

Sahelanthropus tchadensis: the facts

Sir, — In a recent article in this journal,¹ Beauvilain and Le Guellec suggest that our initial description of *Sahelanthropus tchadensis*² was flawed by the inaccurate identification and association of specimens. Their claims are without foundation.

Beauvilain and Le Guellec¹ offered supplementary information on the hypodigm and geological context of the oldest known hominid, *Sahelanthropus tchadensis*, discovered at TM266, in the Djurab Erg, northern Chad, by the Mission Paléoanthropologique Franco-Tchadienne^{2,3} (MPFT). Their stated intention was to describe 'the events surrounding the discoveries themselves'¹ (p. 142), although Beauvilain has already done so at length.⁴ Their contribution in the *South African Journal of Science* alleges that: 1) Vignaud *et al.*³ failed to present correctly the stratigraphic nature of the hominid site TM266; 2) Brunet *et al.*² neglected collected hominid specimens; 3) the mandibular specimen TM266-02-154-1 described by Brunet *et al.*² is in fact a fossil hominid chimera manufactured by a left M₃ incorrectly glued to a right hemimandible; 4) together, these supposed errors affect the Minimum Number of Individuals (MNI) count for the site.

Beauvilain and Le Guellec¹ do not question the attribution of the fossil to the hominid clade² rather than to an African ape, but attempt to show that the MPFT members reached inaccurate conclusions. The team firmly stands by its original statements.

Geological issues

Given the thorough geological survey performed by the MPFT in the Djurab since 1994, including georadar investigations,^{3,5-10} it is clear that the whole Toros-Menalla (TM) fossiliferous area shows no evidence whatsoever of a faulting during at least the last 7 Myr. Except for the modern dunes, the entire landscape is very flat. In the TM area, all of the small scarps pointed out by Beauvilain and Le Guellec¹ are the consequences of aeolian 'over-digging' at the foot of the dunes, as are very common across the Sahara and in many other sandy deserts. These geomorphological features do *not* in our view represent any 'reactivated ancient faulting' as they allege (p. 142). The section given in Vignaud *et al.*³ is synthetic, showing the different encountered facies related to the alternation of humid and dry periods. The section at TM266 is accurate as published, and all

fossil specimens reported in references 2 and 3 were derived from this local section as published therein. There is no doubt about their provenance.

Inventory issues

The MPFT practices of inventorying and publishing fossils does not differ from those normally practised in palaeontology. All collected specimens, including hominids, are registered under an inventory number comprising the name of the site, the year, a specimen number, and, in the case of several pieces of the same individual, a part number (e.g. the cranium nicknamed 'Toumai' was numbered TM266-01-060-1). This attribution of an inventory number occurs at different stages when processing the discoveries: 1) for most of them, directly in the field after a precise identification; 2) in the laboratory (at N'djaména or Poitiers) for all the specimens recovered after sieving, or after cleaning for some specimens completely embedded in matrix. Beauvilain, a geographer in charge of MPFT logistics, was unfamiliar with this process and the way in which specimens were assembled into the published hypodigm of *S. tchadensis*.²

The first paper describing the new taxon *S. tchadensis*² included only the specimens which were definitively identified as hominid by their anatomical characters. These specimens belong to several individuals, as we reported in *Nature*:² the holotype cranium is one of these specimens. Beauvilain and Le Guellec¹ wonder why a very worn incisor (TM266-01-460) and a damaged partial mandibular symphysis (TM266-02-203) were not included in the paratype series. They were not included because their exact affinities are yet to be fully developed and determined. Further studies of more fragmentary remains have identified additional individuals, and the MNI count will expand as both excavations and preparation work continue.

Issues of restoration and interpretation

In the Djurab desert, the discovery of fossils is facilitated by an intense erosion of the sediments in which they are embedded through the action of the sand blown by winds across the sedimentary units. When the fossils are unearthed, the same aeolian erosion also affects them. The damage mostly consists of polishing, cracking, breaking, dispersion of the different parts, and, finally, total destruction of the specimens if they are not collected almost immediately after their first exposure. For example, the cranium TM266-01-060-1 of *Sahelanthropus tchadensis* was partially unearthed when found and had

suffered from such a weathering by sand-blasting. During its exposure, it lost most of its front teeth. As reported in Beauvilain and Le Guellec, the broken right canine belonging to this skull was found separately. There is no doubt that this canine belonged to this cranium, because, as correctly noted by Beauvilain and Le Guellec¹ (p. 143): 'The tooth consisted of two fragments which fitted perfectly onto the right canine root'. However, they erroneously reported it as a 'complete' canine whereas in fact it is the distal half of the canine. This canine was published in its natural position on the cranium.²

