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NOTE

DINOSAUR EGGSHELL FROM THE RED SANDSTONE GROUP OF TANZANIA

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Investigations over the last several decades at Gondwanan Mesozoic localities have significantly expanded our knowledge of the diversity and distribution of Southern Hemisphere dinosaurs. These records are primarily based on skeletal remains, but included among them are instances of preserved eggshell, notably from Argentina (e.g., Calvo et al., 1997; Chiappe et al., 1998) and India (e.g., Khosla and Sahni, 1995). In general, however, dinosaur eggshell is relatively poorly known from Gondwana, and from Africa in particular. Newly initiated (summer 2002) field research in Cretaceous-age deposits of the Red Sandstone Group in southwestern Tanzania has resulted in the discovery of a rich terrestrial/freshwater vertebrate fauna, which includes lungfishes and teleost fishes, turtles, crocodilians, sauropod and both avian and nonavian theropod dinosaurs, and mammals. Included among the dinosaur specimens are pieces of well-preserved eggshell. This is the first dinosaur eggshell from the Cretaceous of Africa to be studied and described in detail; it is here placed in the Oofamily Megaloolithidae on the basis of its structural details and surface ornament, which closely resemble those of Cretaceous megaloolithid eggshell from a number of other, non-African localities.

MATERIALS AND METHODS

A total of 20 individual eggshell pieces were recovered in July 2002 from a single site (TZ-07), located ca. 20 km west of the town of Mbeya in the Mbeya District of southwestern Tanzania (Fig. 1) at approximately 8° 56′ S, 33° 13′ E (precise locality coordinates are on file with the senior author [MDG] at Michigan State University). The eggshell pieces range in size from a few millimeters across to ca. 3 cm; all were found as isolated pieces, and none are large enough to allow interpretation of the overall shape of the eggs. Most were found as float, but three pieces were collected as in situ clasts in the red sandstone matrix at the site, demonstrating that they derive from the same deposit as the other fossils (including dinosaurs) found at TZ-07. Preliminary field identification of the specimens as eggshell was made on the basis of their tuberculate surface ornamentation, and the thin, slightly curved appearance of the pieces.

The eggshell fragments were prepared as standard petrographic thin sections (30 μm) and studied microscopically by transmitted and polarized light, or gold-coated (10 μm), mounted on aluminum stubs, and imaged under a JEOL 6100 SEM. Specimens used in this description are catalogued as NMT (National Museums of Tanzania) 02061, 02069, and 02084, and will be permanently deposited in the national collections in Dar es Salaam, Tanzania.

GEOLOGIC SETTING

The TZ-07 locality lies within the Red Sandstone Group, a series of isolated, northwest-trending alluvial deposits in southwestern Tanzania. TZ-07 exposes ca. 140 m of outcrop section (Fig. 2) through the Red Sandstone Group, which is dominated at the site by thick sequences of red-pink colored sandstone, with minor dark red mudstone and muddy siltstone lenses. Paleocurrent indicators suggest that deposition occurred in northwest-trending braided fluvial systems, and the overall sequence at TZ-07 is consistent with a half-graben rift valley setting.

Contrary to the findings of Wescott et al. (1991), the Red Sandstone Group, at least at TZ-07, preserves relatively abundant vertebrate fossil remains, in both the major sandstone bodies and minor mudstone lenses. Although the age of the Red Sandstone Group is poorly understood (see Damblon et al., 1998), a Cretaceous age is suggested at this site based on (1) the overall composition of the fauna, which includes titanosaurid? sauropods and both avian and nonavian theropods, as well as osteoglossomorph fishes, and (2) the possibility that these deposits may be approximately coeval with the Cretaceous dinosaur beds of Malawi (Jacobs et al., 1990), which lie ca. 200 km southeast of the Mbeya region. Additional study of regional geology and of the biota preserved at TZ-07 is necessary in order to make a more precise age determination.

DESCRIPTION

Radial thin sections of eggshell viewed under a petrographic microscope in both plain (Fig. 3D) and polarized (Fig. 3E) light show a single structural layer of calcite, with well-defined shell units; eggshell thickness varies from 1.1 to 1.7 mm, depending on preservation. The interior eggshell surface exhibits radiating spherulites (Fig. 3C) that extend outward from 75 μm-diameter circular structures that once contained the organic core of calcite nucleation. Eggshell dissolution occurred between the nuclei, with subsequent reprecipitation of sparry calcite. Where discernible, distances between these irregularly spaced nucleation sites range from 214 to 771 μm. Shell units that comprise the eggshell are relatively straight, flaring moderately towards the outer portion of the eggshell (Fig. 3A). In some specimens, an occasional shell unit may exhibit a very pronounced fan-shaped structure compared to the surrounding units. Horizontal accretion lines extend across the shell units, becoming slightly more arched in the outer portion of the shell. The shell unit height is approximately 2.5 to more than 3 times the shell unit width (a representative shell unit with these proportions is indicated on Fig. 3A).

