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Abundance and taphonomy of dinosaur teeth and other vertebrate remains from the Bostobynskaya Formation, north-east Aral Sea region, Republic of Kazakhstan

Gareth J. Dyke[a,*], Dmitry V. Malakhov[b]

[a]Department of Zoology, University College Dublin, Belfield, Dublin 4, Ireland
[b]Institute of Zoology MS RK, Akademgorodok 60, 480032, Almaty, Kazakhstan

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Abstract

Vertebrate microfossils, including abundant dinosaur teeth, recovered from a series of horizons in the Late Cretaceous (Turonian–Campanian) Bostobynskaya Formation (Bostobynskaya Svita), north-east Aral Sea region, Republic of Kazakhstan, display taphonomic characteristics consistent with deposition within floodplain-hosted assemblages. Teeth collected from the horizons confirm the presence of theropods, hadrosaurs and sauropods in the formation, consistent with previous suggestions of the dinosaur fauna. Compositional analysis of microfossil collections show that the material is characterised by low weathering and abrasion states, a high diversity of small fossils that represent aquatic, semi-aquatic and terrestrial taxa, and an abundance of resistant bioclasts, such as teeth. The sedimentology of the Bostobynskaya Formation is dominated by crevasse-splay and flood-event facies. New records from these sites document an important Late Cretaceous vertebrate fauna in an equally important and much understudied part of Central Asia.

Keywords: Late Cretaceous; Turonian–Campanian; Dinosaurs; Teeth; Microfossils; Taphonomy

1. Introduction

During the Late Cretaceous, Central Asia was located on the northern part of the tectonically active Turan Plate, a region that has been understudied from a palaeobiogeographic viewpoint. Few analyses have been undertaken on the Late Cretaceous faunas of Kazakhstan (Kordikova et al., 2001); as a result, fossil vertebrates from this region of Central Asia remain largely unknown. Over the past two years, we have initiated a field programme that is focused on sediments of Cretaceous age in the north-east Aral Sea region of Kazakhstan. Here we present a preliminary report of a large sample of isolated dinosaur teeth and other fossil vertebrate remains collected during 2002 and 2003 from the Late Cretaceous sediments of the Bostobynskaya Formation, which crops out approximately 260 km to the north-east of the Aral Sea (Fig. 1).

Dinosaur teeth represent an important, and often common, constituent of vertebrate samples from terrestrial faunas throughout the Mesozoic System. Early in the history of vertebrate palaeontology, workers concluded that some types of dinosaur teeth were recognised as distinctive enough to be diagnostic, at least at the generic level (Leidy, 1856; Cope, 1876; Marsh, 1892). Overall tooth shape, cross sections, the relative positions of both anterior and posterior carinae, and denticle morphology have been used to identify taxa of theropod dinosaurs (e.g., Currie et al., 1990).

* Corresponding author.
E-mail address: gareth.dyke@ucd.ie (G.J. Dyke).

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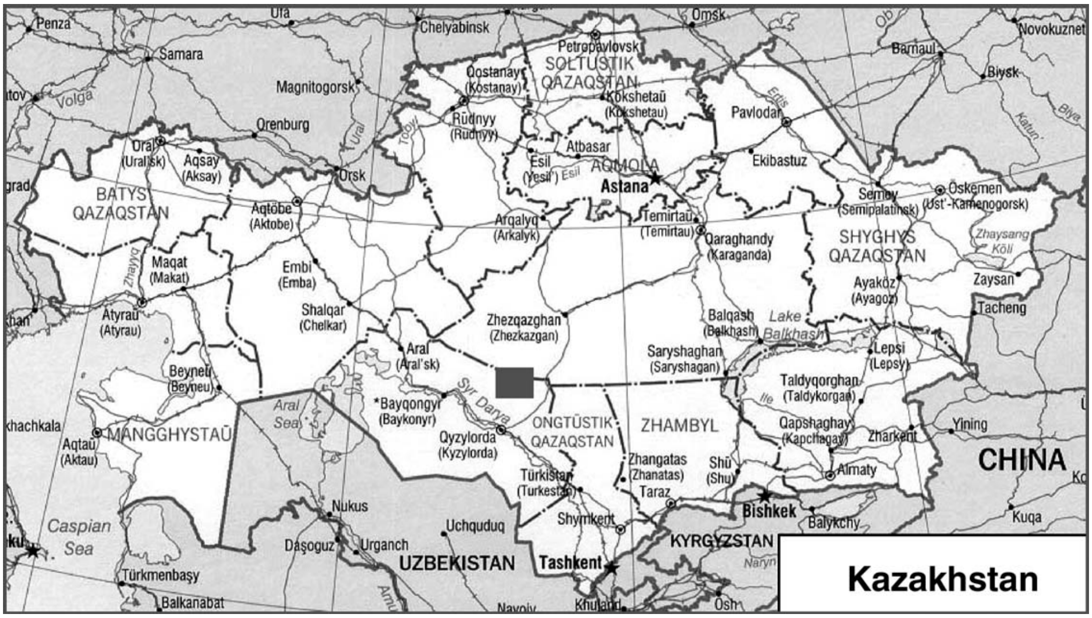

