



Cephalopods from the Badlands National Park area, South Dakota: Reassessment of the position of the Cretaceous/Paleogene boundary

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ABSTRACT

Terry et al. (2001) proposed that the Fox Hills Formation in the area of Badlands National Park, southwestern South Dakota, USA, contains the Cretaceous/Paleogene (K/Pg) boundary, marked by a thick layer of contorted bedding called the Disturbed or Disrupted Zone (DZ). Examination of the ammonites from just below this layer yields *Hoploscaphites nicolletii* (Morton, 1842), *H. spedeni* (Landman and Waage, 1993), *Discoscaphites gulosus* (Morton, 1834), *D. conradi* (Morton, 1834), and *Sphenodiscus lobatus* (Tuomey, 1856). The abundance of *Discoscaphites* and the presence of a coarsely ornamented specimen of *H. spedeni* suggest that this assemblage corresponds to the upper part of the *H. nicolletii* Zone in the type area of the Fox Hills Formation. No ammonites are present above the DZ, but previous analyses of the dinoflagellates from just below, within, and above the DZ by Palamarczuk et al. (2004) are consistent with the ammonite results. Together, these fossils indicate that the interval just below and above the DZ represents the upper part of the lower upper Maastrichtian ($\approx$ middle upper Maastrichtian). Belemnites are present in the strata just below the DZ and occur as guards either isolated in the matrix or associated with fragmentary ammonites in concretions composed of soft sandy marl. The belemnites are assigned to *Belemnitella bulbosa* Meek and Hayden, 1857a, and *B. badlandsensis* n. sp., which is characterized by an unusually large fissure angle. The distribution of ammonites and lithofacies at this time reveals that the western shoreline of the Western Interior Seaway trended northeast–southwest across western South Dakota and adjacent parts of North Dakota. Based on an examination of the oxygen isotopes of the belemnites and scaphites in this area, the seawater temperature was nearly constant along the coast, approximately 17–20 °C. A comparison of the contact between the Pierre Shale and Fox Hills Formation at various localities in the Western Interior Basin indicates that this contact rises in the section toward the east, reflecting the final retreat of the Seaway during the late Maastrichtian.

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1. Introduction

The Upper Cretaceous Fox Hills Formation is well exposed in western South Dakota, USA (Fig. 1). It consists of marginal marine deposits that record a transition from a uniform offshore setting, represented by the Pierre Shale, to a delta plain–terrestrial setting with coal deposits, represented by the Hell Creek Formation. Terry et al. (2001, 2002) described a layer of soft sediment deformation (called the Disturbed or Disrupted Zone) in the Fox Hills Formation in the area of Badlands National Park. They interpreted this layer

as a distal seismic expression of the Chicxulub impact, corresponding to the Cretaceous/Paleogene (K/Pg) boundary. Subsequent studies have questioned this hypothesis, suggesting that the layer is actually below the K/Pg boundary (Harries et al., 2002; Palamarczuk et al., 2004; Terry et al., 2004; Jannett and Terry, 2008). Ammonites collected over the last 10 years from just below the DZ shed additional light on these issues and provide a means of correlation with the Fox Hills Formation in its type area in north-central South Dakota. As a result, it is possible to investigate the paleoenvironment and paleogeography of the western shoreline of the Western Interior Seaway at this time. The Fox Hills Formation in the Badlands National Park area also contains abundant belemnites, a relatively rare occurrence in Upper Cretaceous deposits of the U.S. Western Interior. The belemnites consist of *Belemnitella bulbosa* Meek and Hayden, 1857a, and *B. badlandsensis* n. sp.