A parallel case occurred for the mandible in question. The right third molar had been displaced from the tooth row by erosion and transported by wind to where it was recovered, some decimetres distant from the mandible with the remaining teeth. After recovery, we established that it belonged to the mandible itself, and we attached it where it belonged, as a right M₃ of the hemi-mandible TM266-02-154-1. Beauvilain and Le Guellec now assert that this tooth has been attributed to and mounted on the incorrect side.

This moderately worn tooth bears substantial occlusal anatomy which unambiguously identifies it as a third molar. The identification of the side was based on two decisive independent criteria, one set physical and the other set biological. First, there is an unambiguous match between the lower surface of the tooth and its roots, which remained in the mandible. There is no doubt about the integrity of this join (Fig. 1A, B, C, F, G). This is further confirmed by the matching interproximal facet preserved on the mesial surface of the tooth in question and the second molar retained by the mandible. Second, the anatomy of the third molar allows unambiguous siding. As in all hominoid teeth, the buccal cusps are the more worn, with a larger, most heavily worn cusp (the protoconid), marked here by heaviest occlusion and placed mesiobuccally (Fig. 1D, E). The occlusal rims of the lingual cusps stand out slightly but distinctly, from less wear due to well-known masticatory mechanisms common to modern humans, fossil hominids, and fossil and modern apes.

Conclusion

The logistical contributions of Beauvilain to the fieldwork in Chad are gratefully acknowledged, but the claims and assertions by him and Le Guellec¹ have no bearing on either the interpretation of the geology of TM266 or of the associations, taxonomy, or phylogeny of *Sahelanthropus tchadensis*.

