C. R. Palevol 11 (2012) 89–95

Contents lists available at ScienceDirect

Comptes Rendus Palevol

www.sciencedirect.com

Human palaeontology and prehistory

Homo erectus found still further west: Reconstruction of the Kocabaş cranium (Denizli, Turkey)

Homo erectus toujours plus loin vers l'ouest. Reconstitution du crâne de Kocabaş (Denizli, Turquie)

Amélie Vialet[a,*], Gaspard Guipert[b], Mehmet Cihat Alçiçek[c]

[a] *Institut de paléontologie humaine, fondation Albert 1er de Monaco, 1, rue René-Panhard, 75013 Paris, France*
[b] *Antenne de l'institut de paléontologie humaine, CEREGE, europôle de l'Arbois, bâtiment Villemin, BP80, Aix-en-Provence cedex 04, France*
[c] *Department of Geology, Pamukkale University, Denizli, Turkey*

ARTICLE INFO

Article history:
Received 6 June 2011
Accepted after revision 9 June 2011
Available online 5 October 2011

Written on invitation of the Editorial Board

Keywords:
Homo ergaster
Homo georgicus
First settlements
3D imaging techniques
Morphometrics
Inner anatomical features
Turkey

Mots clés :
Homo ergaster
Homo georgicus
Premiers peuplements
Imagerie 3D
Morphométrie
Caractères anatomiques internes
Turquie

ABSTRACT

Few human fossils are known in Turkey and no *Homo erectus* has been discovered until now. In this respect, the newly discovered partial skull from Kocabaş is very important: (1) to assess the pattern of the first settlements throughout the Old World; and (2) to document the extension of the species *H. erectus* to the west of continental Asia. Using CT data and 3D imaging techniques, this specimen was reconstructed and a more detailed analysis was done, including the inner anatomical features. The preliminary results of this study highlight that the fossil hominid from Kocabaş is close to the *H. erectus* species regarding the following cranial patterns: presence of a clear post-orbital constriction, strong development of the frontal brow-ridge with a depressed supratoral area in the lateral part, as well as endocranial patterns such as the development and orientation of the middle meningeal artery and the presence of a frontal bec. The Kocabaş skull is morphologically very close to the fossils from Zhoukoudian L-C. The partial Kocabaş skull is the oldest *H. erectus* known in Turkey and the only one from this species to have settled so far west in Asia.

RÉSUMÉ

Peu de restes humains sont connus en Turquie et aucun n'a pour l'instant été attribué à *Homo erectus*. De ce fait, le crâne fragmentaire de Kocabaş, récemment découvert, s'avère important pour discuter: (1) des modalités des premiers peuplements de l'Ancien monde; et (2) pour documenter l'extension de l'espèce *H. erectus* à l'ouest de l'Asie continentale. En utilisant les techniques tomographiques et d'imagerie 3D, ce spécimen a été reconstitué et une étude détaillée a été réalisée incluant l'analyse des caractères anatomiques internes. Les résultats préliminaires de cette étude montrent que le fossile de Kocabaş est proche de l'espèce *H. erectus* sur la base, non seulement, de la conformation crânienne (constriction post-orbitaire nette, fort développement du torus supra-orbitaire et, dans sa partie latérale, dépression supratorale marquée), mais également des caractères endocrâniens (développement et orientation du réseau méningé moyen, présence d'un bec

* Corresponding author.
E-mail address: amelievialet@fondationiph.org (A. Vialet).

1631-0683/$ – see front matter © 2011 Published by Elsevier Masson SAS on behalf of l'Académie des sciences.
doi:10.1016/j.crpv.2011.06.005

encéphalique). Très semblable morphologiquement aux crânes de Zhoukoudian L-C, le fossile de Kocabaş est le plus ancien *H. erectus* connu en Turquie. Il est aujourd'hui le seul représentant de cette espèce situé aussi loin, à l'extrémité occidentale de l'Asie.

1. Introduction

In 2002, one of us (MCA) discovered a partial skullcap in a quarry, near a village called Kocabaş, in the Denizli region of Turkey (Kappelman et al., 2008; Nachman et al., 2010). Although the place of discovery cannot be accurately known, it comes from a zone where the age of the travertine sediments was estimated, by ESR, at 1.11 ± 0.11 My (Engin et al., 1999) and thermoluminescence, ranging from $510{,}000 \pm 50{,}000$ to $330{,}000 \pm 30{,}000$ years (Özkul et al., 2004a, 2004b). The biostratigraphic data from the fauna discovered within the travertine sediments (especially *Equus* aff. *suessenbornensis*) seem to confirm this attribution to the Middle, even Lower, Pleistocene.

