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Cretaceous Research 25 (2004) 453–458

CRETACEOUS RESEARCH

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The first record of a Cretaceous dinosaur from southwestern Alaska

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Received 21 November 2003; accepted in revised form 12 March 2004

Abstract

Cretaceous dinosaurs are recorded for the first time from southwestern Alaska by a series of three tracks found in Aniakchak National Monument. This trackway is in the Upper Cretaceous (Campanian–Maastrichtian) Chignik Formation, a cyclic sequence of marine to non-marine clastic sedimentary rocks. The nearest coeval locality is approximately 1500 km northeast of this site, along the Colville River in northern Alaska, which contains abundant dinosaurs. This distance helps to document the occurrence of a widespread Cretaceous Arctic terrestrial ecosystem that supported significant numbers of large-bodied herbivores.
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Keywords: Chignik Formation; Hadrosaur; Alaska Peninsula; Aniakchak National Monument; Arctic

1. Introduction

Although Mesozoic rocks are represented throughout much of Alaska (Beikman, 1980), Mesozoic-age vertebrates in this vast region are limited to a handful of localities (Gangloff, 1998; Pasch and May, 2001). The most productive of these few sites, in terms of numbers of specimens and scientific results, are along the Colville River in northern Alaska (Parrish et al., 1987; Clemens and Nelms, 1993; Clemens, 1994; Gangloff, 1998; Fiorillo et al., 1999; Fiorillo and Gangloff, 2000, 2001). Contributing to this restricted distribution are factors such as outcrop pattern, immensity of the region, costs of research expeditions, and weather patterns in Alaska. As a result, much remains to be explored for the first time in this vast area. As part of a recently initiated inventory and monitoring program by the National Park Service, Alaska Region, access to some remote areas of paleontological interest is now feasible.

Evolution is unquestionably the unifying principle in modern biology. Patterns of large-scale evolutionary phenomena are dependent on the thorough documentation of fossils in time and space, a tenet emphasized and repeated by many (e.g., Moore, 1948; Middlemiss et al., 1971; Weishampel, 1990; Carroll, 1997). This documentation is the basis for large-scale evolutionary (Carroll, 1997) and paleobiogeographic interpretations (Russell, 1993). The purpose of this paper is to document the first occurrence of Cretaceous dinosaurs in southwestern Alaska (Fig. 1). This new locality is approximately 1500 km from the nearest known coeval Cretaceous fossil vertebrate localities and consists of tracks attributable to an ornithopod dinosaur, most likely a hadrosaur. To emphasize the magnitude of this geographic distance, 1500 km is approximately the distance from Boston to Chicago. The purpose of this paper is to document the tracks as this occurrence helps establish a widespread Cretaceous terrestrial Arctic ecosystem that supported significant numbers of dinosaurs.

2. Geographic and geologic setting

Aniakchak National Monument and Preserve comprises approximately 240,000 hectares and is one of the

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0195-6671/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cretres.2004.03.002