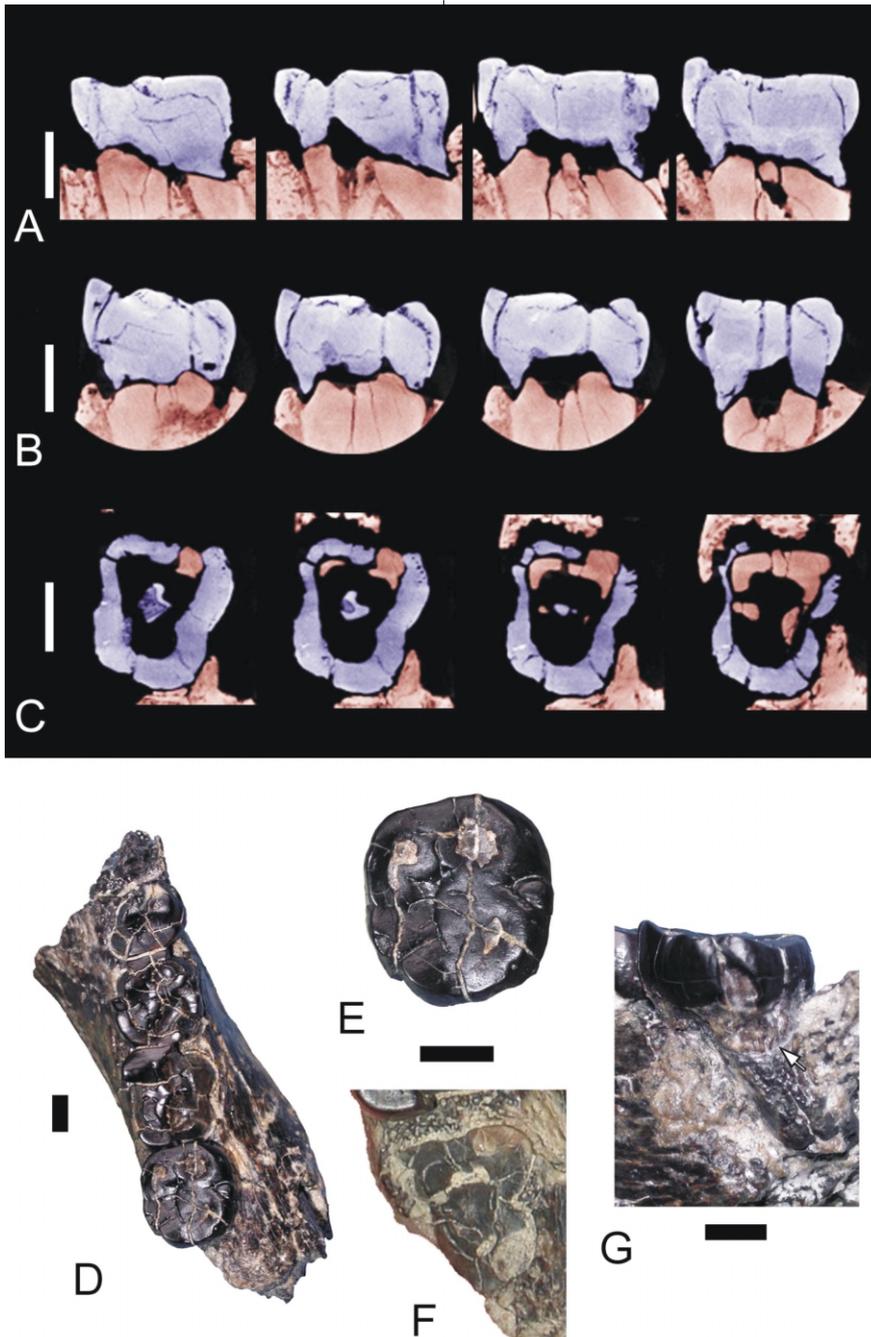


Fig. 1. Right hemi-mandible TM266-02-154-1 of *Sahelanthropus tchadensis*. A, B, and C: CT scans (courtesy: University Museum, University of Tokyo) at the level of the M_3 . The mandibular corpus and the retained roots of the M_3 are in light red. The crown of the third lower molar found separately and claimed to be a left one is in blue. A precise matching between the M_3 crown and the corresponding roots in the hemi-mandible can be observed. The interstitial space between the M_3 and its roots corresponds to thickness of the glue used to affix the tooth to its roots. **A**, Sagittal sections with mesial side at right – from right to left, CT scans are respectively shot at 3.33 mm, 4.41 mm, 7.83 mm, and 8.70 mm from the buccal edge of the tooth; **B**, transversal sections with lingual side at right – from right to left, CT scans are respectively shot at 2.67 mm, 3.69 mm, 4.11 mm, and 9.36 mm from the mesial edge of the tooth; **C**, sections parallel to the occlusal surface, at the cervix level and below, with mesial side at top – from right to left, CT scans are respectively shot at 6.93 mm, 7.14 mm, 7.44 mm, and 7.80 mm from the occlusal edge of the tooth. Mesially, the mesio-buccal and mesio-lingual roots remaining in the corpus (see F) appear in light red and show exact matching with the M_3 crown (in blue); **D**, occlusal view of the complete specimen with its M_3 ; **E**, occlusal view of the M_3 ; **F**, occlusal view of the M_3 roots; **G**, disto-lingual view of the joint (white arrow) between the M_3 and its distal root. All scale bars are 0.5 mm.

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Beauvilain and Le Guellec reply

Brunet *et al.*¹ criticize three main points in our article²: a) the tectonic origin of the Toros-Menalla scarp, b) the determination of side of an isolated molar that was stuck onto a right mandible attributed to *Sahelanthropus tchadensis* from site TM 266, and c) the inventory of fossils. We respond to each of these criticisms in turn and conclude that our original hypothesis and interpretation are likely to be correct.

Geological issues in the Djourab

Brunet *et al.*¹ report that georadar did not yield any evidence of faulting in the Toros-Menalla region, and they ascribe the formation of the scarp to 'overdigging' by wind. Whilst wind deflation does indeed cause depressions in deserts, such basins are seldom linear, usually being undulating in outline or spoon-shaped. The fact that the scarp in question is rectilinear over a distance of more than 40 km suggests an underlying tectonic origin. Elsewhere in the Chad Basin³ there is evidence of neotectonic activity including the western shore of Lake Chad, which runs straight NNW-SSE for nearly 250 km, a trend that continues along the Dilia Valley (Niger) over an even greater distance. The Bahr el Ghazal Valley is almost straight NNE-SSW for more than 450 km, with a cliff on the left bank in its lower reaches. This neotectonic activity frequently reactivates ancient fractures.⁴