The aim of this article is to present: (1) the reconstruction of the Kocabaş skull, the way it was achieved through 3D imaging techniques by re-articulating the fragments and completing the missing parts; and (2) the analysis of the endocranial and exocranial anatomical features, comparing them with those of the Eurasian fossil hominids, in order to place the Kocabaş specimen within the span of human evolution.

2. Material

2.1. The Kocabaş fossil

The skullcap from Kocabaş was discovered while travertine stones were being mined in the Denizli region (South-West Turkey). It escaped the fate reserved by the saw blades that were set to cut standard 35-mm thick slices into the rocks. Therefore, this skull, from which only fragments from the frontal bones and both parietal bones remain, is only preserved along this measurement. The blade that « sliced » it left a distinctive mark exposing the diploe: following a transverse cut slicing the parietal bones, and along the edge of the middle frontal part, destroyed in the process.

The fossil shows (Fig. 1):

- anterior parts of the right and left parietal bones, preserved respectively over 60 and 52 mm in length and over 82 et 64 mm in width;
- lateral parts of the frontal bone with, on the right, the lateral supratoral area and the almost complete temporal portion rimmed, on its superior part, by fused temporal lines forming a marked ridge. On the left, only the superior half of the temporal portion remains. It is rimmed, like its right counterpart, by fused temporal lines forming a marked ridge. Beyond it, the frontal squama is preserved over 70 mm in length and 26 mm in width at most. On the left, there is nothing left of the orbital cavity, neither of the torus nor the supratoral area, except for a very small lateral part of the orbital roof measuring about 10×18 mm. On the right, the lateral supratoral region is preserved over 19 mm in length and 50 mm in width; the supraorbital torus remains intact from the lateral extremity to the supraorbital notch (it is slightly worn, in its superior part, over 20 mm medio-laterally from the break) and 1/3 of the right orbital roof is preserved inferiorly. The glabellar region is damaged, exposing the right and left ethmoidal cells.

Fig. 1. The Kocabaç skull composed by three bone fragments.

Fig. 1. La calotte crânienne de Kocabaç composée de trois fragments osseux.

When discovered, this fossil consisted of three fragments: (1) the left part of the frontal bone and the fragment of the left parietal bone, still connected; (2) the right parietal fragment; and (3) the right part of the frontal bone. The sagittal and coronal sutures were not completely fused, which means that we are dealing with a young individual.

2.2. Reconstructing the Kocabaş fossil

In order to redefine the anatomic connection between the cranial parts and compensate for the missing parts, a reconstruction was carried out (Guipert et al., 2011; Vialet et al., 2011). The three fragments from the Kocabaş skull were scanned, using the Philips helical scanner at the Pamukkale teaching hospital, in Denizli, on September

14th, 2009; slice thickness was 0.80 mm, the space between slices was 0.4 mm (field of view: 20 cm, matrix: 512 × 512, power: 175 mA, intensity: 120 kV).

From the 3D reconstruction of each element (Fig. 2a) using the *Mimics Version 13.1 Materialise®* software, a re-connection of the fragments was achieved using the *RapidForm 2006 Inus Technology®* software.

As the anatomical connexion preserved was between the left lateral part of the frontal bone and the anterior fragment of the left parietal bone, this frontoparietal block was used as a basis to reposition the two other fragments. The transverse plane (i.e. the slicing of the skull by the saw blade) of the parietal bones was used as a reference plane to replace the fragments within their original space. The right parietal bone was anatomically positioned with its left counterpart thanks to a good interdigitation of both bones along the sagittal suture. This suture, owing to the young age of this individual, had not fused completely. The anatomical features located on the inner surface of the parietal bones (orientation of the middle meningeal artery) also served as a guide, as well as the good continuity in the biparietal curve on the inner plate (Fig. 2b).

Once these two bones were connected again, it was the turn of the right part of the frontal bone (Fig. 2c). The left part of the frontal bone being preserved and connected to the left parietal bone, a mirror image was produced in order to serve as a guide to reposition the right fragment of the frontal bone with the right parietal bone. In order to avoid biases in the process due to symmetrization performed using a relatively short reference plane (Guipert and Mafart, 2008), the sagittal suture was not used as the sole reference plane in the connection process. However, the good continuity of the curve formed by both inner plates (right parietal bone and right lateral part of the frontal bone) was thoroughly checked.