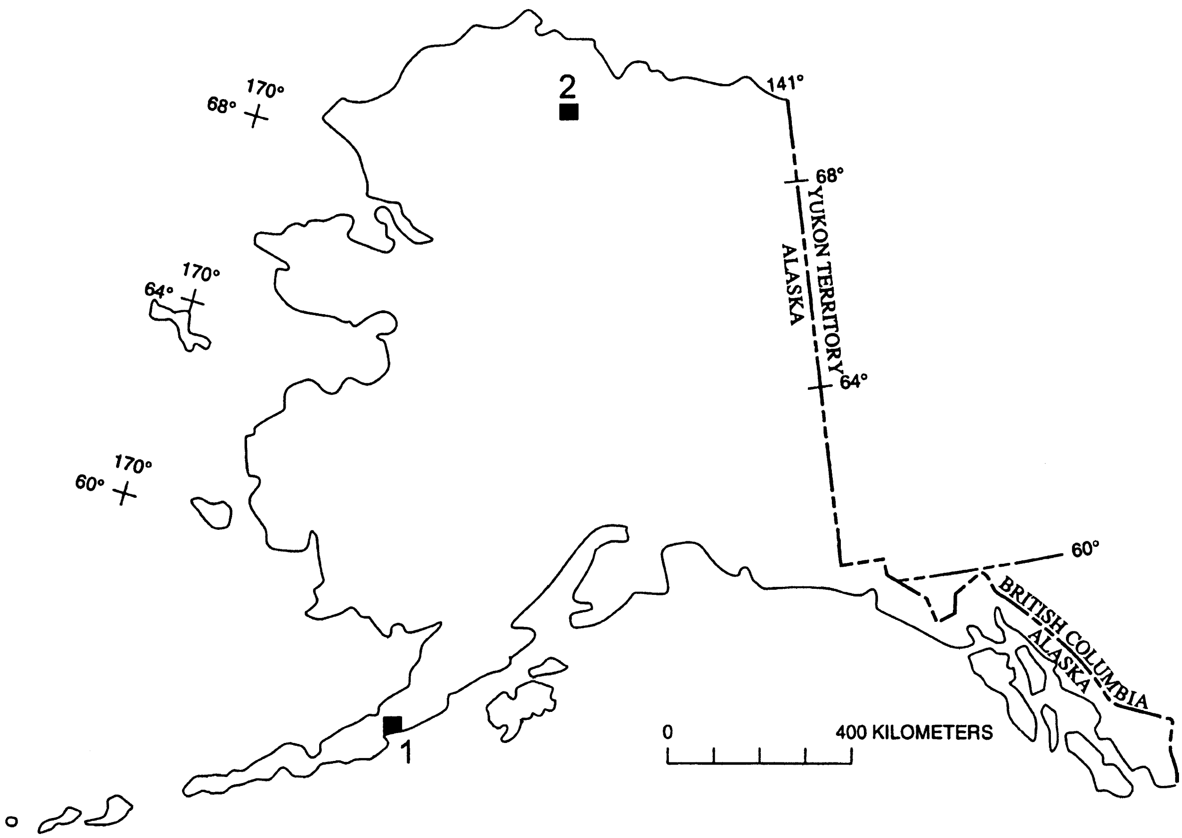

Fig. 1. Location of tracksite at Aniakchak National Monument discussed in this report (no. 1). Included on this map is the general location of the more famous coeval dinosaur localities on the Colville River of northern Alaska (no. 2).

least-visited parks within the National Park Service. The park was established in 1978 because of the volcanic features in the region, the most notable of which is the 10-km-wide Aniakchak Caldera, a 610-m-deep circular feature that is the result of the collapse of a magma chamber. In addition to this prominent volcanic feature, sedimentary rocks ranging in age from the Late Jurassic (Naknek Formation) to Eocene (Tolstoi Formation) are also preserved in the park (Detterman et al., 1981; Wilson et al., 1999). Part of this section, the Upper Cretaceous Chignik Formation, contains this new fossil locality.

These rocks are part of the Peninsular Terrane, the structural unit that encompasses much of southwestern Alaska. Paleomagnetic reconstruction based on the Upper Cretaceous and lower Tertiary volcanic rocks of this terrane suggest that the Chignik Formation was deposited at approximately the current latitude (Hillhouse and Coe, 1994). In contrast, coeval sedimentary rocks of the Peninsular Terrane elsewhere in southern Alaska provide more ambiguous paleomagnetic results, suggesting positions as far as 3000 km south of the present position of the rock sequence (Hillhouse and Coe, 1994).

The Chignik Formation was named by Atwood (1911) for rocks exposed in the vicinity of Chignik Bay, southwest of what is now Aniakchak National Monument and Preserve. The formation has a maximum stratigraphic thickness of approximately 600 m in the type area of Chignik Bay (Detterman et al., 1996). The thickness varies outside this area, thinning rapidly to the northeast and southwest (Detterman et al., 1996). The Chignik Formation is a cyclic sequence of rocks representing predominately shallow marine to nearshore marine environments in the lower part, and predominately continental environments in the upper part of the section (Fairchild, 1977; Detterman, 1978; Wahrhaftig et al., 1994; Detterman et al., 1996).

