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Stratigraphy, correlation, and age estimates for fossils from Area 123, Koobi Fora

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ABSTRACT

Geological data from the Bura Hasuma region at Koobi Fora provide important constraints for estimating the ages of hominin fossils recovered there, including the cranium KNM-ER 1813. Strata of the upper Burgi, KBS, and Okote members in this part of Koobi Fora reflect three depositional regimes driven by changing paleogeography through time. The upper Burgi and lowermost KBS sequence in the southern Bura Hasuma region accumulated in a lacustrine to delta front setting, with highly localized depositional patterns, limiting the lateral extent of lithostratigraphic markers. Farther north, uppermost upper Burgi through KBS member strata document a fluctuating lake margin, with complex facies patterns. This interval is marked by laterally extensive lithostratigraphic markers, including molluscan packstones, beach sandstones, and stromatolite beds. The uppermost KBS and Okote members show a transition to dominantly fluvial character, with localized and discontinuous accumulation.

An age model for the richly fossiliferous Area 123 sequence demonstrates the complexity of terrestrial accumulation patterns. Early lacustrine and delta front accumulation is marked by fairly continuous sedimentation, and high accumulation rates (up to ca. 91 cm/k.yr.). The fluctuating lake margin interval reflects lower sedimentation rates coupled with intervals of exposure, decreasing accumulation significantly (to ca. 13 cm/k.yr.). The capping fluvial interval is marked by significant erosion surfaces, breaks which may drop the overall accumulation rate even lower (ca. 0.3 cm/k.yr.).

The data provided here establish a geological framework at odds with a recent proposal of ages considerably younger (by ca. 250 k.yr.) for many of the fossils from Area 123 and elsewhere. Tests of age models demonstrate that the younger ages are not possible. While minor refinements to age estimates for fossils are indicated by improved chronostratigraphic control, in the case of KNM-ER 1813, an age of younger than 1.78 Ma is precluded on magnetostratigraphic grounds.

Introduction

The establishment of an accurate and precise framework for the fossil and archaeological record has long been a preoccupation of geologists interested in evolutionary and environmental problems (e.g., Bishop and Miller, 1972; Bishop, 1978). In East Africa, the context of hominin fossils and sites has been a particular focus, in part due to the excellent opportunities afforded by the stratigraphic record, and the intercalation of significant chronostratigraphic markers. In the four decades since the first application of numerical dating techniques to the hominin record of Olduvai Gorge (Evernden and Curtis, 1965), a detailed and robust framework of numerical age markers has been established for the Neogene of East Africa (e.g., Walter et al., 1991; Brown, 1994; Deino et al., 2006). Throughout this interval of development, scientific testing of numerical age estimates has confronted inconsistencies and apparent conflicts (e.g., Lewin, 1987). This has ultimately resulted in a high-resolution dataset, often allowing the control of fossil and archaeological localities to very limited numerical age spans. Of central importance to this process has been the interplay between geological field techniques and laboratory approaches. Critical field tools include mapping, analysis of stratigraphic sections, and correlation, while laboratory techniques such as geochemistry and isotopic age estimation provide more quantitative approaches to correlation and age.

Here we present stratigraphic data that falsify suggested revisions to age estimates for hominin and other fossils from Area 123 of the Koobi Fora region (Gathogo and Brown, 2006). Detailed mapping and stratigraphic analysis provided here obviate revisions in correlations made in that publication, while magnetostratigraphic data demonstrate that the younger ages are not possible.

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The Bura Hasuma region and its fossils

The discovery of the hominin fossil KNM-ER 1813 during the 1973 field season in Koobi Fora Area 123 focused geological interest on a complicated set of strata in the southern part of the Bura Hasuma region at Koobi Fora (Fig. 1). Exposures there include a prominent landmark, Bura Hasuma Hill (in southern Area 110), which is separated by nearly 2 km of poor exposure from a highly faulted belt of badlands exposures in Area 123 where KNM-ER 1813 and a number of associated fossils were recovered. The KBS Tuff was identified at the base of Bura Hasuma Hill, but no tephra were encountered in Area 123. Strata of comparable antiquity were recognized based on faunal assemblages and lithologic similarity, but crucially, the KBS Tuff itself is not present in Area 123.

Early reports concerning KNM-ER 1813 (Leakey, 1974; Leakey et al., 1978; Walker and Leakey, 1978) listed the specimen's stratigraphic derivation as either "Lower Member" or "Upper Member" within the Koobi Fora Formation, reflecting the uncertainty of the fossil's stratigraphic position relative to the KBS Tuff. With revisions to the stratigraphic nomenclature of the Koobi Fora region (Brown and Feibel, 1986), the interval of concern became the upper Burgi Member and the overlying KBS Member. The problem of stratigraphic attribution remained unchanged, however, as the delimiting KBS Tuff was not found in Area 123, and the position of the member boundary continued to be estimated. Lithologic correlations placed the level from which KNM-ER 1813 derived close to that of the tuff. While the actual chronostratigraphic significance of a precise attribution might be minimal, the relative placement of the Area 123 fossils with respect to other specimens, such as KNM-ER 1470, is significant. Subsequent detailed analysis of Koobi Fora stratigraphy (Brown and Feibel, 1986) and of the context of fossil hominins throughout the Turkana Basin (Feibel et al., 1989) placed KNM-ER 1813 beneath the level of the KBS Tuff, and assigned it an age between 1.88 Ma and 1.90 Ma (essentially 1.89 ± 0.05 Ma). Since that time, the framework within which the Koobi Fora hominins are constrained has been refined, but no major revisions have been proposed.