The surface ornamentation (Fig. 3B) consists of domed tubercles approximately 0.45 to 0.77 mm in diameter. In some specimens the surface ornamentation coalesces into sinuous ridges, while in others the tubercles appear prominent and well separated, accentuated by recent weathering. Scanning electron microscope (SEM) imaging of eggshell reveals a multicanaliculate system with pores (Fig. 3A) that occasionally bifurcate and vary in diameter from 0.46 to 0.93 μm. Pores visible on the shell surface (Fig. 3B) are round to oval in shape, very abundant, evenly distributed, and typically filled by diagenetic sparry calcite.

DISCUSSION

Records of Mesozoic eggs from Africa are very limited, and, prior to this report, no detailed accounts of Cretaceous African dinosaur eggshell have been published. Kitching (1979) described as dinosaurian a clutch of six eggs from the Lower Jurassic Elliot Formation of South Africa, which contain embryonic remains including a reasonably well-preserved skull. Carpenter later (1999) suggested that these small (65 × 55 mm) eggs were not dinosaurian, as Kitching originally believed, but instead may have derived from crocodylomorphs; more recently, Zelenitsky and Modesto (2002) reexamined the six eggs and regarded them as dinosaurian (possibly prosauropod) in origin.

Two putative fossil dinosaur eggs were earlier collected near Mbeya, from the same general (but not precisely specified) area that produced the eggshell described here. A brief description, and a figure of one of the specimens, was provided by Swinton (1950), who stated that the material was of probable Cretaceous age. One of us [MDG] recently

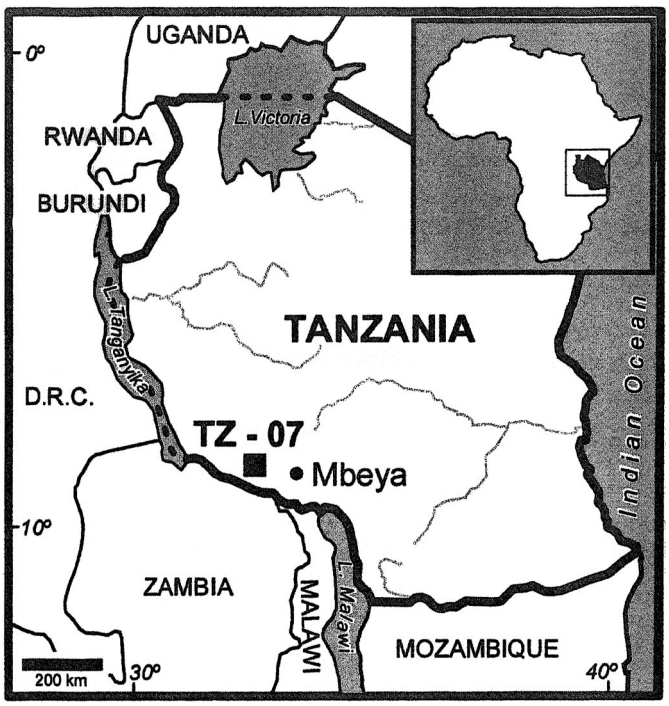

FIGURE 1. Location of the dinosaur eggshell-producing site (TZ-07), in the Mbeya District of southwestern Tanzania.