Fig. 1. Map of the Republic of Kazakhstan showing the location of the field area (inset as shaded grey box).

Vertebrate teeth are exceptionally abundant at a series of field sites within the Bostobynskaya Formation and can be used to provide a preliminary understanding of the dinosaur fauna of this area. Although dinosaurs have been described previously from north-east Kazakhstan (Nessov and Khissarova, 1988; Nessov, 1995), the majority of this material is either highly fragmentary or from localities that cannot be precisely relocated. Our fieldwork in this region is the first in more than 20 years to comprehensively sample vertebrate fossils from this part of Central Asia (but see Kordikova et al., 2001). Samples recovered establish the presence of at least three major groups of dinosaurs on the basis of their teeth and confirm previously published accounts that indicate their presence in this region of Kazakhstan (Kordikova et al., 2001). All of the material presented here is housed in the collections of the Institute of Zoology, Academy of Sciences, Almaty, Kazakhstan.

2. Geological context of Bostobynskaya outcrops

Abundant dinosaur teeth and other fossils were surface collected from three field sites within the Bostobynskaya Formation (Fig. 1). This succession of marginal marine and continental rocks has sometimes been referred to as the Bostobe Formation (Kordikova et al., 2001). It comprises an approximately 100-m-thick sequence of interbedded silty mudstone and coarse-grained sandstone units cropping out approximately 85 km north-east of the village of Jhosaly (Dzhusaly) in Kzylorda District, north-east Aral Sea region, Kazakhstan (Figs. 1, 2). On the basis of the fossil plants and vertebrates, in particular sharks' teeth, collected from this region in the 1970s and 1980s, the Bostobynskaya Formation has been estimated to be between Turonian and Campanian in age (Nessov and Khissarova, 1988; Nessov, 1995).

At the three sites we investigated, fossil remains were concentrated as clasts within basal mudstone units, although with a high degree of reworking into overlying sandstones (Fig. 2). Vertebrate remains dominate, but smaller proportions of fossilised wood and invertebrates were also collected. Within the mudstones, clast composition is dominated by resistant bone and carapace fragments as well as teeth. This bone is freshly broken, angular and well preserved, suggesting a low degree of subaerial weathering and transport (Figs. 3, 4). In contrast, reworked material recovered from the sandstone units at these sites is well rounded, often heavily abraded, and is pyritised (probably as a result of surface diagenesis). This suggests that fossils found in the sandstones have undergone a higher degree of subaerial weathering and transport within channels (Fiorillo, 1991; Blob and Fiorillo, 1996). We have identified little fossil material preserved in situ, except towards the base of the thinner mudstone units.

Our preliminary work suggests these sediments are consistent with a floodplain-type depositional environment including some degree of channel action and clast exposure at the surface prior to diagenesis. Field observations indicate that while the mudstone units within the formation are massive (up to 6 m thick) and continuous, the coarser-grained sandstone units are not. The mudstones are creamy-white in colour whereas the sandstones are a deep red to orange, containing large amounts of secondary pyrite (Fig. 2). In general, sediments form cycles of upward coarsening units,

