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Testing the terrestrial $\delta^{13}C$ Cretaceous–Paleogene (K–Pg) chemostratigraphic marker

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ABSTRACT

Multiple >1‰ $\delta^{13}C$ isotopic excursions measured across the Cretaceous–Paleogene (K–Pg) boundary in an iridium-bearing stratigraphic section from Mud Buttes, North Dakota, USA, fail to demonstrate an unambiguous chemostratigraphic signal for the extinction. Results of two-sample Kolmogorov–Smirnov tests using $\delta^{13}C$ records for the Mud Buttes section as well as five other published K–Pg sections from Montana, North Dakota, Wyoming, and Canada – all of which report a −1.0‰ to −2.8‰ chemostratigraphic marker at or just above the extinction – demonstrate that it may not be possible to distinguish a statistically meaningful isotopic shift to lower $\delta^{13}C$ values at the boundary in the context of background variations. Carbon isotopes as terrestrial chemostratigraphic markers of the K–Pg extinction boundary are thus of limited utility.

1. Introduction

A −1‰ to −3‰ shift in the carbon isotope composition of surface ocean dissolved carbonate, and a loss of the ocean's biologically mediated $^{13}C/^{12}C$ gradient from surface waters to deep waters at the K–Pg boundary have been well-documented in marine sections around the globe (Thierstein and Berger, 1978; Arthur, 1979; Boersma et al., 1979; Boersma and Shackleton, 1981; Thierstein, 1981; Hsü et al., 1982a, 1982b; Perch-Nielson et al., 1982; Smit, 1982; Hsü and McKenzie, 1985; Zachos and Arthur, 1986; Keller and Lindinger, 1989; Stott and Kennett, 1989; Zachos et al., 1989; Stott and Kennett, 1990; Robin et al., 1991; Zachos et al., 1992; Keller et al., 1995; D'Hondt et al., 1998; Sial et al., 2001; D'Hondt, 2005; Hart et al., 2005). The existence of a robust marine K–Pg isotopic excursion suggested to several workers that a terrestrial $\delta^{13}C$ isotopic excursion might also exist, and indeed $\delta^{13}C$ shifts ranging from −1.0‰ to −2.8‰ have been reported at the terrestrial K–Pg boundary (Schimmelmann and DeNiro, 1984; Arens and Jahren, 2000; Beerling et al., 2001; Arens and Jahren, 2002; Gardner and Gilmour, 2002; Maruoka et al., 2007; Therrien et al., 2007).

In addition to the negative $\delta^{13}C$ shift associated with the K–Pg boundary, other excursions of various magnitudes have also been observed in terrestrial sections (Arens and Jahren, 2000, 2002; Maruoka et al., 2007; Therrien et al., 2007). Arens and Jahren (2002) used these additional shifts in the carbon record, along with supplementary data including biostratigraphy, to attempt to correlate several sections and identify potential unconformities.

The presence of K–Pg boundary or near-boundary negative excursions against a background of other large (>1‰) shifts in $\delta^{13}C$ both above and below the boundary (e.g., Arens and Jahren, 2000, 2002; Therrien et al., 2007), as well as the acknowledgment by these authors that the K–Pg $\delta^{13}C$ excursion cannot be distinguished without biostratigraphic data and/or an iridium anomaly to confirm the location of the extinction boundary (e.g. Therrien et al., 2007), suggested to us the possibility that the K–Pg $\delta^{13}C$ excursion might not be as definitive in the terrestrial realm as it is in the marine realm. Accordingly, then, we present here a new carbon isotopic study across the K–Pg boundary, testing whether a distinct, statistically meaningful negative carbon isotope shift can be identified at the terrestrial K–Pg boundary in our results, as well as in some of those previously published (Arens and Jahren, 2000, 2002; Maruoka et al., 2007; Therrien et al., 2007).

We carried out an organic carbon isotopic profile of the K–Pg boundary-bearing stratigraphic section in Mud Buttes North Dakota (Fig. 1). This locality is one of the most complete and best-studied K–Pg boundary localities in the Williston basin and contains a full suite of K–Pg indicators, including an iridium anomaly, boundary clay, and fern spore spike (Nichols and Johnson, 2002); moreover, it has been investigated magnetostratigraphically (Hicks et al., 2002), and biostratigraphically, via vertebrates (Sheehan et al., 1991, 2000;

