimen of Wajak 1 has the furthest kinship with other fossils based on maximum cranial length and minimum frontal breadth. Based on these parameters, the Wajak 1 has the largest size in comparison with other fossil samples. The fossil Ngawi 1 and Sm 3 have a close relationship because both of the samples have a smallest size among others, as indicated by their maximum cranial length, minimum frontal breadth, parietal chord, and occipital chord.

The specimens of Ng 9, Ng 10, Ng 11 closed to one another and formed in one group, while Sm 1 and Sm 4 close to Sn 17 and form another group. Ng 9, Ng 10, and Ng 11 have a greater values on four parameters compared to the specimens Sm 1, Sm 4, and Sn 17. The result of cluster analysis shows the cluster pattern similar to PCA as shown in the dendrogram. Based on comparative anatomy, the Wajak 1 has most rounded shape and largest cranium. Another different could be seen visibly in the supraorbital torus which is thin and curve tends to follow the shape of orbital.

A prominent supraorbital torus is a character belongs to *Homo erectus* was observed in the specimens Sm 1, Sm 4, Sn 17, Ng 9, Ng 10, Ng 11, Sm 3, and Ngawi 1, but it was not observed in Wajak 1. So, it could be concluded that Wajak 1 is belongs to *Homo sapiens* which has a characters no prominent supraorbital torus, most rounded form and largest size among other specimens.

**Keywords:** Wajak Man/Wajak 1, comparative anatomy, Principal Component Analysis (PCA)

**Sari-** Fosil manusia dari Wajak yang dikenal sebagai Manusia Wajak dan dinyatakan sebagai Wajak 1 telah ditemukan pada tahun 1888 oleh Rietschoten ketika sedang melakukan kegiatan eksplorasi prospek marmer di daerah pertambangan di Tulungagung, Jawa Timur. Wajak 1 ditemukan dalam sedimen gua dalam sebuah penggalian yang tidak mengikuti kaidah penggalian yang seharusnya, sehingga kedudukan stratigrafi lapisan sedimen tersebut tidak dapat ditentukan.

Sejak ditemukannya fosil tersebut hingga kini, tidak banyak penelitian maupun publikasi yang dilakukan atas Wajak 1. Oleh sebab itu, penelitian atas fosil Wajak 1 sekarang ini dilakukan untuk memahami garis evolusinya berdasarkan pada ciri fisik tengkoraknya (*cranial*) dengan membandingkan terhadap fosil *Homo erectus* dari Ngandong, Sambungmacan, dan Sangiran. Penelitian ini dilakukan melalui analisis kualitatif dengan membandingkan anatomi contoh-contoh fosil, dan analisis kuantitatif dengan pengukuran beberapa parameter biometri tengkorak yang hasilnya kemudian diproses dengan metode statistik.

Hasil analisis PCA, memperlihatkan bahwa fosil-fosil Ng 9, Ng 10, Ng 11, Sm 1, Sm 3, Sm 4, S17, Ngawi 1 dan Wajak 1 mempunyai hubungan kekerabatan yang ditunjukkan oleh dua *principal component* sebagai variabel yang paling berkontribusi. Khusus untuk Wajak 1, memiliki hubungan kekerabatan dengan fosil-fosil lainnya berdasarkan *maximum cranial length* dan *minimum frontal breadth*. Berdasarkan parameter tersebut, terlihat Wajak 1 mempunyai ukuran tengkorak lebih besar dibandingkan dengan tengkorak fosil-fosil lainnya. Fosil Ngawi 1 mempunyai hubungan yang dekat dengan Sm 3 karena kedua contoh fosil tersebut mempunyai ukuran tengkorak yang paling kecil dibandingkan ukuran dari fosil-fosil lainnya, yang diperlihatkan oleh *maximum cranial length*, *minimum frontal breadth*, *parietal chord*, dan *occipital chord*-nya.

Spesimen Ng 9, Ng 10, Ng 11 terlihat saling berdekatan dan membentuk satu kelompok, sedangkan Sm 1 dan Sm 4 dekat dengan S 17, dalam satu kelompok yang lain. Fosil Ng 9, Ng 10, dan Ng 11 memiliki nilai yang lebih tinggi pada empat parameter dibandingkan nilai pada spesimen Sm 1, Sm 4, dan S17. Hasil analisis *cluster* menunjukkan pola *cluster* yang sama pada PCA, seperti diperlihatkan dalam dendogram. Dari analisis perbandingan anatomi (*comparative anatomy*), Wajak 1 mempunyai ukuran tengkorak lebih besar dan bentuk yang lebih membundar. Perbedaan lainnya dapat dilihat dengan sangat jelas pada supraorbital torus yang tipis dan cenderung lengkung mengikuti bentuk dan ukuran orbital.