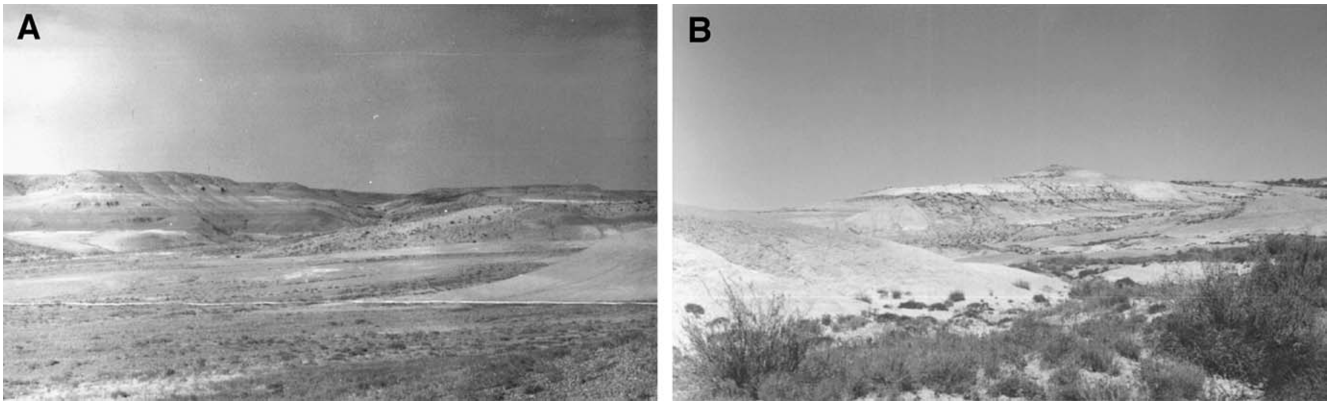

Fig. 2. Field photographs of Bostobynskaya Formation outcrops north-east of Jhosaly, Kazakhstan. A, predominantly mudstone-intercalated sequence near the base of the Bostobynskaya Formation. B, top of the Bostobynskaya Formation showing a graded unconformity into the Palaeogene Akzhar Formation at the crown of the hill (see text for details).

although a number of sandstone lenses are discontinuous across the field area and contain laminar cross-bedding structures consistent with their interpretation as ephemeral channel deposits. The mudstone units are often capped within massive, blocky sandstone bodies that contain high proportions of gypsum and calcite nodules. Correlated with our sedimentary observations and again on the basis of fossil shark material (i.e., Hybodontidae, Polyacrodontidae), and a smaller number of amphibians (i.e., Scapherpetontidae), Nessov and Khissarova (1988) suggested that the depositional environment of the formation is consistent with slightly saline water conditions.

Fossils within Bostobynskaya sediments are concentrated in at least three distinct horizons that appear to be continuous across the field area surveyed. Sediments comprise the eastern limb of an approximately east–west trending, very shallow anticline (not north–south trending as reported in Kordikova et al., 2001) that is at least 20 km in length and inclined at angles of always less than 10 degrees. These sediments constitute part of the "Lower Syr-Dar'ya Uplift" (to the north of the Syr-Dar'ya River, east of the Aral Sea) (Kordikova et al., 2001). Much of the Bostobynskaya succession in this region is overlain by a probable Palaeogene pebble conglomerate referred to as the Akzhar Formation (B. Tzirelson, pers. comm. 2002) (Fig. 2).

3. Abundance of dinosaur teeth and other fossil vertebrates

Based on preliminary fieldwork in the north-eastern regions of Kazakhstan, Nessov (1995) reported the presence of a range of dinosaur taxa including birds, pterosaurs and other fossil vertebrates from a series of sites in the vicinity of the village of Jhosaly (including Shakh-Shakh Hill; Kordikova et al., 2001) (Malakhov and Dyke, 2003) (Fig. 1). Based on Nessov's (1995) report, the sites we have surveyed were expected to include the remains of both saurischian (i.e., sauropod and theropod) and ornithischian (i.e., hadrosaur, ceratopsian and ankylosaur) dinosaurs. Some more details of the dinosaur fauna of the Jhosaly region can be found in Kordikova et al. (1996, 1997, 2001).