A slight rotation of the newly connected entire right frontoparietal block was done so that the frontal crest, which develops from front to back along the medial plane, aligned with the sagittal suture in the same plane.

The missing left part of the supraorbital torus was recreated using the mirror image of its preserved right counterpart (Fig. 2d). A slight adjustment was necessary to match the temporal lines, the coronal suture and the orbital part of the frontal bone. The missing glabellar region could not be reconstructed.

The Kocabaş specimen, as reconstructed by 3D imaging, is more complete and displays a more accurate articulation of its three bone components. This prototype, a reconstructed physical form, enables us to take transverse measurements to compare the Kocabaş skull with the other fossil hominids selected in this study.

2.3. Comparison sample

In order to carry out the morphological and metric analysis of the Kocabaş specimen, the *Homo erectus* skulls from the following Chinese and Indonesian sites were selected: Zhoukoudian Lower Cave (L-C) (skulls III, X, XI and XII), Hexian and Sangiran 17. Moreover, fossils from the Lower Pleistocene of Africa (ER3733, ER3883 and OH9) and Georgia (D2280, D2282 and D2700 from Dmanissi) and European specimens from the Middle Pleistocene (Arago 21, Sima de los Huesos and Petralona) were included in this study. Observations and measures were taken on the casts from the collection at the Institut de Paléontologie Humaine, whereas those concerning the genuine fossils from Dmanissi and the Arago 21 specimen, on one hand, and from Sima de los Huesos skulls, on the other hand, come respectively from M.-A. de Lumley (2006) and Arsuaga et al., 1997.

3. Methods

3.1. Metric analysis

Considering the state of preservation of the Kocabaş skull, only a few variables were measured (Table 1) above all from Martin (1928). These were: (1) the minimum frontal breadth (regardless of the temporal lines); (2) the maximum frontal breadth, measured between the two coronions (M10), point of maximum width along the coronal suture; (3) the distance between the temporal lines, at the frontotemporale landmarks (M9); (4) the distance between the temporal lines, at the stephanion landmarks (M10b); (5) the maximum supraorbital torus breadth between both outer orbital processes (M43) at the frontomalare orbital landmark on the lateral rim of the orbit, on the anterior portion of the frontomaxillary suture; (6) minimum and maximum supraorbital torus height.

The frontal index (minimum frontal breadth/M10*100) as well as the temporal line index (M9/M10b*100) and the post-orbital constriction index (minimum frontal breadth/M43*100).

3.2. Morphological analysis

As for the external anatomical features, these are the bony superstructures (supraorbital torus and supratoral depression, sagittal keel and parasagittal depressions) and the muscle attachments (temporal lines) which were observed on the frontal bone and parietal bones of the Kocabaş skull and on the fossil skulls used for comparison. The internal anatomical features are: development of vascular and cephalic impressions.

4. Results

4.1. Metric analysis

Measurements and indices are shown in Table 1.

4.1.1. Minimum and maximum frontal breadth

As far as the minimum breadth is concerned, the Kocabaş skull and ER 3733 are alike, showing a value higher than that of the Dmanissi specimens, ER 3883 and skull III from Zhoukoudian L-C. Other fossils from this site and Sangiran 17 are slightly wider, whereas Hexian, Arago 21 and Petralona are markedly wider.

As for the maximum breadth (M10), the Kocabaş skull is narrow. It stands among the smallest fossil values in this study (Fig. 3).