Tonjolan pada *supraorbital torus* (*prominent supraorbital torus*) adalah ciri yang dimiliki *Homo erectus* dapat diamati pada spesimen Sm 1, Sm 4, Sn 17, Ng 9, Ng 10, Ng 11, Sm 3, dan Ngawi 1, tetapi tidak teramati atau tidak terdapat pada fosil Wajak 1. Dengan demikian dapat disimpulkan bahwa tengkorak fosil Wajak 1 adalah *Homo sapiens* yang tidak memiliki ciri tonjolan supraorbital torus (*prominent supraorbital torus*), mempunyai bentuk lebih membundar dan ukuran yang lebih besar dibandingkan spesimen lainnya.

Kata kunci: Manusia Wajak/Wajak 1, anatomi perbandingan, *Principal Component Analysis* (PCA)

## INTRODUCTION

Human fossils from Wajak, which is better known as Wajak Man, has been discovered by von Rietschoten in 1888 during exploration prospecting activities at the area of marble mining in Tulungagung – East Java (Storm and Nelson, 1992). This fossil was then handed to Eugene Dubois who then called this fossil as Wajak 1. The discovery of Wajak 1 led Dubois to explore Java and finally he found human fossil from Trinil in 1893. So that Wajak 1 could be considered as the first human fossil ever found in Indonesia.

Wajak 1 found in cave sediments in disorganized excavation, so the stratigraphic position is uncertain. Since discovery until now, not many research and publications have been done on the fossil Wajak 1. Based on its anatomy, the Wajak 1 was identified as *Homo sapiens*, but biometric measurements and environmental investigations of Wajak 1 has never been done before.

For this reason, this research attempted to compare Wajak 1 with *Homo erectus* fossils from Ngandong, Sambungmacan, and Sangiran to see if there was a linearity pattern based on anatomy. The research was conducted through qualitative analysis by comparing the anatomy of all samples, and quantitative analysis by measuring some biometric parameters of cranium which then processed by statistical methods.

## METHODS

This research was held by method as follows:

### a. Morphological (anatomical) Description

Morphological or anatomical description is a stage of qualitative analysis performed in this study, carried out on different fossils. In this analysis will be described conditions of each fossil, which parts that could be analyzed and prominent morphological appearance. In addition, it should also be mentioned condition of the fossil, it is original or a replica.

### b. Biometric Parameter Identification

Biometric parameter identification is done to determine the location of the reference points in biometry measurements. Due to the condition of fossils that are sometimes are incomplete, there were may be as a point of unobservable parameters, however, if possible, it could be done by reconstructing it and in such situation, it should be mentioned.

### c. Biometric Measurement

Biometric measurement is an effort to quantified the morphological data. Biometric measurements standard performed in this study were taken from Aftandilian et al. (1994).

### d. Statistical Analysis

Statistical analysis was performed as the data analysis of biometric methods through PCA and Cluster analysis.

### e. Principal Component Analysis (PCA)

A method in multivariate data which aims to reduce the original variables into some new variables called principal components. Basically, the PC analysis is to select the most important variable among the many variables that have significant contribution to the whole data.

Cluster is a method which done by sample grouping based on similarities or dissimilarities in certain elements. Basically, cluster analysis aims to simplify the number of samples into groups based on similarities or dissimilarities of certain variables. Cluster methods used in this study is the Joining Principle or Tree Clustering which produces a hierarchical tree, called Dendrogram.

## **FOSSIL OBJECTS**

This study will be based on the description of the morphology/anatomy, biometric measurements, and comparative anatomy of some hominid fossil samples. The fossil samples are as follows:

### **a. Sangiran Fossil**

Fossil from Sangiran specimens for this study was S17 which is a replica from the original fossil which was discovered in Sangiran. The specimen consist of the frontal, parietal, and occipital. Most of the biometric parameters could be observed clearly.

