News and Views

A new archaic *Homo sapiens* fossil from Lake Eyasi, Tanzania

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Introduction and general stratigraphy

The Kohl Larsen expeditions to Lake Eyasi (Tanzania) in the early 20th century discovered the remains of three hominid skulls, one of them fairly complete (Eyasi 1), of unknown Middle Pleistocene age (Mehlman, 1984, 1989). The lack of chronological control resulted in the exclusion of these remains from the mainstream of discussions concerning the emergence of *Homo sapiens*. Since then, a hominid mandible and occipital fragments have been discovered (Mehlman, 1989; Brauer and Mabulla, 1996). Recently a new frontal bone was retrieved from the lake sediments in association with a core and flake industry classified within the early MSA (Middle Stone Age) tradition (Domínguez-Rodrigo et al., 2007). All these specimens come from the areas of Northeast Bay and West Bay into which the fossiliferous Eyasi region can be divided (Mehlman, 1987, 1989; Fig. 1).

Lake Eyasi is an asymmetric lacustrine basin in relation to the Tanzanian Divergence Zone of the Gregory Rift. It is situated south of the Crater Highlands and is formed by a tectonic step constituted by the escarpment resulting from a northwest fault. A flexure zone can be documented to the east where the Proterozoic and Archaean basement outcrops (Ebinger et al., 1997). The Eyasi lake basin adopted its modern form about 1 million years ago (Pickering, 1961; Mac Intyre et al., 1974; Ebinger et al., 1997; Foster et al., 1997). The fossiliferous outcrops are situated at the north side of a Proterozoic substrate horst relief. Previous geological test pits in these deposits yielded a maximum thickness of 11.5 m before reaching a vitreous trachitic tephra at the bottom of the sequence (Mehlman, 1989). Our study of the upper beds, where most fossils are located, indicate that there are two fossiliferous units (Fig. 2).

The lower fossiliferous unit—which corresponds to Mehlman's Beds A, B, and C, or red soils—consists of over 3 m of sandy clays and red or brown zeolitic and edaphic clays. These clays are well-cemented and show evidence of extensive bioturbation consisting of sandy rootcasts. These clays are locally tuffaceous and orange, and form a hardground surface on the top. The lower fossiliferous unit has yielded abundant fossil remains of typical savanna fauna, among which hippopotamus remains are abundant. The layers in this unit underwent some folding after their deposition.

The upper fossiliferous unit—Mehlman's capping horizon—is more heterogeneous. At the base of the unit, over the erosive contact with the lower fossiliferous unit, are encrusted stromatolites with medium to large size bioherms. Then, approximately 1.5 m of green, massive, slightly sandy clays overlie the stromatolites. Approximately 0.3–0.4 m of conglomerates containing well-preserved fossils and lithic artifacts overlie the massive clay. Overlying these conglomerates, small- to medium-sized stromatolites and oncolites have been observed locally in a sandy matrix. The conglomerates are more extensively covered by a highly weathered volcanic

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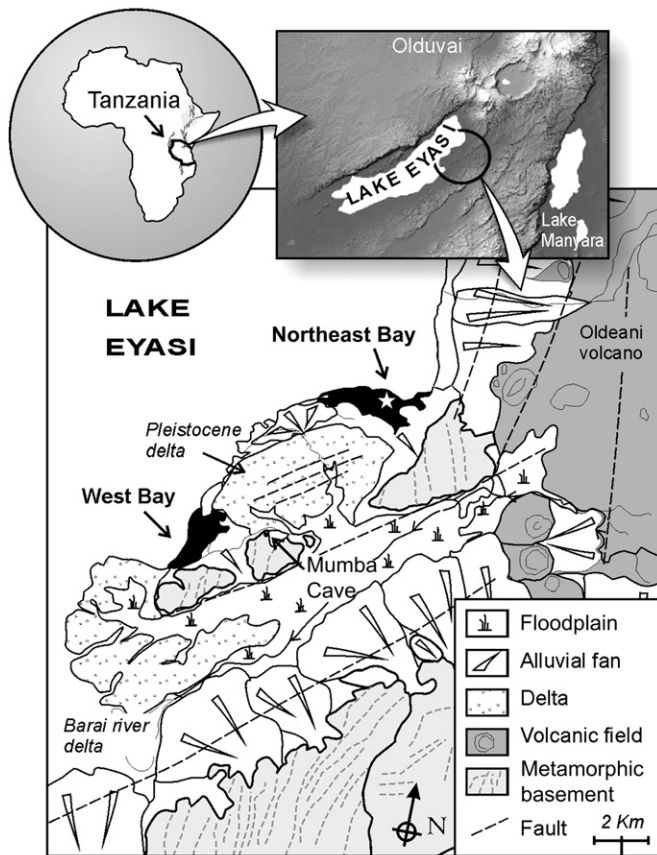*E-mail address:* manueldr@ghis.ucm.es (M. Domínguez-Rodrigo).