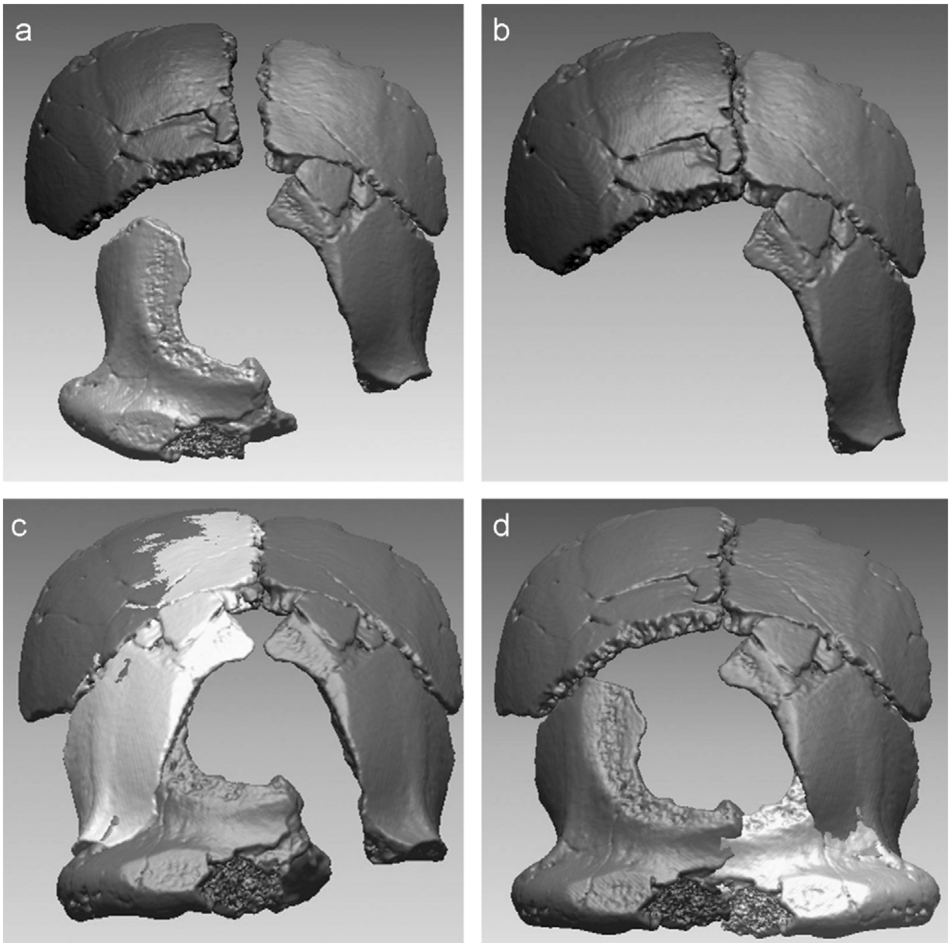

Fig. 2. Reconstitution of the Kocabaç skull: (a) 3D reconstruction of each of the three fragments, (b) re-establishment of the anatomical connection between the two parietal bones, (c) re-establishment of the anatomical connection between the frontal bone (lateral and anterior right parts of the bone) and the right fragmentary parietal using as guide the left frontoparietal bones, previously doubled and inverted by mirroring (in grey) and (d) reconstruction of the supraorbital torus (in grey: mirrored-image of the right part fitted with the left part of the frontal bone).

Fig. 2. Reconstitution du crâne de Kocabaç: (a) reconstitution 3D de chacun des trois fragments, (b) repositionnement en connexion anatomique des os pariétaux, (c) repositionnement en connexion anatomique du fragment d'os frontal (parties latérale et antérieure droites de l'os) avec le fragment d'os pariétal droit en utilisant comme guide l'ensemble frontopariétal gauche, doublé et inversé par image miroir (en gris) et (d) reconstitution du torus supraorbitaire (en gris: miroir de la partie droite ajustée à gauche).

4.1.2. The frontal index

The Kocabaş frontal bone is slightly less flared than that of all the fossils in this study. Arago 21 and OH9 are much less divergent. The strong index value of these two skulls is due to the significance, in OH9, of the minimum frontal breadth and, in Arago 21, of the frontal lobe development.

4.1.3. The temporal line index

The ratio between both variables (M9 and M10b) shows that, in the Kocabaş fossil, the distance between the temporal lines is greater between the frontotemporale landmarks than between the stephanions, which means that the temporal lines tend to converge towards the coronal suture. It is also the case for two of the three Dmanissi skulls, ER 3733, OH9, Sangiran 17, skulls III and XI from Zhoukoudian L-C and Arago 21. As for the other fossils, it is quite the opposite; the temporal lines diverge towards the coronal suture, and the values for M10b are significantly higher than those obtained for M9.

4.1.4. Supraorbital torus breadth and height

It has to be borne in mind that the measurement of the supraorbital torus taken between the orbital processes on the reconstructed Kocabaş skull, being 116 mm, is smaller than that published by Kappelman et al., 2008. These authors obtained a value of 124 mm, from a photographic reconstruction of the supraorbital torus. In addition to this methodological difference between the present study and the work from Kappelman et al., 2008, the position of the frontal block in the reconstructed Kocabaş fossil that we proposed and previously justified explains the gap between these two values.

Table 1
Cranial measurements in mm and comparisons (*Dmanissi and Arago 21 from de Lumley, 2006, **Sima de los Huesos from Arsuaga et al., 1997, #Zhoukoudian L-C from Weidenreich, 1943); ER3733 and ER3883 from East Turkana and OH9 from Olduvai.
Tableau 1
Données métriques crâniennes en mm et comparaisons (*Dmanissi et Arago 21 d'après de Lumley, 2006, **Sima de los Huesos d'après Arsuaga et al., 1997, #Zhoukoudian L-C d'après Weidenreich, 1943), ER3733 et ER3883 de l'Est Turkana et OH9 d'Olduvai, en italique : valeurs estimées.