### **b. Sambungmacan Fossils**

Human fossils from Sambungmacan in this study are Sm 1, Sm 3, and Sm 4. Those fossils were found at the base of the Bengawan Solo River in Sambungmacan Village. According Hasibuan et al. (1995), Baba et al. (2003), and Aziz et al. (2004) in Kaifu et al. (2008), Sm 3 and Sm 4 derived from Kabuh Formation, Middle Pleistocene in age. Meanwhile, by Jacob (1973) and Jacob et al. (1978) in Kaifu et al. (2008), Sm 1 is Early Pleistocene to Middle Pleistocene in age. The specimens Sm 1, Sm3, and Sm4 are a well preserved of the cranium fossils, consists of frontal, parietal, occipital, and temporal part.

### **c. Ngandong Fossils**

Ngandong fossil specimens used in the study was Ng9, Ng10, and Ng1. All the three specimens are replicas of original fossils found in Ngandong East Java, consisting of frontal part, temporal, parietal, and occipital. Human fossils in Ngandong found along with hundreds of vertebrate fossils by von Koenigswald in 1930s. Age of these fossils is controversial, but most experts agree that the age of Ngandong fossils is younger than Sangiran fossils, that is between the end of Middle Pleistocene to the middle of the Upper Pleistocene (Swisher et al., 1996 in Kaifu et al., 2008)

### **d. Ngawi Fossil**

Human fossils from Ngawi used in this study is Ngawi 1, which is the original fossil from Museum MPU Tantular's collection. Ngawi 1 was found loose on the base of Bengawan Solo, and its stratigraphic position is not certainly known. Ngawi 1 is possibly come from Pitu Terrace in Watualang which is comparable with Ngandong Terrace, Upper Pleistocene age. But the fossilisation is perfect so it is also possible came from the Middle Pleistocene age, Kabuh Formation. Ngawi 1 consists of the frontal, parietal, temporal, occipital, sphenoid, and basal part.

### **e. Wajak Fossil**

Wajak fossil specimen used in this study was Wajak1, property belongs to Geological Museum Bandung, which is a cranium replica of original fossil found in Lawa Cave near Wajak, Tulungagung, East Java. The Wajak1 was found in terrace deposit, and the age estimated between end of Upper Pleistocene to Holocene (Storm and Nelson, 1992).

## RESULT AND DISCUSSION

Statistical analysis through PCA performed on all samples using 4 variables, maximum cranial length, parietal chord, and occipital chord (**Table 1**). From all these variables, selected two principal components (PC1 and PC2) that are supposed to represent the entire distribution of the data change in cranial shape and geometry based on eigenvalue (**Table 2**). On PC1, the most contributing variables are parietal chord and occipital chord, whereas the variables that mostly contributed to PC2 are maximum cranial length (-6939) and minimum frontal breadth (-06829). Thus, the variables are the most important parameter that affects the shape and size differences of each sample, represented in loading (**Table 3**).

Based on PC1 and PC2 (**Figure 1**), all of the samples has some kinship based on the variables that contributed more of those principal component. Particularly, Wajak 1 has the furthest kinship with other samples based on maximum cranial length and minimum frontal breadth. Based on these parameters, Wajak 1 has the largest size in comparison with other samples. Whereas, Ngawi 1 and Sm 3 have a close relationship because both samples have a smallest size among others based on maximum cranial length, minimum frontal breadth, parietal chord, and occipital chord. Ng 9, Ng 10, Ng 11 adjacent to one another and form a separate group, while Sm 1 and Sm 4 adjacent to S 17 and form another group. Ng 9, Ng 10, and Ng 11 have a greater values on four parameters compared with Sm 1, Sm 4, and S 17.

The result of cluster analysis showed the cluster pattern similar to PCA, as shown in the dendrogram (**Figure 2**). The Dendrogram displays grouping of samples based on similarity index which is counted by Euclidean Distance and do not shows a phylogenetic continuity. The greater similarity index of some clusters means that the clusters has a greater resemblance, and smaller similarity index means the clusters have a smaller resemblance. In the dendrogram, there are some patterns as follows:

1. Ng 10 and Ng 11 have similarity index -4, then merge into one cluster with Ng 9 by similarity index -18.
2. Sm 1 and Sm 4 have similarity index -6 and merge into one cluster with S 17 by similarity index -19.
3. Ng 10, Ng 11, Ng 9 merge into one cluster with Sm 1, Sm 4, S 17 by similarity index -33.
4. Ngawi 1 and Sm 3 combine in a separate cluster by similarity index -4, and then merge into the earlier cluster by similarity index -46.
5. Wajak 1 separated distant from other clusters by similarity index -58.

