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Crayfish burrows from the latest Cretaceous lower Cantwell Formation (Denali National Park, Alaska): Their morphology and paleoclimatic significance

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ABSTRACT

Latest Cretaceous strata of the lower Cantwell Formation, Denali National Park, central Alaska Range, contain an abundance of megafloral remains and invertebrate and vertebrate trace fossils. Though dominated by herbivorous dinosaur footprints, the abundance and diversity of fossil bird tracks are unique. We present newly discovered crayfish burrows from several areas along a 50 km transect with Denali National Park. Most crayfish burrows from the lower Cantwell Formation are preserved only in cross-section and range from approximately 5–10 cm in diameter. Where preserved in full relief and terminations present, burrow depth is generally < 50 cm. Burrow morphology is similar to burrow morphology of modern freshwater crayfish (Cambaridae).

The Cantwell Formation fills the Cantwell Basin, a 135 km-long and up to 35 km-wide, east–west trending basin, bracketed by the Hines Creek Fault to the north and the McKinley Fault to the south. Basin fill comprises up to 4000 m of continental deposits, interpreted as braided rivers, alluvial fans, floodplains, swamps, and ponds.

Crayfish burrows provide evidence of water table level, soil moisture fluctuations, as well as insight into mean annual temperatures at the time of deposition of the lower Cantwell Formation, a Late Cretaceous high-latitude paleoecosystem. Despite a relatively high latitudinal setting (~71°N paleolatitude), the Late Cretaceous (i.e., Campanian–Maastrichtian) mean annual temperature, based on the distribution of similar present-day crayfish burrows, was more like that of southernmost Ontario, Canada, where the northernmost burrowing crayfish are found today. The burrow depth suggests (1) no permafrost was present, and (2) the phreatic zone was ~30–50 cm below the paleo-ground surface. Based on the presence of these crayfish burrows, the paleoclimate is interpreted as humid continental (Köppen scheme), with average summer high temperatures between 25 °C and 28 °C and average winter low temperatures between −6 °C and 0 °C. These estimates compare somewhat favorably with previous CLAMP estimates of a warm monthly mean temperature of 17.08 +/− 1.6 °C and a cold monthly mean temperature of −2.31 +/− 1.9 °C.

1. Introduction

In general, climate is defined by the average pattern in temperature, precipitation, wind, humidity, solar insolation, and other meteorological factors that, over short time scales, are referred to as weather (e.g., Lydolph, 1985). Modern climate is directly measurable and is often discussed at decadal or millennial time scales (e.g., Ruddiman, 2007). And while modern climate captures the attention of the public, the geologic record serves as an archive for understanding climates and environments of the deep past (e.g., Parrish, 1998). Given that those ancient climates and environments are not directly measurable, for the geologic record, scientists use physical, biological, and chemical evidence as proxies for indicators of past climatic conditions. Examples of proxies can be abiotic data obtained from glaciers, stable isotopes, paleosols, and lacustrine sediments; or biotic data from tree rings, corals, or other body or trace fossils. The time scales for past climates are measured in terms of hundreds, but more often millions of years (Sellwood and Price, 1994; Parrish, 1998). In comparing the study of modern climates with climates of the deep geologic past, the time scales clearly vary by orders of magnitude and these differences can be problematic when attempting direct comparisons. However, it remains true that providing a more robust understanding of past climates serves as a means to test and refine climate models for the future at time when human society is increasingly concerned with the consequences of a warming world (e.g., Ruddiman, 2007).

In this paper, we discuss new fossil invertebrate ichnological data from the Upper Cretaceous lower Cantwell Formation of Denali National

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Park (Fig. 1) that serves as a paleoclimate proxy. Denali National Park is located within the Alaska Range and has a current latitude of approximately 63°N. These new data, in the form of numerous fossil crayfish burrows discovered along a 50 km transect, corroborate paleobotanical data that have shown that during deposition within this high-latitude basin, the climatic conditions were significantly warmer than the modern climatic setting at this latitude.

Over the last decade or so, the United States National Park Service has supported a series of paleontological surveys within a number of National Park units throughout the state of Alaska. As a result of these surveys, the central Alaska Range, and specifically Denali National Park, is now recognized to record a remarkable Late Cretaceous Arctic terrestrial ecosystem (Fiorillo et al., 2009a, 2011, 2014a,b,c; Tomsich et al., 2010, 2014; Fiorillo and Adams, 2012).