Geological context of the Bura Hasuma region

Over more than four decades of geological investigations at Koobi Fora, geologists have amassed a large database, and considerable understanding of its stratigraphic framework (e.g., Brown and Feibel, 1991). Recent difficulties in assessing the stratigraphy of Area 123 (Gathogo and Brown, 2006) result from neglecting crucial spatial context, integrating Area 123 with geographic and geologic mapping, and from misinterpreting lithological correlation and its chronostratigraphic calibration. We will treat first the spatial context surrounding the important fossils of Area 123, and then develop the stratigraphic framework within which the fossils can be placed. We will also demonstrate with stratigraphic data that the proposed age revisions of Gathogo and Brown (2006) can be falsified. We will then discuss the implications for the chronostratigraphic context of the Area 123 fossils as well as related examples. We hope to provide sufficient data here to demonstrate what is, and is not, possible with respect to the ages of these fossils.

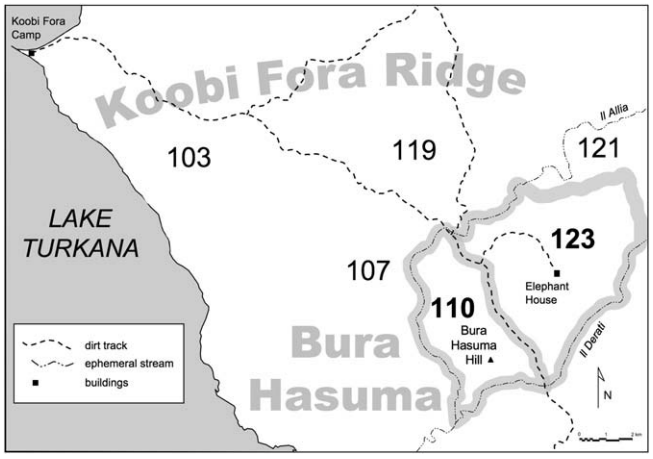

Figure 1. Location map of the Koobi Fora Ridge and Bura Hasuma regions showing major drainages, established dirt tracks (roads), and geographic landmarks discussed in the text. Boundaries of Areas 123 and 110 are outlined (for a detailed map of Koobi Fora collecting areas see Brown and Feibel [1986]).

Spatial context

There are two aspects of spatial context that are central to understanding the problems in Area 123: geographic localization and geologic mapping. The geographic component of spatial context is generally not a problem these days, especially in this age of GPS navigation and Google Earth. The location map provided by Gathogo and Brown (2006), however, is inaccurate, with implications for interpretation of the associated geology. Several landmarks are misplaced, such as the dirt track that forms the boundary between Area 110 and Area 123 (compare Fig. 1). This is significant in that it provides the only easily mappable landmark in the exposures most confounding to lithologic correlation. More problematic is the location of the marked stratigraphic sections. One of the sections used by Gathogo and Brown (2006) as a basis for their proposed correlations passes next to a local landmark, the Elephant House. This feature (and even the outhouse next to it) is easily seen on Google Earth imagery (near location point 162, Table 1). It is clear that the location given by Gathogo and Brown (2006) for their "Elephant Site" section is misplaced by some 2.5 km. Such problems in geographic placement call into question the location of other features and sections as documented by Gathogo and Brown (2006). For example, the placement of section PNG-123.2 as located by Gathogo and Brown (2006: Fig. 1b) crosses a mapped fault (Fig. 2). If the location provided for the section is accurate, then the tephra used to constrain the upper age of the sequence by Gathogo and Brown (2006) is not in continuity with the underlying strata (the mapped fault would have brought it down from higher in the section). We suspect, however, that the location provided is inaccurate, and does not necessarily bear on the continuity of that particular section.

No geological mapping was provided by Gathogo and Brown (2006). Existing mapping (e.g., Findlater, 1978) and more detailed subsequent work (Feibel, unpublished: Fig. 2) were available at the time of the investigation reported in Gathogo and Brown (2006). Unpublished maps were provided to the Koobi Fora Research

Table 1
GPS Coordinates of significant localities discussed in the text (WGS84 datum).

Point #	Lat/Long	Feature
155	N3.83461 E36.34686	Fault at Bura Hasuma Hill
162	N3.86712 E36.36102	ridge above Elephant House top Section 123-2/3
174	N3.88167 E36.37600	Northern Area 123 fault
MGL 1	N3.88797 E36.35024	Tuff MGL04-1
183	N3.87960 E36.32765	base Section CSF 123-1