Comparative anatomy of all samples showed a different shape and size of each group. Ng, Ng 10, Ng 11 have a similar shape to Sm 1, Sm 4, and S 17, but the size is slightly different on maximum cranial length, minimum frontal breadth, parietal chord, and occipital chord. The morphology of Ngandong samples (Ng 9, Ng 10, Ng 11) tend to have a higher posterior part than Sambungmacan (Sm 1, Sm 4) and Sangiran (S 17) samples, visibly seen at lateral view of samples which shows a more rounded cranial shape. Ngawi 1 and Sm 3 also have a very similar shape to Sm 1, Sm 4, and S 17, but the size are smaller. It is possibly that Sm 3 and Ngawi 1 are coming from female cranium and proportionally have a smaller size than male cranium. Meanwhile, Wajak 1 has a shape and size which is intensely different from other samples, it could seen based on qualitative and quantitative analysis. Based on anatomical comparison, Wajak 1 has most rounded shape and largest cranium. Another difference is visible in the supraorbital torus which is thin and curve tends to follow the shape of orbital. A prominent supraorbital torus is a characteristic belongs to *Homo erectus* was observed in the specimens Sm 1, Sm 4, S 17, Ng 9, Ng 10, Ng 11, Sm 3, and Ngawi 1, but it was not observed in Wajak

1. So, it can be concluded that Wajak 1 belongs to *Homo sapiens* which has a character no prominent supraorbital torus, most rounded form and largest size among other specimens.

Changes in cranium size are affected by changes in shape, and these changes are likely influenced by the expansion of the brain which increases in size by increasing of nutrition absorption. The development of cranium shape anatomically has an impact in increasing height of temporal bone (heightening) and parietal bone formed the cranium be more rounded. In addition, the more rounded shape also pointed out in angle between Frankfurt horizontal line and frontal part which is greater as shown in **Figure 3**.

## CONCLUSION

Based on PCA and cluster analysis combined with anatomical comparison, the most important parameters for determining the shape and size of all samples are maximum cranial length, minimum frontal breadth, parietal chord, and occipital chord. Wajak 1 has most rounded shape and largest cranium. Another difference could be seen visibly in the supraorbital torus which is thin and curve tends to follow the shape of orbital. One of character in morphological features in *Homo sapiens* which was not observed is a prominent supraorbital torus, a character belongs to *Homo erectus*. So, it could be concluded that the Wajak 1 is *Homo sapiens* which has a most rounded form and largest size, while the other specimens (Sm 1, Sm 4, Sn 17, Ng 9, Ng 10 Ng 11, Sm 3, and Ngawi 1) are belong to *Homo erectus*.

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**Table 1.Data Used in principal component analysis (PCA)**

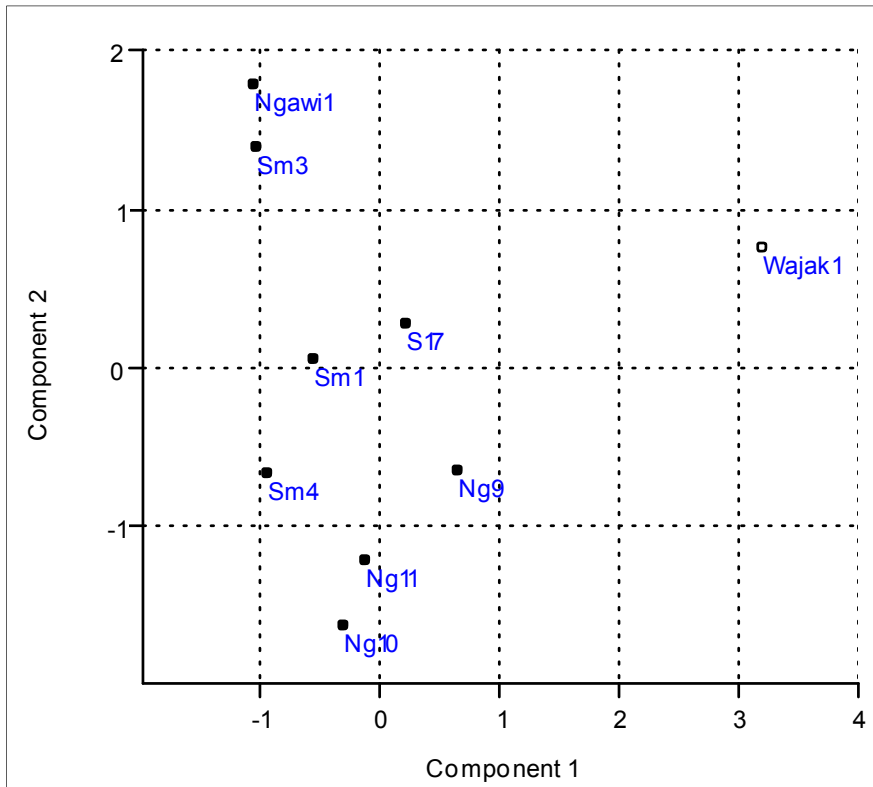
<b>Variable</b> <b>Sample</b>	<b>maximum cranial length</b>	<b>minimum frontal breadth</b>	<b>parietal chord</b>	<b>occipital chord</b>
Wajak 1	191,5	99	132,2	106
Ngawi 1	179	94,8	94,2	82,8
Ng 9	199	107	120	84
Ng 10	203	119	107,3	82
Ng 11	201	117	104	86,5
Sm 1	199	101	96	85
Sm 3	178	101	97	82
Sm 4	199	109	100	79
S 17	207	88	106	85