Because of the predominantly small size and often fragmentary nature of the fossil material we have collected from the surface of the sites so far surveyed, it is impossible to identify approximately one-third of the specimens in our samples (Fig. 3). Among identifiable elements, vertebrate bones and dinosaur and crocodile teeth are dominant, whereas turtle shell fragments and fish scales are less common (Fig. 3). Identifiable dinosaur teeth belong to theropods, hadrosaurs, ceratopsians and sauropods. Theropod teeth are recurved and bear small, sharp serrations on both anterior and posterior keels (Currie et al., 1990; Fiorillo and Currie, 1994). Our collections include tyrannosaurids (stout and lenticular in cross-section, with broad, chisel-shaped denticles; Molnar et al., 1990; Fiorillo and Currie, 1994) (Fig. 4A, F), as well as a smaller unidentified dromaeosaurid taxon (Fig. 4D). Hadrosaurian teeth (Fig. 4B) are characterised by their clear, diamond-shaped cross-section and can be distinguished from contemporaneous ceratopsian teeth (Fig. 4E) by the presence of a single root (when found complete), in the form of the primary ridge and absence of a secondary ridge. The primary ridge of ceratopsian teeth is much more prominent than that of hadrosaurs (P. Barrett, pers. comm. 2004). In contrast, the teeth of sauropod dinosaurs that we have collected are elongate and pencil-like (Fig. 4). The Bostobynskaya sauropod teeth are broadly cylindrical in cross section, a generalised feature that when combined with their slender and tapered crowns suggests that they are from either diplodocoid or titanosaurid taxa; because of this uncertainty, we refer these specimens to Neosauropoda incertae sedis (Upchurch, 1998; Upchurch and Barrett, 2000; Barrett et al., 2002). This