Fig. 1. Location of Lake Eyasi in the divergence zone of the Gregory Rift in the north of Tanzania and exposure of the two fossiliferous areas: North Bay and West Bay. The location of the hominid discovery is indicated by a star.

tuff. Finally, about 1 m of clayey sands complete the sequence. In the West Bay, this sequence appears condensed, reworked, and with few outcrops. In the North Bay, the sequence is more extensively exposed. This bed is covered with recent sandy deltaic, eolian, and lacustrine deposits.

The distribution of the fossiliferous sediments and the geomorphological study of the eastern side of the lake basin indicate that the red soils (lower fossiliferous unit) occur over a large area, and correspond to a lacustrine mudflat deposit with vegetation and large periods of subaerial exposure. The gray sands (upper fossiliferous unit) are associated with an old fan-delta active during the Pleistocene, indicating the course of the paleo-Barai River. Both units were produced during a high lake-level, and in-between both units, a lake regression and tectonic subsidence enabled the erosion of the lower deposit and its tectonic deformation. The sequence reflects variations of the lake level during the Middle Pleistocene. Stromatolites appear frequently in lake basins during the Quaternary. High content in authigenic palygorskite and analcime suggest a semiarid climate and an alkaline water depositional environment.

Discovery and taphonomic information of the EH 06 locality

The new hominid fossil was found on the surface of the gray sands (upper fossiliferous unit: UTM coordinates 757747-961414) together with abundant fossils (see Online Supplemental Material), some of which were also located in situ in this unit through excavation. The hominid was located within a cluster of stone tools and fossils eroding out of a low-relief (<1 m) outcrop.

The fossils found with the hominid in the clays and sands along the outcrop include several types of anatomical elements from small and large animals. Horn fragments, teeth (the most abundant), vertebrae, and scapulae, together with long bones make up the bulk of the assemblage at this locality. The preservation of all specimens is very good, which allowed careful scrutiny for bone surface modifications and no traces of microabrasion or polishing typical of bone transport were detected. Most fossil surfaces were dark-colored, similar to bones affected by manganese. The representation of elements belonging to diverse anatomical parts from several carcass sizes, which present different physical resisting properties to water transportation, the presence of very small fragments (2 cm) in combination with very large ones (>30 cm), the similar preservation of these specimens, and the lack of any taphonomically detectable trace of transportation (on their cortical surfaces) supports the interpretation that most of the specimens retrieved in this locality are autochtonous and did not undergo any significant water transport. This receives further support from the discovery of two fossils in situ in the excavated clay deposit. It can confidently be said that the fossils in this locality, including the hominid fragment, are stratigraphically situated in the upper unit, characterized by the Gray Sands. The teeth used for the present dating study were obtained in the same bone assemblage and lacked any traces of microabrasion or polishing, thereby indicating lack of transport and the same provenience as the remainder of the assemblage.

Age estimates of EH 06

Electron spin resonance (ESR) age calculations were attempted for five teeth found on the surface of the Gray Sands. Dental tissues were selected for isotopic analysis and $^{230}Th/^{234}U$ (U-series) age calculations. Results are presented for the tooth for which we have concordant ESR and $^{230}Th/^{234}U$ data (EYJR 2; wildebeest); results on the remaining teeth were inconclusive. For methodological details, see Grün et al. (1988), Ivanovich and Harmon (1992), Rink et al. (1994), Rink (1997), Brennan et al. (1997), and Jones et al. (2004). The full methodological coverage of EYJR 2 and the inconclusive samples are reported in the Online Supplemental Material.