**Table 2.Results of PCA contains of eigenvalues and percent variances which are used to pick the amount of principal components (PC).**

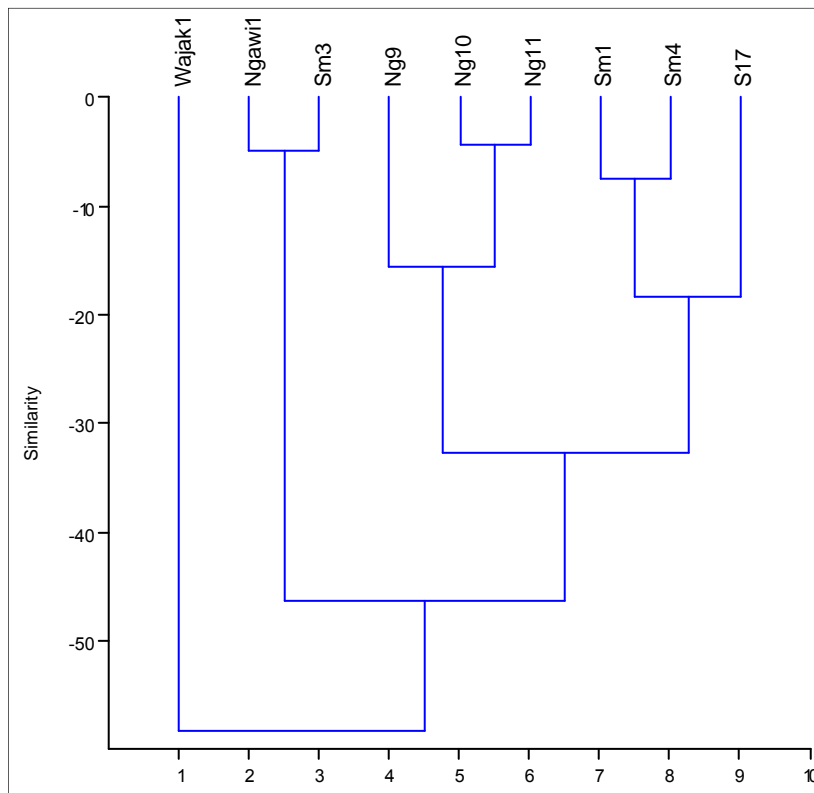
<b>PC</b>	<b>Eigenvalue</b>	<b>%variance</b>
1	1,78351	45,097
2	1,34433	33,992
3	0,675843	17,089
4	0,151143	3,8217

**Table 3. Loading of each variables, show contribution of each variables to principal component (PC).**

<b>Variable</b>	<b>Principal Component</b>	
	<b>PC1</b>	<b>PC2</b>
maximum_cranial_length	0,1316	-0,6939
minimum_frontal_breadth	0,09665	-0,6829
parietal_chord	0,7054	-0,1404
occipital_chord	0,6897	0,1803