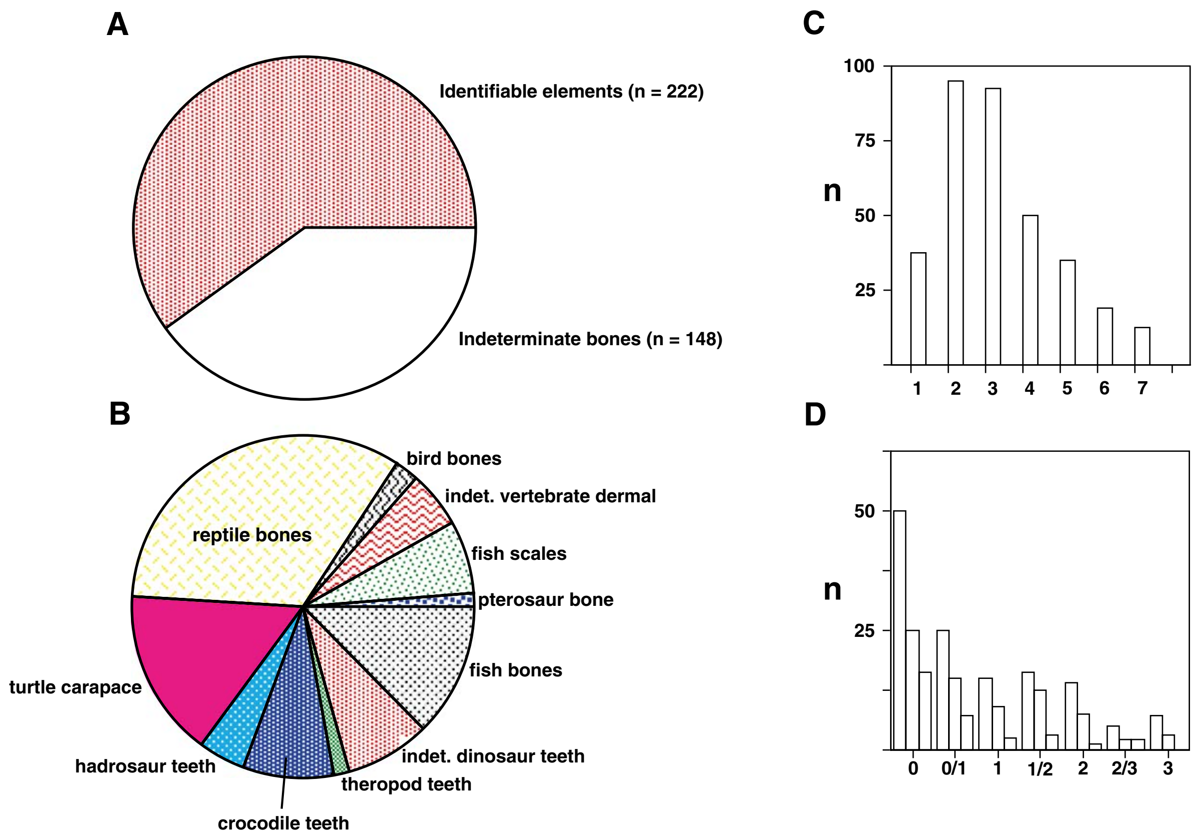

Fig. 3. Details of fossil vertebrate material collected during 2002–2003 from the Bostobynksaya Formation. A, broad-scale compositional details. B, taxonomic categories of identifiable vertebrate remains. C, fossil element size distributions (size distribution classes in mm are on the x-axis and are as follows: 1, 0–4.9; 2, 5.0–9.9; 3, 10.0–14.9; 4, 15.0–19.9; 5, 20.0–24.9; 6, 25.0–29.9; 7, 30.0–34.9). D, observed abrasion states for fossil material (see text for details) (left hand bar represents all elements; middle bar, bone only; right hand bar, teeth only).

identification is consistent with their provenance and the estimated age of the formation (Nessov, 1995).

The presence of the small tyrannosaurid theropod *Alectrosaurus* was noted in this region of Kazakhstan by Nessov (1995); this taxon has also been reported from the Upper Cretaceous (?Cenomanian) of China and Mongolia (Molnar et al., 1990). The size and arrangement of the denticles in some specimens collected from the Bostobynskaya sites are consistent at least with the presence of a tyrannosaurid theropod of intermediate size within the formation (Fig. 4F). Rarer still, we have collected just two representative dental fragments of a smaller dromaeosaurid theropod (Fig. 4D); the cross-section of the root of these teeth, their curvature and denticle density count are consistent with their referral to Dromaeosauridae (Farlow et al., 1991). In contrast the remains of hadrosaurs, although distinctive based on their dental anatomy (Fig. 4B), have rarely been reported on the basis of diagnostic fossil material from this area (Nessov, 1995). Large collections of weathered postcranial bones collected from the Bostobynskaya and surrounding outcrops in the Aral Sea area are housed in the Institute of Zoology, Almaty, but to date only two genera of these dinosaurs have been described from the region. *Aralosaurus* was described by Rozhdestvensky (1968) on the basis of almost complete articulated skull material (Weishampel and Horner, 1990) from a nearby series of outcrops (referred to as the Beleutinskaya Svita), whereas *Arstanosaurus* is much less well represented (Norman and Kurzanov, 1997). This latter taxon, listed as nomen dubium by Weishampel and Horner (1990) and Norman and Kurzanov (1997), was named on the basis of just the caudal portion of an isolated maxilla.

4. Discussion

Microvertebrate remains collected from horizons within the Bostobynskaya Formation exhibit low degrees of both surface weathering and abrasion (Fig. 3). If we were to draw conclusions on this basis, using classical interpretations of such taphonomic parameters (e.g., Behrensmeyer, 1978; Fiorillo, 1988; Cook, 1995), these data would indicate that most fossil material has undergone minimal transport, reworking and subaerial weathering. Our preliminary sedimentological interpretations of the Bostobynskaya Formation are consistent with the interpretation that much of the microvertebrate debris accumulated in shallow water