Georadar was indeed used in January 1999 but only at sites east of the Bahr el Ghazal (the Toros-Menalla region is on the west side). On fossil and recent dunes it revealed reflectors only 1 to 2 metres thick,⁵ and in sandstone it 'did not yield an image at depths greater than 1 metre.'⁵ This georadar equipment is not designed to locate evidence of faulting, and it was not used to search for faults in the Djourab. Thus failure of the equipment to reveal faults in the region does not provide a sound argument against our view that the linear structures that occur there are likely to be of tectonic origin.

We thus maintain our original view that the Toros-Menalla scarp, which yielded all the fossils of *Sahelanthropus tchadensis*,

owes its origins to tectonic activity. It has subsequently been deflated by the wind, but this has only modified its form rather than being the original cause of it.

Restoration and interpretation of *Sahelanthropus* fossils

The fossils from the Djourab are well mineralized but are often abraded by wind-blown sand. There are strong daily changes in temperature, which can range from 50°C air temperature at ground level in the day to light frost at night. At midday, pebbles and fossils lying on the surface of the ground can be too hot to touch. These changes lead to fissuring of fossils, which usually have planar fracture surfaces rather than strongly curved ones. Crusts covering the fossils are either in the form of a very adhesive, hard grey, chemically-resistant matrix, or as an iron-rich concretion, coloured by manganese, often separated from the fossil itself by a small space occupied by sand (see Fig. 1).

The skull of Toumaï, which was found upside down on the sand, was protected from erosion by the second type of crust, whereas the right hemi-mandible TM 266-02-154-1 had traces of grey matrix (Fig. 2), which also covered the base of the isolated M₃. For this reason we consider that the cranium on the one hand, and the mandible and the M₃ on the other were not fossilized in the same deposits and are thus probably not contemporary.

The simplest reconstruction of the history of the M₃ and the right hemi-mandible is that they were broken before burial and fossilization some 6 to 7 million years ago, as shown by the matrix covering the broken surface of the distal root of the M₃ (Fig. 2). Later on, they became encrusted under near-surface conditions. Recently exhumed by the wind, abrasion has removed much of their cover of matrix and has polished their surface, while thermal variations have resulted in damage to some of the teeth. The M₃ was presumably the last specimen to erode out of the sediments as its surface is well

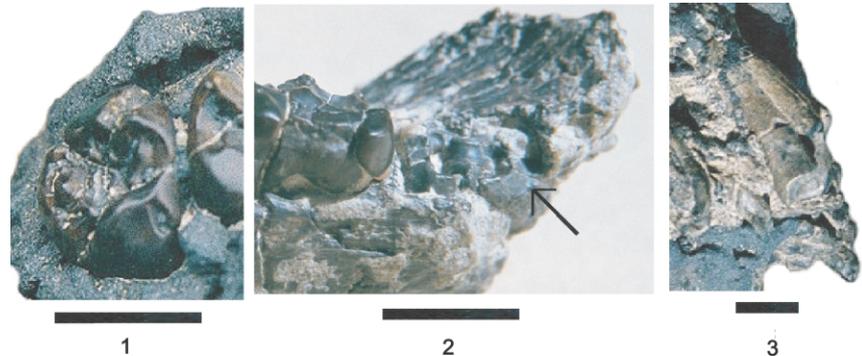
preserved. Conversely, the other right mandible (TM 266-02-203), discovered in March 2002 without teeth a dozen metres from the mandible and M₃, was the first to erode out.

Biological considerations of the M₃

One of the arguments put forward by Brunet *et al.*¹ concerning the determination of side of the isolated M₃ is the wear pattern. However, examination of the last upper molar in the skull of Toumaï (Fig. 1) indicates that we need to be cautious about the interpretation of wear on cusps in general. Curiously, in this particular instance wear on the buccal cusps is closely similar to that on the lingual ones.