	Min F b (Minimum frontal breadth	M10 (Co-Co)	Frontal Index(Min F b/M10)	M9 (Ft-Ft)	M10b (St-St)	Temporal lines index (M9/M10b	M43 (Outer biorbital breadth)	Post-orbital constriction index (Min F b/M43)	Sus-orbital torus height
D2280*	86.0	106.0	**81.1**	74.0	65.0	**113.8**	114.0	**75.4**	10 to 13
D2282*	80.0	*91.0*	***87.9***	67.0	72.0	**93.1**	105.0	**76.2**	8 to 11
D2700*	77.0	90.0	**85.6**	67.0	67.0	**100.0**	97.0	**79.4**	4 to 7
ER3733	92.0	111.0	**82.9**	83.0	77.0	**107.8**	116.0	**79.3**	8 to 9
ER3883	88.0	*108.0*	***81.5***	81.0	89.0	**91.0**	*116.0*	***75.8***	8 to 12
OH9	98.0	105.0	**93.3**	84.0	84.0	**100.0**	130.0	**75.4**	16 to 20
ZKD Sk III#	88.5	101.5	**87.2**	81.5	*78.0*	**104.5**	109.0	**81.2**	10 to 12
ZKD Sk X#	94.0	110.0	**85.5**	89.0	–	–	–	–	12
ZKD Sk XI#	94.0	106.0	**88.7**	84.0	81.0	**103.7**	*111.0*	***84.7***	–
ZKD Sk XII#	95.0	108.0	**87.9**	91.0	103.0	**88.4**	–	–	14 to 14.5
Sangiran 17	96.0	115.0	**83.5**	96.0	90.0	**106.7**	119.0	**80.7**	17 to 19
Arago 21*	105.0	105.0	**100.0**	105.0	102.0	**102.9**	126.0	**83.3**	10 to 16
Petralona	108.0	120.0	**90.0**	108.0	119.0	**90.7**	130.0	**83.1**	13 to 20
SdlH 5**	–	118.5	–	105.7	*110.8*	***95.4***	129.3	–	–
SdlH 6**	–	–	–	100.0	*116.0*	***86.2***	111.0	–	–
Hexian	100.0	*116.0*	***86.2***	96.0	104.0	**92.3**	*111.0*	***90.1***	10 to 17
Kocabaş	92.0	*102.0*	***90.2***	85.0	80.0	**106.2**	116.0	**79.3**	14 to –

In bold: indexes; in italics: estimated values.

The outer biorbital breadth (M43) in Kocabaş is close to the values found in D2280, ER3733, ER3883 and Sangiran 17 (Fig. 4). The two other Dmanissi fossils, skulls III and XI from Zhoukoudian L-C, Hexian and Sima de los Huesos 6 have a narrower torus, whereas it is larger in OH9, Arago 21, Petralona and Sima de los Huesos 5. Only the lateral part of the supraorbital torus is preserved in the Kocabaş fossil and is thicker than that of the specimens from Dmanissi, ER3733 and ER3883 and the skulls from Zhoukoudian L-C. It falls within the range of values obtained from specimens with a developed supraorbital tori without reaching the strong expression of OH9 or Sangiran 17.

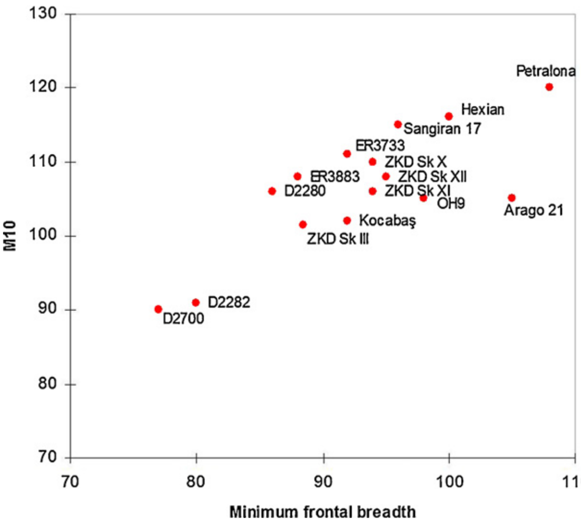

Fig. 3. Divergence of the frontal bone: minimum frontal breadth and maximum frontal breadth (M10).
Fig. 3. Divergence de l'os frontal : largeur frontale minimum et largeur frontale maximum (M10).