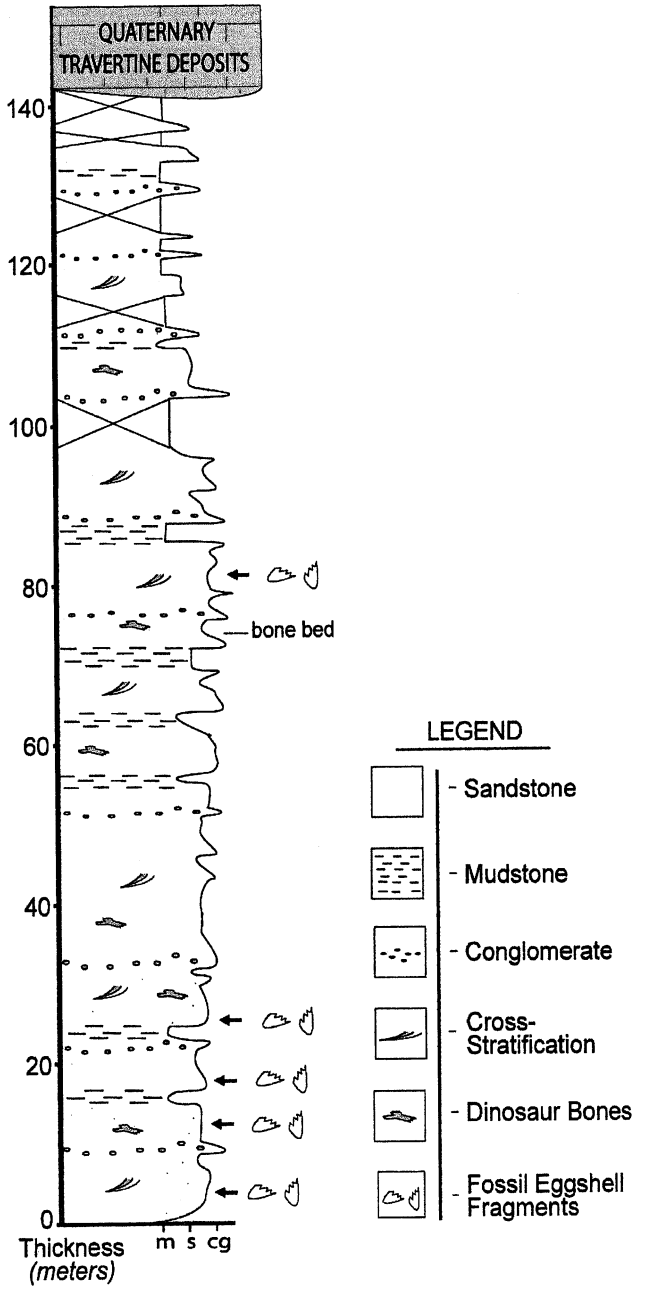

FIGURE 2. Measured stratigraphic section at TZ-07, showing levels at which dinosaur eggshell was recovered (cg, conglomerate; m, mudstone; s, sandstone).

examined these specimens at The Natural History Museum (NHM), London. One specimen, R12223, which measures ca. 15 × 14 cm, has patches of poorly preserved eggshell on an ovoid egg-shaped mass of red sandstone matrix; the other, R12709, which is larger (ca. 22 × 19 cm), and is composed of a brown (rather than red) sandstone, does not exhibit any specific egg features and may simply be an ovoid concretion. The specimen that is clearly an egg displays a high degree of diagenetic alteration and surface weathering, such that anatomical details of the remaining eggshell, including pore structure and microscopic characteristics, could not be assessed (as Swinton mentioned in 1950).

The Tanzanian eggshell described here exhibits tuberculate surface ornamentation and calcite structure consistent with the parataxonomic Oofamily Megaloolithidae (Zhao, 1979). The microstructural characteristics are similar to several types of *Megaloolithus* eggshells: *M. aureliensis*, *M. mammilare*, and *M. petralta* from France (Vianey-Liaud et al., 1994), and *M. baghensis* (Khosla and Sahni, 1995) and *M. matleyi* and *M. phenseniensis* (Mohabey, 1996, 1998) from India. However, the validity of some of these oospecies has been questioned based on their similar microstructure and surface morphology, and their often overlapping ranges of eggshell thickness (Carpenter, 1999).

Considerable variation in thickness and structural morphology also occurs within the Tanzanian eggshells. Some specimens exhibit shell thickness and surface ornamentation that are similar to the French specimens (Vianey-Liaud et al., 1994). However, the Tanzanian eggshells display more abundant pores, with more even distribution over the shell surface. The pore diameter in the Tanzanian specimens is typically less than that found in *M. aureliensis* and *M. mammilare*, while the shell unit height-to-width ratio is the same as *M. aureliensis* and greater than *M. mammilare*. More defined shell units in some specimens may differentiate the new material from eggshell previously described from India (Khosla and Sahni, 1995; Mohabey, 1996, 1998). Similar megaloolithid eggshell (*M. patagonicus*) occurs in the Upper Cretaceous Neuquén Group of Argentina (Calvo et al., 1997). However, the microstructure of these eggs (now identified as sauropod by their embryonic remains) typically displays shell units that are relatively wide and exhibit parallel margins (Chiappe et al., 1998), rather than the narrower, and sometimes fan-shaped, units (see Fig. 3) present in the Tanzanian material. The Argentine specimens also display a shell unit height that is typically less than two times greater than the shell width.

The specimens described here represent the only study of microstructural characteristics of Cretaceous eggshell from Africa. Without intact eggs, however, no assessment of morphological variation is possible, and assignment of the Tanzanian eggshells to a new or existing parataxonomic oospecies serves no useful purpose at this time. Although megaloolithid eggshell is often attributed to sauropod dinosaurs (Case, 1978; Erben et al., 1979; Sahni et al., 1994; Moratalla and Powell, 1994; Cousin et al., 1994), only eggs from the Auca Mahuevo locality in Argentina contain embryonic remains (Chiappe et al., 1998) that can be directly referred to Sauropoda. While it is most parsimonious to assume that the Tanzanian eggshell is sauropod in origin (an assumption that is supported by the presence of titanosaurid? sauropod skeletal remains and teeth recovered from the same site), the precise systematic identity of the eggshell must remain uncertain until more definitive material is recovered.