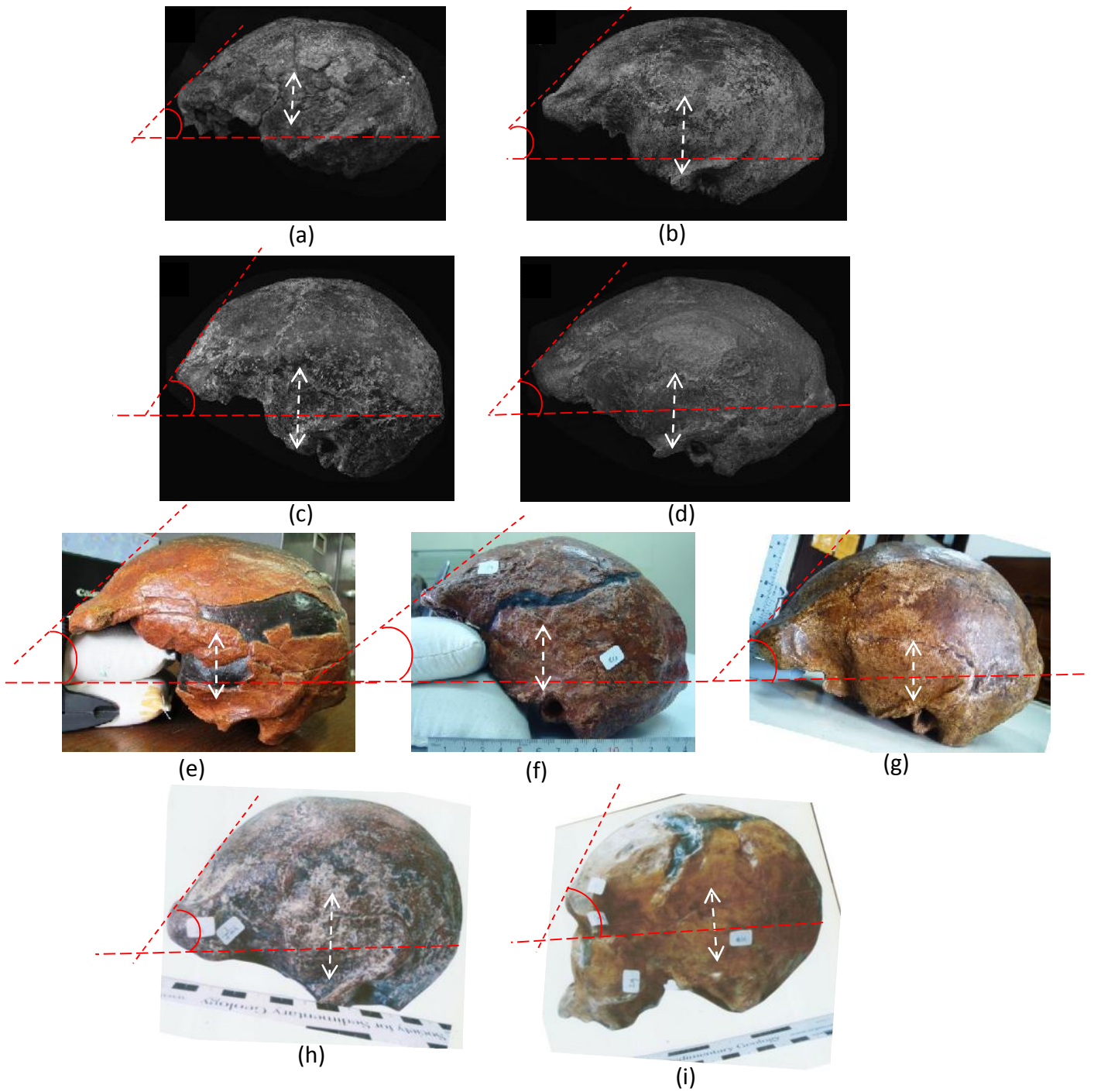


**Figure 1. Graphic shows plotting Component 1 (PC1) and Component 2 (PC2)**



**Figure 2. Dendrogram shows clustering of the samples based on similarity and does not show any phylogenetic continuity.**





**Figure 3. Lateral view of S 17 (a), Sm 1(b), Sm 3 (c), Sm 4 (d), Ng 9 (e), Ng 10 (f), Ng 11 (g), Ngawi 1 (h), and Wajak 1 (i). White dashes show the different of temporal height in each samples, and the red dashes show the different of angle which is formed between frankfurt horizontal line and frontal line in each samples.**