EYJR 2 was found at UTM 757948-961414 on the surface of the Lake Eyasi beach within 5 m of the eroding shelf outcrop of Gray Sands. Due to the unusually high concentration of thorium in the dental tissues, calculation of the ESR ages required particular care. Software limitations precluded the possibility of determining a coupled ESR/U-series age. However, EYJR 2 yielded agreement between the ESR age and the $^{230}Th/^{234}U$ (closed-system) age for the tooth, which indicates early-uptake (closed-system) behavior.
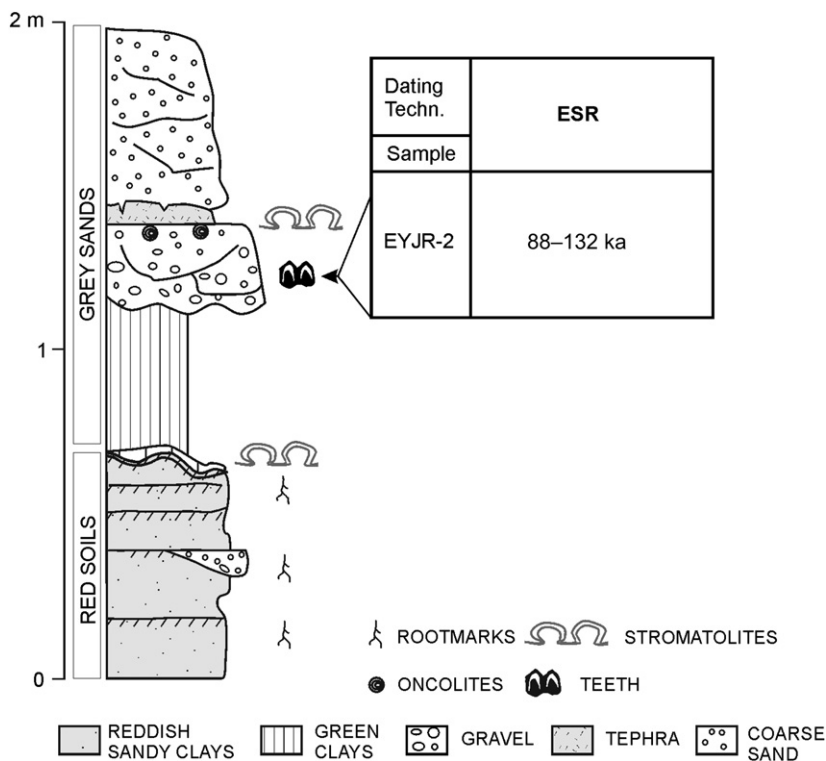
Fig. 2. Stratigraphic section of the Eyasi fossiliferous beds, showing the main sedimentary features of the gray sands and red soils, and the position of the tooth dated by ESR and ^{230}Th/^{234}U.

ESR ages of tooth enamel are typically calculated according to two models: early-uptake (EU), which assumes immediate uptake of exogenous uranium, and linear-uptake (LU), which assumes a linear uptake of exogenous uranium (thorium rarely contributes a significant dose to the enamel). ^{230}Th/^{234}U ages are calculated assuming closed-system behavior (early-uptake of uranium), but these ages must be corrected for contamination by exogenous thorium (contamination is revealed by the presence of ^{232}Th, which cannot be produced by parent uranium). The closed-system ^{230}Th/^{234}U ages, therefore, depend on the unknown initial activity ratio, ^{230}Th/^{232}Th (r_{02}). Generally, r_{02} is assumed to be 1.5 worldwide (Blackwell and Schwarcz, 1995), but in actual fact may be as large as 3.3 (measured in the Dead Sea Basin; Kaufman, 1993). The latter r_{02} is assumed to represent an extreme value; in this study, ^{230}Th/^{234}U ages are calculated for r_{02} of 1.5 and 3.3.

This study revealed extraordinary concentrations of thorium in the dental tissues (115 ppm in the dentine layer of EYJR 2).

The calculation of ESR ages must take into account the dose-rate due to the presence of thorium; the ESR ages depend, therefore, on two model parameters: the uptake model and r_{02}.

Software limitations precluded the calculation of coupled ESR/U-series ages for the case of large concentrations of thorium. However, the ESR model ages and ^{230}Th/^{234}U model ages may still be compared (Table 1). EYJR 2 yielded concordance between the EU-ESR model ages and the ^{230}Th/^{234}U model ages for the enamel layer, which indicates closed-system behavior. The minimum age was obtained for the extreme case of $r_{02} = 3.3$ (maximum exogenous thorium; 104 ± 13 ka, which agrees with the ^{230}Th/^{234}U age of $92.4^{+4.1}_{-4.2}$ ka for the enamel layer), while the maximum age was obtained for $r_{02} = 1.5$ (118 ± 14 ka, agreeing with the ^{230}Th/^{234}U age of 125.5 ± 3.0 ka).