4.1.5. *The post-orbital constriction*

The post-orbital constriction is clear on all the studied fossils (the index shows values between 75 and 90). It is more strongly expressed in D2280 and D2282, ER3883 and OH9 and is attenuated in other specimens, especially Hexian, with a higher index value (90). The Kocabaş value is close to those of D2700, ER3733, Zhoukoudian skull III and Sangiran 17.

4.2. *Morphological study – Ectocranial features*

4.2.1. *The temporal lines*

The superior and inferior temporal lines form, in the Kocabaş fossil, a single prominent ridge on the frontal bone

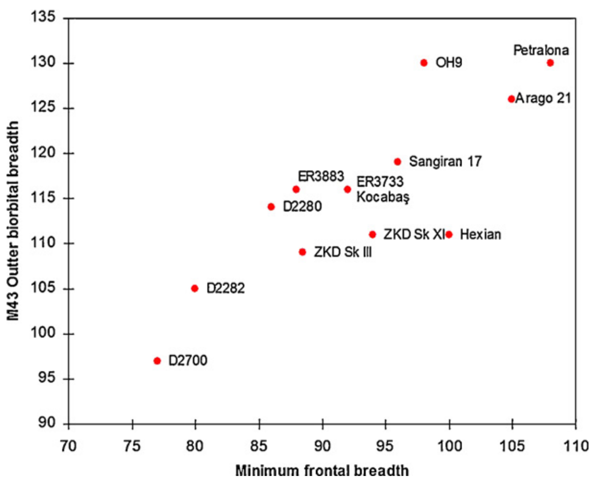

Fig. 4. Post-orbital constriction index.
Fig. 4. Indice de constriction post-orbitaire.

that split on the parietal bone, from the coronal suture, into two neat crested lines, although less marked. These lines follow a steady curve on the frontal and parietal bones. They do not deviate from the coronal suture as in the D2280, ER3733 or even OH9 specimens.

4.2.2. The torus and the supraorbital constriction

As previously mentioned, the supraorbital torus is strongly marked in the Kocabaş fossil. A lateral supratoral depression is clearly expressed as in ER3733, OH9 and the skulls from Zhoukoudian L-C. It is weakly expressed in D2282 and Arago 21 and cannot be found on the other fossils. However, there is a noticeable variability as for the supraorbital torus thickness as well as for the supratoral depression in small groups such as those including fossils from Zhoukoudian (Weidenreich, 1943) or Dmanissi (de Lumley, 2006), perhaps linked to some expression of sexual dimorphism.

4.2.3. Sagittal keel and parasagittal depressions

In the Kocabaş fossil, there is no keel on the parietal bones. The parasagittal depressions are clearly expressed on both side of suture from 8 mm beyond bregma and over 25 mm, along the parietal edge, as measured from the 2D tomographic slices. Because the frontal bone was damaged in its middle part, no data could be obtained for the presence of a fronto-sagittal keel.

4.3. Morphological analysis – Endocranial features

4.3.1. Vascular impressions

The pteric region being absent from the fossil, the origin of the meningeal artery cannot be found on the right parietal bone endocranial surface (Fig. 5). The anterior ramus (bregmatic) of the middle meningeal artery, clearly expressed, shows an even width (about 2 mm). It is located 8 mm beyond the coronal suture and splits, 9 mm above the broken temporal of the parietal bone, into an anterior collateral branch and a posterior one. After running obliquely and anteriorly along 31 mm in height, the anterior collateral branch merges with the coronal suture, over 24 mm in height, until it reaches the endo-bregma; 17 mm from the point of divergence, the posterior collateral branch splits into two collateral branches spreading upward and backward over 38 mm in height. The impression left by the posterior ramus (obeliac) is shallow (1 mm wide) and narrower than the brematic one. It is located 14 mm beyond the point of origin of the latter and is only preserved over 22 mm in height. On the left parietal endocranial surface, only the splitting of the bregmatic branch into collateral anterior and posterior rami, is noticeable, 17 mm away from the coronal suture. The first one spreads over 35 mm in height. It then reaches the coronal suture. The posterior collateral branch spreads over 34 mm, along the parietal cutting plan. On both Kocabaş parietal bones, the superior longitudinal sinus is not visible along the sagittal suture.