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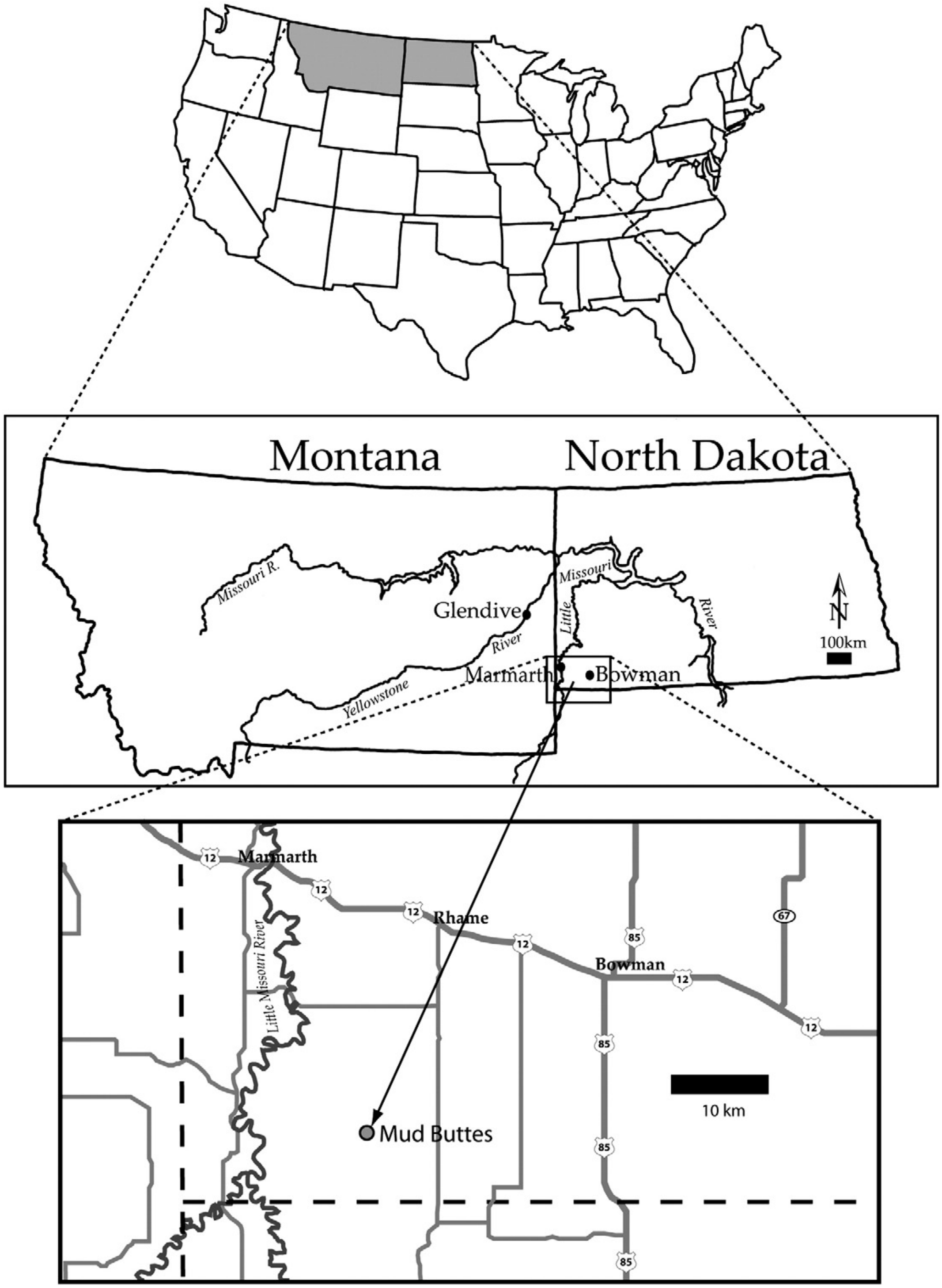

Fig. 1. The Mud Buttes locality, western North Dakota, USA.

Pearson et al., 2001, 2002), a palynoflora (Nichols, 2002; Nichols and Johnson, 2002; Nichols, 2007), and a megaflora (Johnson, 2002).

2. Locality and horizon

The exposures in Mud Buttes, located south of the town of Marmarth in Bowman County, North Dakota (Fig. 1), are composed of the Hell Creek and Fort Union Formations (Frye, 1969; Moore, 1976; Fastovsky, 1987; Johnson, 1992; Murphy et al., 2002; Grandpre, unpublished thesis). The Cretaceous Hell Creek consists mainly of gray to green interbedded paleosol-bearing mudstones and siltstones that are interpreted as forested gleyed floodplain paleosols, and sandstones, which are inferred to be channel thalweg deposits (Fastovsky, 1987; Fastovsky and McSweeney, 1987; Fastovsky, 1990; Murphy et al., 2002). In Mud Buttes, the Hell Creek consists mainly of rooted mudstones interpreted as poorly-drained floodplain environments (Fig. 2a, b). The conformably overlying Fort Union Formation consists of laterally extensive iron-stained laminated variegated siltstones, lignites,