The best estimate of the burial age of EYJR 2 is an age range that encompasses the uncertainty in the model EU-ESR ages of EYJR 2: 88–132 ka. We use this estimate to infer

Table 1
ESR ages (ka) for enamel and closed-system ^{230}Th/^{234}U ages (ka) for enamel and dentine tissues (calculated for "dry" conditions of $5 \pm 5\%$ water content; under "wet" conditions of $30 \pm 5\%$ sediment water content, the ages increase by 2%). ESR ages are given using either a early-uptake (EU) or linear-uptake (LU) model. Both ESR and ^{230}Th/^{234}U ages are determined by assuming an initial r_{02} of either 1.5 or 3.3. Errors in calculated ^{230}Th/^{234}U ages are given by maximizing and minimizing the parameters within the errors of the input parameters

Sample		ESR age [ka]				^{230}Th/^{234}U age [ka]	
		$r_{02} = 1.5$		$r_{02} = 3.3$		$r_{02} = 1.5$	$r_{02} = 3.3$
		EU	LU	EU	LU		
EJYR 2	ENAM A	118 ± 14	207 ± 26	104 ± 13	187 ± 24	$125.5^{+3.0}_{-3.0}$	$92.4^{+4.1}_{-4.2}$
	DEN 1	n/a	n/a	n/a	n/a	$138.3^{+0.7}_{-0.7}$	$118.7^{+0.8}_{-0.8}$

Fig. 3. The hominid frontal bone (EH06) from superior (a), basilar (endocranial) (b), anterior (c), partial lateral (d), and lateral (e) views.

the age of the associated finds, including EH06. This provides a tentative age estimate of the Gray Sands that is within MIS 5 (Cutler et al., 2003).

Morphological description of EH 06

The new fossil frontal bone (EH06) shows excellent cortical preservation, on which no traces of polishing of the edges or abrasion are observed (Fig. 3). Approximately half of the frontal bone with the left supraorbital rim has been preserved. A very small portion of the lateral ridge of the sagittal sulcus (3 mm) can be documented on the endocraneal surface. No portion of the internal part of the groove is preserved. The forward projection of the midline brow ridge relative to the frontal squama creates a very flat and straight supratoral surface (25 mm), interrupted by a prominent lateral glabellar swelling. This is shown in a raised midline glabellar torus in the sagittal plane

of the frontal bone. Behind glabella, there is a slight depression, but a well-defined postorbital sulcus was not developed. The glabellar swelling extends approximately 16 mm to the medial side of the orbital rim. A supraorbital notch is present just below the lateralmost extent of the glabellar swelling. The glabellar torus creates a robust superciliary arch which thins abruptly before reaching the midsection of the orbital rim. This supratoral section is 6 mm[1] at midorbit and thickens again towards the lateral aspect of the supraorbital trigone (10 mm). The temporal line is crested anteriorly and there is marked postorbital constriction.[2] There is a very slightly protruding frontal boss. A portion of the coronal suture superior to pterion has been preserved. The

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[1] The superior-inferior dimension was measured.
[2] Postorbital constriction was derived by establishing a ratio between minimum frontal breadth (behind the orbits below the temporal line) and biorbital chord. Measurements were derived by reconstructing the midline and missing bone portion by symmetry.

endocranial surface preserves several fossae including meningeal vessel impressions.

The present age of EH06 probably provides a younger chronological context for the previous three Eyasi crania and brings them back into the debate of the emergence of *Homo sapiens*. The previous crania were found overlying the red soils unit. Since there were patches of gray sands in the area where the skull fragments appeared, they probably could have the same stratigraphic provenience as EH06. Alternatively, they could belong to the top of the red soils unit, in a stratigraphic position less than 1 m under EH06 (Mehlman's Beds A−C). If the latter possibility is correct, EH06 shows an interesting continuation of the primitive features shown in Eyasi 1, in a period for which other areas have yielded, from a morphological standpoint, substantially more modern-looking specimens.

These modern-looking features are defined in broadly contemporary hominids by the expansion of the frontal area of the skull, with a more elevated and rounder slope of the frontal bone, together with a reduction of the supraorbital torus, supratoral area, and postorbital constriction. These are some of the features that morphologically differentiate *Homo sapiens* from earlier hominids. These features can be observed on the Omo and Herto crania (Ethiopia) and the Ngaloba (Tanzania), Jebel Irhoud (Morocco) and Florisbad (South Africa) crania, dated between 265,000 and 120,000 years ago (Wolpoff, 1999; White et al., 2003; McDougall et al., 2005).

Acknowledgements

Appendix. Supplementary material

Supplementary data associated with this article can be found in the online version, at doi:10.1016/j.jhevol.2008.02.002.

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