Based on the presence of the marine bivalves *Inoceramus balticus* var. *kunimienis* and *I. schmidti* and the ammonite *Canadoceras newberryanum*, the age of the Chignik Formation is considered to be late Campanian–early Maastrichtian (Detterman et al., 1996). The age of this sequence is correlative with at least some of the dinosaur localities in the Prince Creek Formation, along the Colville River of northern Alaska, which is considered to straddle the Campanian/Maastrichtian boundary (Obradovich, 1993).

We measured a 280-m section of the Chignik Formation in the study area in Aniakchak Bay (Fig. 2). The outcrop is exposed in a bluff averaging approximately 10 m high along the coastline, and most of it is accessible

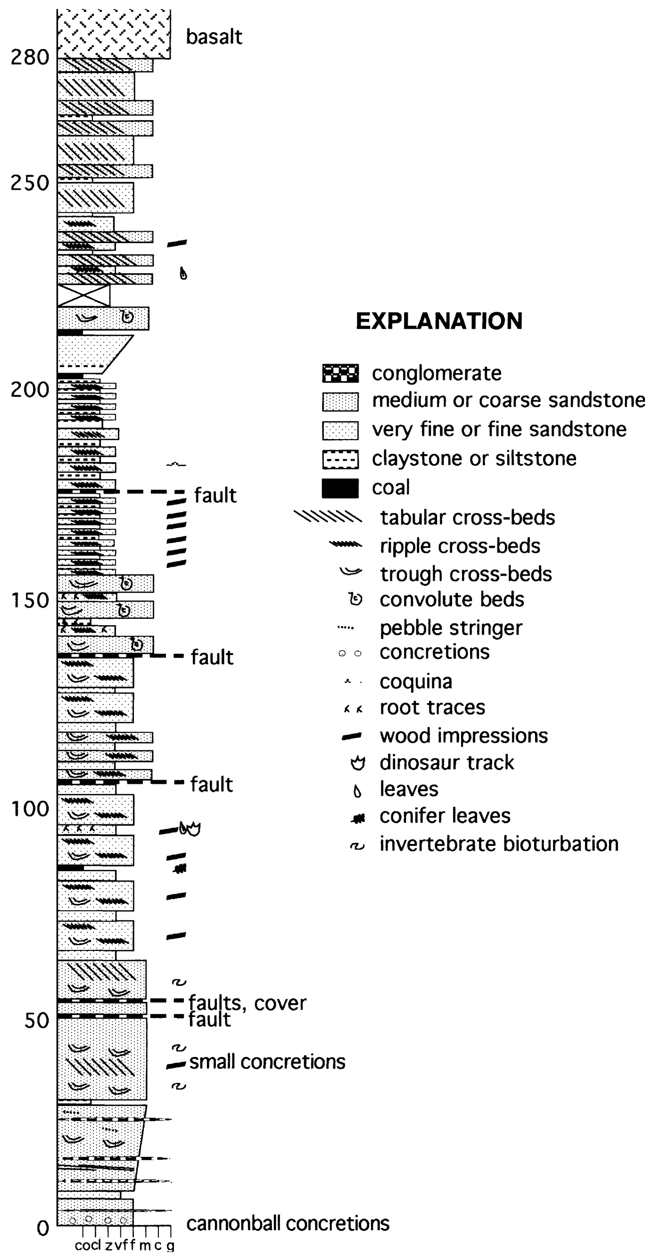

Fig. 2. Measured section at Aniakchak Bay.

only at low tide. Faults are visible in numerous places and there are vegetated breaks that might be additional, covered faults. Owing to the nature of the outcrop, the faulting, and the time constraints imposed by both the length of the field season and the tides, parts of the section in Fig. 2 may be either missing or repeated. Further complicating measurement is the changing orientation of the coastline relative to the dip and strike of the beds, which in places exacerbated the challenges presented by cover of the formation by vegetation and/or fallen blocks. In general, the formation here dips about 20° to the northeast.