The anterior meningeal vessels pattern, located on one third of the bone, anteriorly, and its orientation toward the sagittal rim such as those observed on the Kocabaş fossil are common features in archaic hominids (Grimaud-Hervé, 1997).

4.3.2. The cephalic impressions

The ethmoidofrontal fossa that can be observed on the frontal endocranial surface is deep in the Kocabaş fossil and the frontal crest dividing it forms a sharp marked crest. Both features imply the presence of a cephalic beak-shaped feature (or frontal bec). The latter, reconstructed, can be

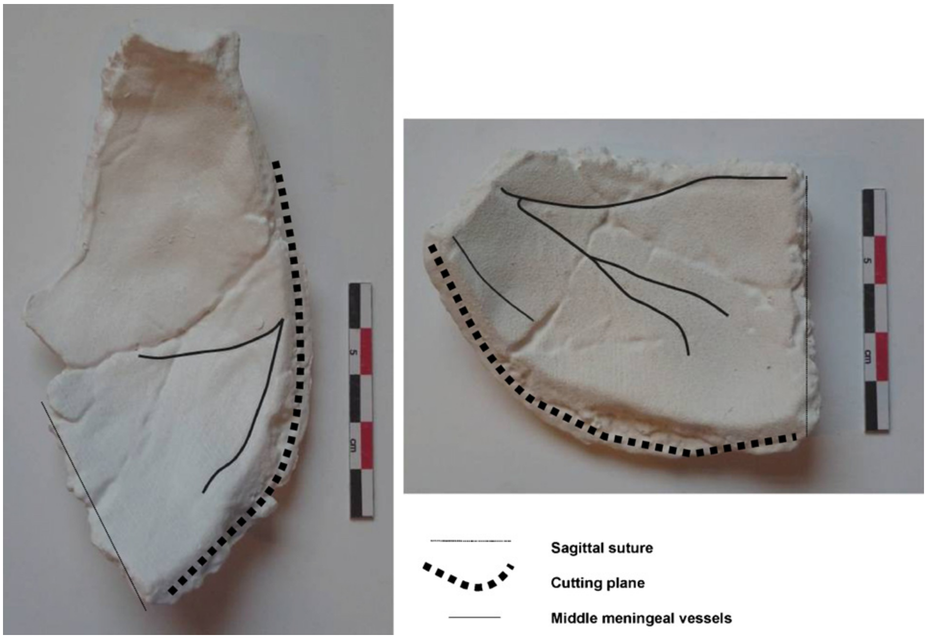

Fig. 5. The middle meningeal artery on the internal face of the left parietal (at left) and of the right parietal (at right) of the Kocabaç skull.

Fig. 5. Réseau méningé moyen sur la face interne du pariétal gauche (à gauche) et du pariétal droit (à droite) du crâne de Kocabaç.

observed above all on its right part. It is formed by the downward extension of the first and second frontal circonvolutions between the orbital cavities. The form of the frontal lobes and the frontal bec in Kocabaş, following a steady curve between the internal orbital lobe and the external surface of the frontal bec, seems close to that of the hominids from Sangiran, Zhoukoudian L-C and Dmanissi (Grimaud-Hervé, 1997; Grimaud-Hervé et al., 2006). Moreover, the interhemispheric fissure dividing the right and left parts of the frontal bec of Kocabaş is wide as in archaic hominids.

5. Conclusion

The reconstruction of the Kocabaş skull was produced, by 3D imaging, from the re-articulation of its three bone fragments, completed with a restored left lateral part of the supraorbital torus. This reconstruction has enabled us to gain more accuracy and a more complete fossil. The supraorbital breadth was clearly reduced compared to that measured on the torus reconstructed by Kappelman et al. (2008).

The Kocabaş skull, displaying a marked post-orbital constriction as well as a massive supraorbital torus, is close to *H. erectus s. sensu* (e.g., restricted to Asian fossils). If its breadth falls into the variability of all the specimens considered in this study, its thickness is more significant and similar to the values measured on individuals displaying a well developed supraorbital torus. Unlike the latter and the fossils from Dmanissi, a lateral supratoral depression is clearly visible on the Kocabaş skull, as in OH9, ER3733 and the specimens from Zhoukoudian L-C. Unlike the Chinese specimens, the Turkish fossil does not display any sagittal keel but has slight parasagittal depressions. Finally, the development of the vascular and cephalic impressions is typical of the *H. erectus* species. The morphometric variability observed among the fossils considered in this study and the closeness of the Turkish skull with the specimens from Africa and Georgia strongly support our conclusions (see Grimaud-Hervé et al., 2002) and those from different authors (see Baab, 2008 for a synthesis). Indeed, we considered *H. erectus* a single species showing some variation due to its great geographic range and temporal depth. Therefore, the Kocabaş specimen is the first *H. erectus* discovered in Turkey. It opens the distribution zone of this species further west in Asia. Considering the geographical position of Turkey, the Kocabaş fossil is now a major landmark to study the way the Old World was populated.