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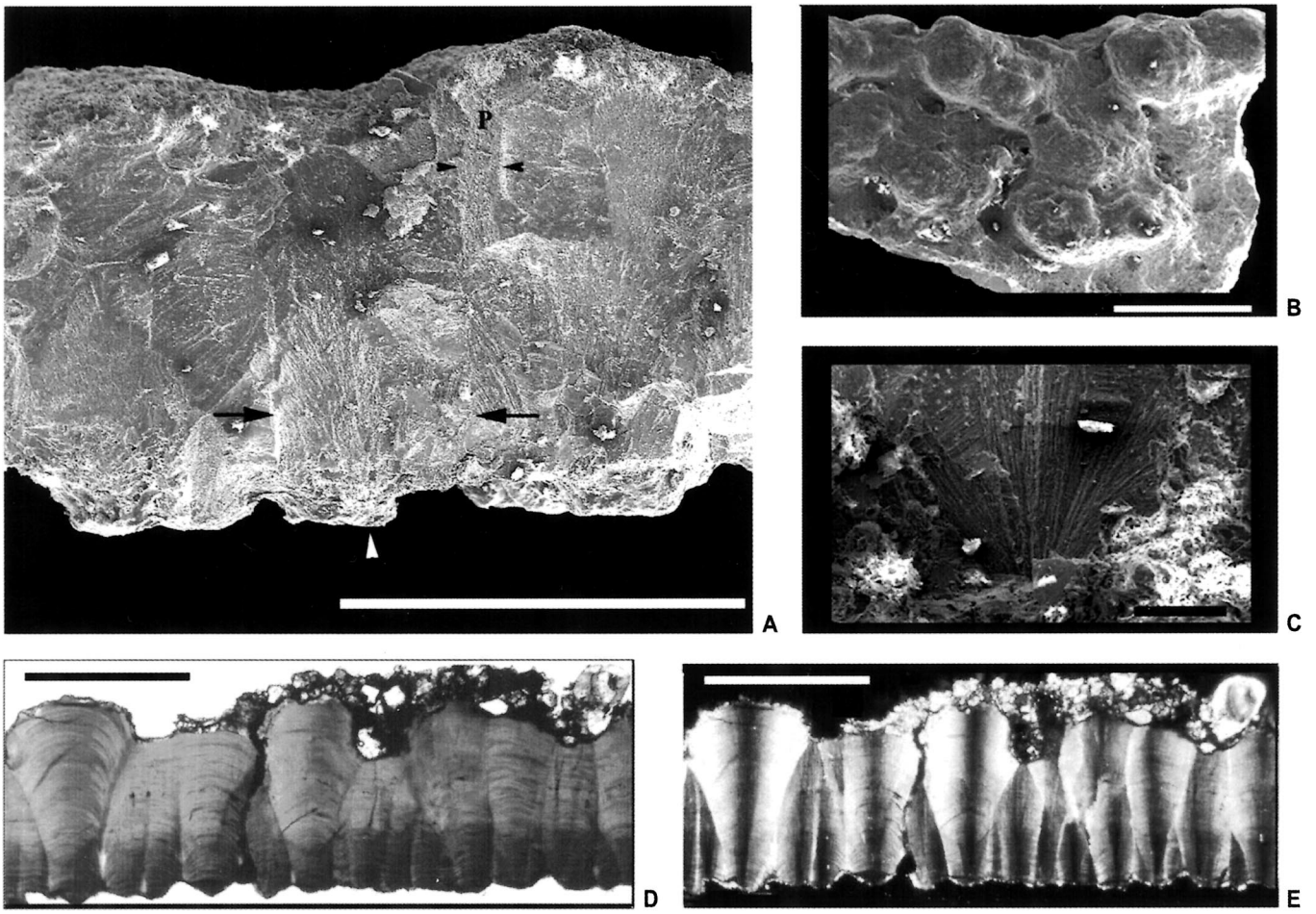

FIGURE 3. Structural features of megaloolithid eggshell from Tanzania. **A**, SEM image of eggshell in cross-section—lower black arrows indicate shell unit margins, upper black arrows show pore (P) width, white arrow shows calcite nucleation site; scale bar equals 1 mm. **B**, SEM of eggshell surface, showing tubercles and abundant pore openings; scale bar equals 1 mm. **C**, SEM image showing radiating spherulites of calcite that originate from a central nucleation site at the base of the eggshell; scale bar equals 100 μm. Petrographic thin section of eggshell in cross-section view in (**D**), plain light, and (**E**), polarized light; scale bars in D and E equals 1 mm. [NMT 02069 in A,B, and C; NMT 02061 in D and E].

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