Because of this, from the beginning of our study,² we attached more importance to the grooves, which were less affected by wear during life (and more recently by wind abrasion), and are thus better preserved than the tops of the cusps. Firstly, the similarity between the fossil M₃ and a 'modern' human molar is striking. The alignment on a regular curve of the three buccal cusps (protoconid, hypoconid, hypoconulid) and their decrease in size mesio-distally constitute a determining criterion. Secondly, the intercuspid column that we named the metaconulid in our article evokes more a morphological variant of the lingual surface of the tooth than one of the buccal surface. Thirdly, the orientation of the main disto-buccal groove accords precisely in its occlusal articular dynamic relationship with the oblique crest (*crista obliqua*) [*pont d'email*] of the non-working maxillary molar when the opposite side of the jaw is engaged in chewing as in other anthropomorphs.⁶

A second line of argument employed by Brunet *et al.*¹ to demonstrate that the M₃ fits onto the right mandible was a series of scans in which the broken surface of the base of the tooth and the roots in the mandible were shown to be compatible with each other, being separated only by a thin but continuous layer of glue. It is



Figs 1–3. Photographs of specimens attributed to *Sahelanthropus tchadensis* (taken of the cranium at 08:00 on 19 July 2001): 1, the M² in the cranium; 2, oblique lingual view of the roots of the M₃ in the mandible (note in particular the relatively planar fracture surface of the distal root, which curves distally and buccally at a constant level (black arrow), and compare it with the antero-posteriorly curved surface marked by an arrow in the image provided by Brunet *et al.*¹); 3, root of the right C¹ in the cranium of Toumaï. (Scale bars: 10 mm.)

necessary to recognize the detailed work which allowed the fitting of the M_3 crown so precisely onto the roots of the hemimandible. The hard sandy matrix which covered the base of the isolated molar when it was found first had to be removed and then the space now occupied by glue had to be prepared millimetre by millimetre. A similar operation was required for the parts of the root in the mandible, which were similarly covered in matrix (Fig. 2). In general, a section immediately beneath the cervix of left and right mandibular molars reveals radicular surfaces that may be superposed to within about one millimetre. So, it is not surprising in this particular case that a left tooth seemed to correspond to the roots in a right mandible.

The right upper canine of Toumaï

We apologize for the possibility that our text regarding Toumaï's right C^1 could be misinterpreted, the canine root being *in situ* in the skull as shown in Fig. 3. In contrast we could only write that the canine crown found in November 2001 fits onto the root, we being in the Djourab, and the skull at the University of Poitiers.

Curatorial issues

Writing catalogue numbers on fossil specimens is a daily activity in the field. At such an important site as TM 266, all the fossils were collected. That is why, from July to December 2001, 52 postcranial bones, whose zoological group could not be determined in the field, were catalogued, in the expectation that some of them might belong to *Sahelanthropus*. Among these fragments, 36 are long bones (tibia, femur, humerus and ulna) including intact specimens and broken diaphyses. Considering the excellent preservation of the Toumaï cranium, a careful examination of these bones should yield interesting information, as we consider it likely that postcranial fossils of a large primate may be present at the site, although nothing has been reported until now. Note that in the cata-

logue returned to N'Djaména by the University of Poitiers in December 2001, a single fossil had been added to the field catalogue. It consists of specimen TM 266-01-447 (a right M^3 according to Brunet *et al.*⁷), whereas the catalogue entry states that it is 'Classification – primate; Description – fragments morceaux racines $M1/M3$; Dépôt – Poitiers (reliquat tamis)'. These specimens were returned to the CNAR, N'Djaména, on 30 January 2002.

Conclusions

We see no compelling reason to modify radically our hypothesis about the geomorphology of the Toros-Menalla region, nor our interpretation of the isolated left M_3 and damaged right mandible from locality TM 266 attributed to *Sahelanthropus tchadensis*. Finally, given the excellent preservation of fossils at the site, we consider it likely that the collection of postcranial elements collected there may well contain some specimens that belong to *Sahelanthropus*.

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Sir, — We, the undersigned, have carefully examined the photographs and digital crown images of a fossilized third molar from the upper Miocene of Chad. This tooth was originally identified by the discoverers (Brunet *et al.* 2002, *Nature* **418**, 145–151) as a right third mandibular molar. A recent paper by Beauvilain and Le Guellec (2004, *S. Afr. J. Sci.* **100**, 142–144) claimed that this tooth had been misidentified and was in fact a left lower third molar. Based on crown anatomy evident in the images examined by us, we confirm the identity of this tooth as a right molar, as originally published by Brunet *et al.* (2002).

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