Acknowledgement

The study supported by TUBITAK-CNRS bilateral cooperation of 110Y335 grant. MCA thanks for the supports of TUBITAK-105Y280 grant and Turkish Academy of Sciences. The authors thank Fabienne Rame for his help in translating this article into English, Marie-Antoinette de Lumley, Christine Verna and Liu Wu for their fruitful remarks.

References

Arsuaga, J.L., Martinez, I., Gracia, A., Lorenzo, C., 1997. The Sima de los Huesos crania (Sierra de Atapuerca Spain). A comparative study. J. Hum. Evol. 33, 219–281.

Baab, K.L., 2008. The taxonomic implications of cranial shape variation in *Homo erectus*. J. Hum. Evol. 54, 827–847.

de Lumley, M.-A., 2006. Les restes humains du Pliocène final et du début du Pléistocène inférieur de Dmanissi, Géorgie (1991–2000). I–Les crânes, D 2280, D 2282, D 2700. L'Anthropologie 110, 1–110.

Engin, B., Guven, O., Köksal, F., 1999. Electron spin resonance determination of a travertine sample from the southwestern part of Turkey. Applied Radiation and Isotope 51, 689–699.

Grimaud-Hervé, D., 1997. L'évolution de l'encéphale chez l'*Homo erectus* et l'*Homo sapiens*. In: Les cahiers de Paléoanthropologie. Éditions du CNRS, Paris, 405 p.

Grimaud-Hervé, D., Marchal, F., Vialet, A., Détroit, F., 2002. Le deuxième Homme en Afrique: *Homo ergaster, Homo erectus*. In: Collection Paléontologie Humaine 4. Artcom-Errance, Paris, 257 p.

Grimaud-Hervé, D., de Lumley, M.-A., Lordkipanidze, D., Gabounia, L., 2006. Étude préliminaire des endocrânes de Dmanissi: D 2280 et D 2282. L'Anthropologie 110, 732–765.

Guipert, G., Mafart, B., 2008. Medial sagittal plan of human cranium and virtual reconstitution by mirroring. Am. J. Phys. Anthropol. suppl. 46, 110.

Guipert, G., Vialet, A., Alçiçek, M.C., 2011. The *Homo erectus* from Kocabaş in Turkey and the first settlements in Eurasia. Am. J. Phys. Anthropol. suppl. 52, 151.

Kappelman, J., Alçiçek, M.C., Kanzancı, N., Schultz, M., Özkul, M., Şen, S., 2008. Brief communication: First *Homo erectus* from Turkey and implications for migrations into temperate Eurasia. Am. J. Phys. Anthropol. 135, 110–116.

Martin, R., 1928. Lehrbuch der Anthropologie in systematischer Darstellung mit besonderer Berücksichtigung der anthropologischen Methoden. Verlag von Gustav Fischer, Jena: 1182 p.

Nachman, B.A., Akyar, S., Alcicek, M.C., Kappelman, J., Kazanci, N., 2010. A 3D reconstruction of the first *Homo erectus* specimen from Turkey. Proceedings of the Annual Meeting of the AAPA. Am. J. Phys. Anthropol. Suppl. 50, 175.

Özkul, M., Alçiçek, M.C., Erten, H., Şen, Ş., 2004a. Travertine deposits of the Denizli basin (SW Turkey) and the vertebrate fossil record. In: 5th International Symposium on Eastern Mediterranean Geology (5th ISEMG) Proceedings, Thessaloniki, Greece, p. 337.

Özkul, M., Engin, B., Alçiçek, M.C., Koralay, T., Demirtasli, H., 2004b. Thermoluminescence dating of Quaternary hot spring travertines and some implications on graben evolution, Denizli, western Turkey. 32nd International Geological Congress, Florence, Italy, 1474.

Vialet, A., Guipert, G., Alçiçek, M.C., 2011. Reconstitution 3D et étude de l'*Homo erectus* de Kocabaş en Turquie. Bulletins et mémoires de la Société d'Anthropologie de Paris.

Weidenreich, F., 1943. The skull of *Sinanthropus pekinensis*. A comparative study on a primitive hominid skull. Paleantologica sinica New serie D 10, 1–484.