The rocks are marine in the lowermost part of the section, below about 60 m, but it should be noted that the base of the formation is not exposed here. A thin coquina of marine mollusks occurs at about 180 m (Fig. 2), but most of the section appears to be terrestrial, based on lithology, sedimentary structures, and fossils. This section represents deposition in shallow marine to distal coastal plain settings.

3. Tracksite description

A set of dinosaur tracks was found in the measured section (Fig. 2). The tracks are located on several large fallen blocks of sandstone. Each block is clearly derived from the adjacent outcrop of the Chignik Formation, and can be attributed to a particular bed. The base of this sandstone is at about 95 m on the measured section (Fig. 2).

The tracks are in a light- to medium-gray, fine-grained sandstone and are preserved in positive relief. The largest impression is 8–10 cm in height. There is a medium gray siltstone layer approximately 1 cm thick between the exposed track and the rest of the boulder. The tracks preserved in the sandstone are interpreted as undertracks (sensu Lockley, 1991), with the actual track preserved in the siltstone interbed. This bed was likely to have been relatively soft, as demonstrated by the slight sliding motion in emplacement of the pes track in Fig. 3.

4. Systematic description

Suborder: Ornithopoda Marsh, 1881
Family: Hadrosauridae
Ichnogenus uncertain

Horizon and locality. Chignik Formation, Campanian/Maastrichtian, tracks (and flora) at 95-m level of our section (Fig. 2) along the coastal outcrop belt of Aniakchak National Monument. Exact location on file with the National Park Service, Alaska Regional Office.

Description. One block contains a track assemblage that consists of a single large impression and two smaller associated impressions, interpreted as a pes and two manus prints respectively (Fig. 3). Casts of these tracks are housed at the Dallas Museum of Natural History (DMNH 12143). Preservation of the pes track does not allow for differentiation between digits II and IV. The pes impression shows three clearly defined digits with no claw impressions (Fig. 3), whereas the manus tracks are smaller, shallower, and ellipsoidal in shape. The manus tracks show no separate digit impressions and the long axis of each track is perpendicular or nearly perpendicular to the long axis of the pes track.

Remarks. Lee (1997) illustrated an ornithopod trackway from the Lower Cretaceous Woodbine Formation of Texas. His illustration showed manus tracks lateral to the anterior–posterior axis of each pes track. As the manus tracks in the Chignik Formation are similarly