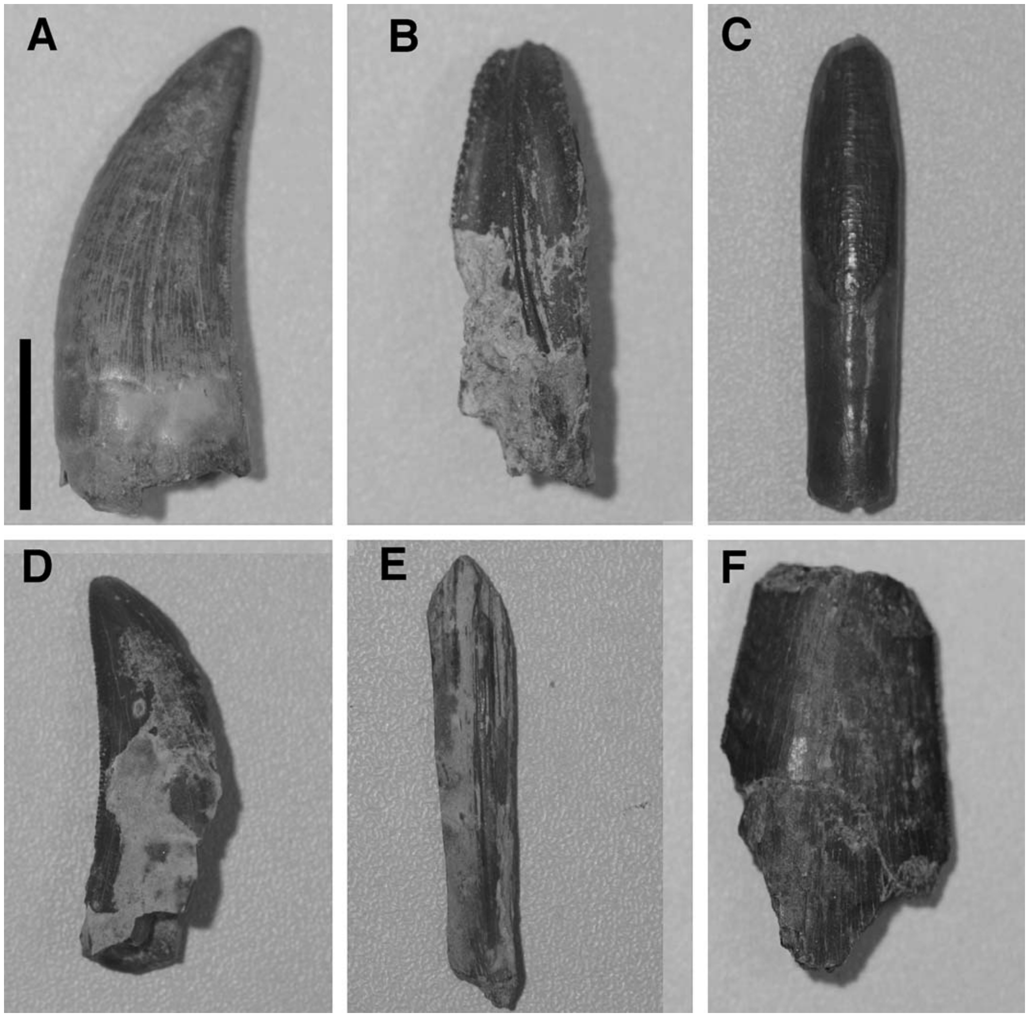

Fig. 4. Dinosaur teeth from the Bostobynksaya Formation. A, large tyrannosaurid theropod (cf. *Alectrosaurus*). B, hadrosaur (cf. *Aralosaurus*). C, neosauropod (cf. Titanosauridae). D, dromaeosaur. E, Ceratopsidae incertae sedis; F, large well-abraded tyrannosaur tooth fragment. Scale bar represents 10 mm.

bodies via attritional mortality of the endemic aquatic and semi-aquatic taxa. The fossils that we have collected appear to have undergone limited transport prior to burial; this is at least consistent with both our sedimentological and abrasion data.

However, a few elements in our collections exhibit significantly higher weathering and abrasion states (Figs. 3, 4). Also consistent with local sedimentology, these fossils have different preservational attributes, having been reworked from overlying sandstone bodies, and represent the skeletal remains of taxa that may have been introduced into the water bodies by overland transport during flood events; we suggest that many of these remains have been introduced either by floods or via the associated erosion and subsequent collapse of banks and channel incisions. We would expect material of this type to exhibit higher weathering and abrasion stages, since these fossils have experienced periods of transport within the suspended load sediment and prolonged exposure to subaerial processes. Input into the muds via this mechanism would be expected to be minimal because of the nature of the standing water bodies: we interpret the mudstone bodies at the base of the Bostobynskaya succession to be indicative of low levels of turbidity and turbulence, suggesting poor current circulation. As is the case in all studies of this type, the effects of multiple reworking on weathering and abrasion states are almost impossible to predict.

In general, these data suggest that the vertebrate microremains in the Bostobynskaya Formation are characterised by the following taphonomic features: a high diversity of small fossils that represent aquatic (fish and indeterminate turtle), semi-aquatic (crocodile, turtle and amphibian) and terrestrial (lizard and dinosaur) taxa; an abundance of physico-chemically resistant bioclasts such as teeth, dermal scutes and carapace fragments; vertebrate debris distributed throughout the horizon, not concentrated in lenses; most elements exhibiting only minimal weathering although the occasional element shows more advanced surface degradation (stages 2–3);

large dinosaur bones found occasionally within the microvertebrate horizons.

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