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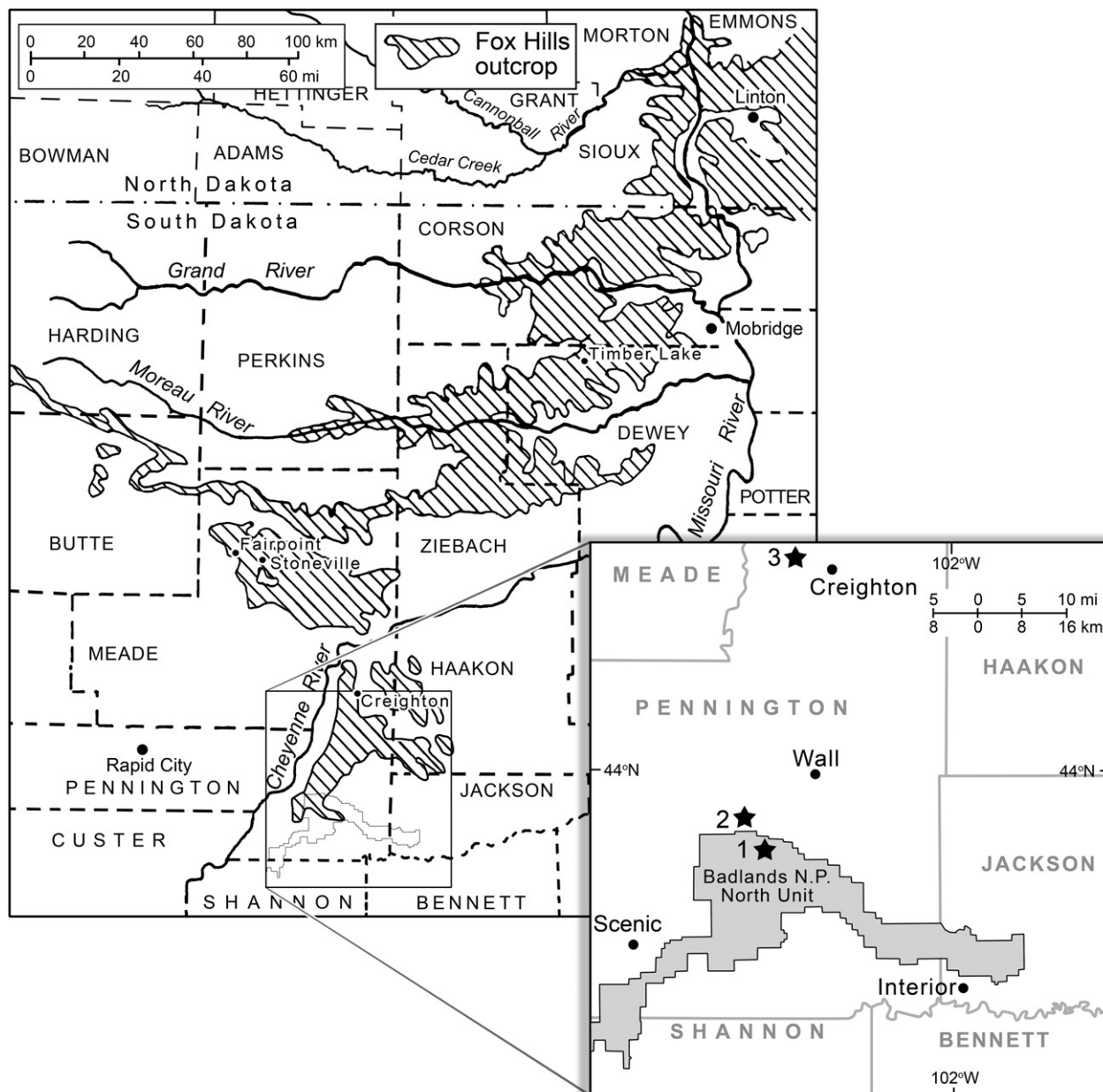


Fig. 1. Map of parts of South Dakota and North Dakota showing the outcrop band of the Fox Hills Formation and the three localities described in the text. 1 = AMNH loc. 3283, Fox Hills Formation, SE¼ sec. 3, T. 2S., R. 15 E., Wilderness Access Trail, Badlands National Park, Pennington County, South Dakota. 2 = AMNH loc. 3508, Fox Hills Formation, SE¼ sec. 24, T. 1S, R. 15 E., Buffalo Gap National Grassland, approximately 6 km north of the boundary of Badlands National Park, Pennington County, South Dakota. 3 = AMNH loc. 3286, Fox Hills Formation, NW ¼ sec. 34 T. 3N, R.15 E., near Creighton, Pennington County, South Dakota.

2. Methods

Several samples of ammonites and belemnites were analyzed for oxygen and carbon isotopes. The samples were examined under light microscopy to remove any adhering particles from the surface. They were subsequently rinsed in distilled water, sonified for five minutes, and dried. They were observed under scanning electron microscopy (SEM) to evaluate their state of preservation. Only samples of ammonites with Preservation Index ≥ 3 according to the criteria of Cochran et al. (2010) were used in the analysis. In sampling belemnite guards, we avoided cracks and the midline area where alteration is most prevalent, according to Vonhof et al. (2011).

The isotopic analyses were performed at the Keck Paleoenvironmental & Environmental Stable Isotope Laboratory at the University of Kansas (KPESIL). All samples were reacted with phosphoric acid to

release CO_2 , which was then analyzed for C and O isotopes using a Thermo Finnigan dual inlet MAT253 isotope ratio mass spectrometer (IRMS). Three standards were used – NIST (National Institute of Standards) NBS-18, NBS-19, and an internally calibrated calcite standard – which were included with each run in order to generate a three point calibration curve to the VPDB scale. A fourth standard, NIST 88b dolomitic limestone, acted as a quality control.

3. Fox Hills Formation in its type area

3.1. Lithostratigraphy

The type area of the Fox Hills Formation occupies parts of Corson, Dewey, and Ziebach counties in north-central South Dakota. It is referred to as the type area because it includes the locality

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