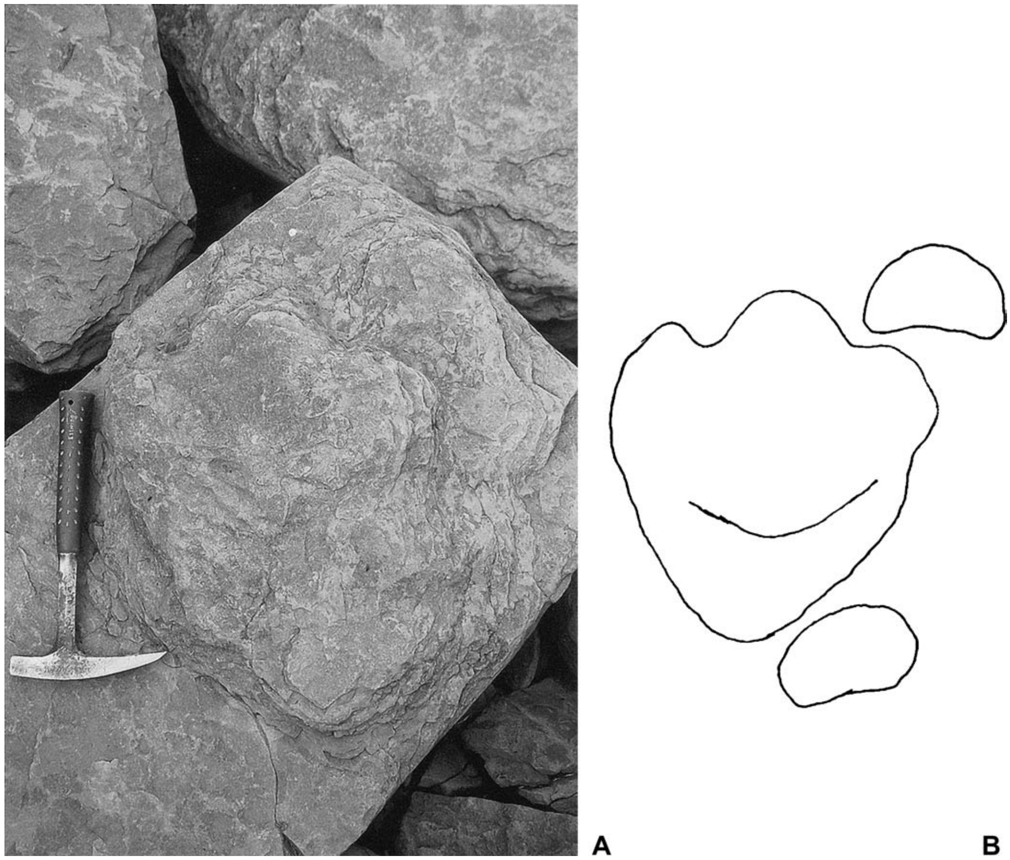

Fig. 3. A, photograph of the three tracks discussed in this report. B, outline of the three tracks.

positioned in relation to the pes track, their position suggests that this is a right pes track. By this interpretation, one manus track is located anterior to digit IV whereas the other track is located posterior to digit IV.

Three characteristics attribute the prints to an ornithopod: the morphology of the feature is the right shape (Fig. 3), the size is appropriate, and the preserved bedding is consistent with a load structure (Fig. 4). Fig. 5 is a laser-scanned image of a cast of the pes track, and the image has been contoured. This image clearly shows three toes and the heel. Because of the smooth edge of the track, the elongation of the heel is interpreted here as the result of a slight sliding motion of the foot prior to stopping rather than a set of superimposed tracks. The maximum width of the pes track is approximately 34 cm and the maximum length is approximately 30 cm. Ornithopod pes tracks are typically wider than they are long (Lockley, 1991). Given the age determination of the Chignik Formation, these ornithopod tracks can be attributed to a hadrosaur.

5. Discussion

The previous section demonstrates the existence of dinosaurian footprints, attributable to hadrosaurs, within the Chignik Formation of southwestern Alaska. It is more than just a novelty that these tracks occur so far removed from any previously known coeval dinosaurian locality. Rather, combined with known dinosaurian localities in northern Alaska, they indicate the widespread existence of a high-latitude terrestrial ecosystem during the Cretaceous that was capable of supporting large-bodied herbivores. Although this

Fig. 4. Oblique view of the pes track showing the disturbed bedding created by the compression of a hadrosaur (Ornithopoda) dinosaur.

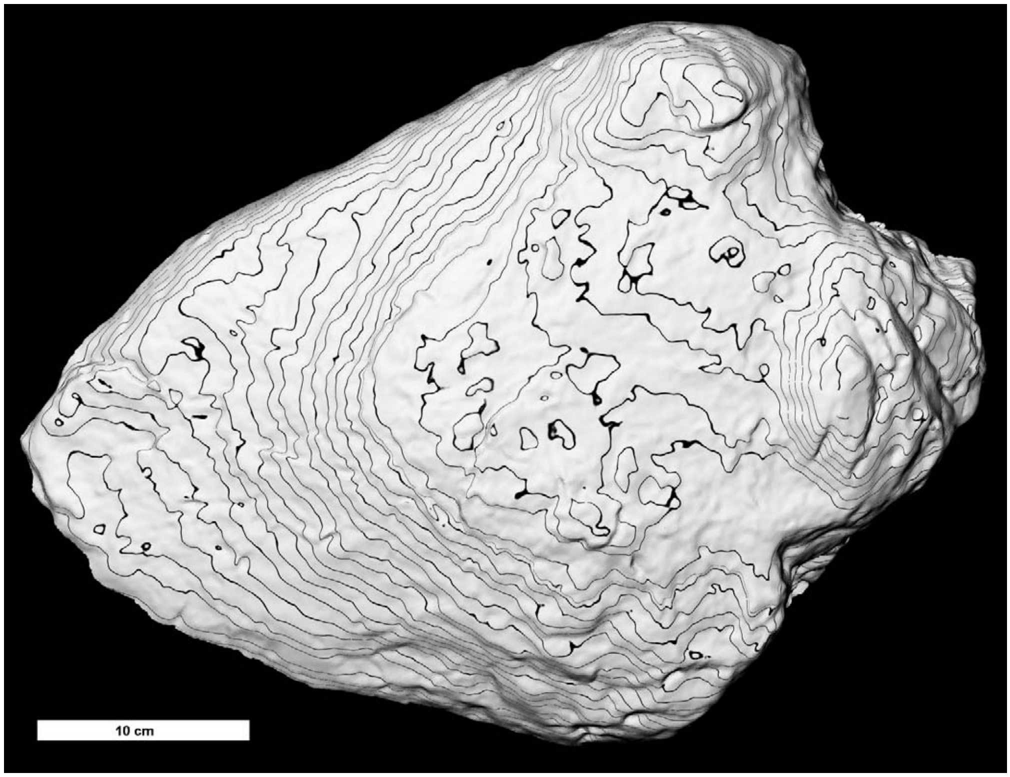

Fig. 5. View of laser-scanned image of a cast of the pes track (DMNH 12143) with contouring. Note the well-developed tridactyl impression and the heel mark. The smooth nature of the elongated heel is interpreted here to be the result of a slipping motion of the foot before stopping.

ecosystem has been inferred previously, the existence of these tracks extends its known geographic range. The nature of this ancient ecosystem begs further speculation.

Recent discussion of the significance of polar dinosaurs submitted that understanding the ancient Arctic climate and ecology of the Cretaceous was critical for interpreting such faunas (Rich et al., 2002). Current Arctic ecological studies address the relative importance of the large-scale determinants of the ecosystem that help shape the adaptive responses of the Arctic taxa (Jefferies et al., 1992; Walker et al., 1998; Karels and Boonstra, 2000; McKane et al., 2002). Therefore, understanding the roles of those same primary factors is important for interpreting the adaptive response of a Cretaceous terrestrial Arctic fauna.

The initial issue here is the question, were these tracks in the ancient Arctic? Murie (1973) asked the simple question "Where is the Arctic"? Pielou (1994) and Officer and Page (2001) discussed in more detail the various perceptions of the biological versus the physical definitions of the Arctic. Given the obvious differences between modern Arctic organisms and those of the Cretaceous Period, it is more meaningful here to focus on the physical perspective, i.e. the high-latitude component.

Paleomagnetic reconstructions place the Peninsular Terrane over a wide range that includes its present position to 3000 km south of this (Hillhouse and Coe, 1994). However, the argument that the terrane, at least the portion of concern to this study, was near its present position during the Late Cretaceous is stronger for two reasons. First, the resolution of the data for this position is higher and, second, these more precise data were collected in the vicinity of the Aniakchak National Monument rather than much farther east (Hillhouse and Coe, 1994), where the data giving southern paleomagnetic results were collected. The current latitude of the tracksite is between 56° and 57° North. Therefore, this tracksite is within the latitudinal range of the Arctic to sub-Arctic of the Cretaceous.

6. Conclusions

Late Cretaceous dinosaurs, represented by a series of footprints attributable to hadrosaurs, are now known from western Alaska. This new record is 1500 km distant from any previously known coeval locality. Previous paleomagnetic results show that this new dinosaur locality was near its current latitude in the Cretaceous. Such a distance is consistent with a widespread, ancient terrestrial ecosystem capable of supporting populations of large herbivores.

Acknowledgements

We thank Russell Kucinski and Peter Armato of the Alaska Region National Park Service (NPS) for their administrative support for this work, and Troy Hamon, Amanda Austin, and Thor Tinghey, also of the NPS, for their assistance in the field. Vincent Santucci, NPS, provided additional logistical assistance. Fiorillo also thanks Mike Polcyn for providing the support for the laser scan and contouring for Fig. 5. Funding for this work was provided by the NPS, the Jurassic Foundation, and the Dallas Museum of Natural History. American Airlines provided additional assistance in the field.

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