While many of these reports of fossil taxa are, in fact, their northernmost known occurrences, the integration of detailed sedimentology and palaeobotany with the vertebrate palaeontological record, has provided an exciting picture of a biologically productive ancient high-latitude continental ecosystem in the far northern end of Laramidia during the Late Cretaceous. Further, coupled with the Late Cretaceous fossil vertebrate remains found throughout Alaska, this was a widespread and rich terrestrial polar ecosystem (Brouwers et al., 1987; Parrish et al., 1987; Clemens and Nelms, 1993; Gangloff, 1995, 1998; Fiorillo and Gangloff, 2000, 2001; Fiorillo and Parrish, 2004; Gangloff et al., 2005; Fiorillo et al., 2009a,b, 2011, 2014a,b,c; Gangloff and Fiorillo, 2010; Fiorillo and Adams, 2012; Fiorillo and Tykoski, 2012, 2014).

By far, the most well-studied aspect of this ecosystem is the fossil vertebrate record. Within the lower Cantwell Formation, emphasis has been on the vertebrate ichnological record, and more specifically, the dinosaur track record (Fiorillo et al., 2009a, 2011, 2014a,b; Fiorillo and Adams, 2012) with some additional focus on the paleobotanical record (Tomsich et al., 2010, 2014). The invertebrate record is as diverse and impressive a track record but has only received limited recognition in the literature (Fiorillo et al., 2009a). While fossil vertebrate tracks can provide information regarding questions related to biodiversity, behavior, and past ecosystems, vertebrates can cross over many environments with different physical or chemical characteristics (Hasiotis and Platt, 2012). Consequently fossil vertebrate tracks have limited use in providing insights into ancient climates. In contrast, invertebrates are more intimately tied to specific environmental settings, which then make fossil

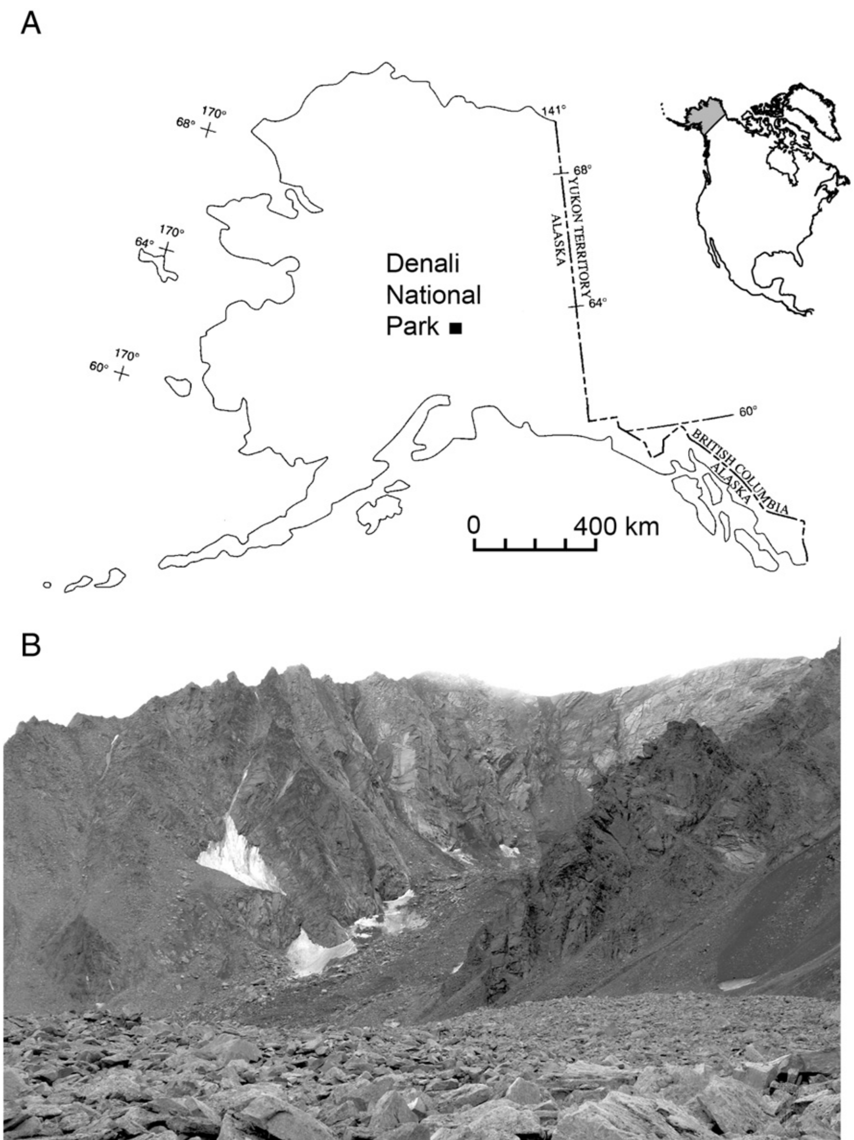

Fig. 1. A. Location of Denali National Park, Alaska, U.S.A. B. Representative outcrop image of lower Cantwell Formation showing alternating bedding of finer and coarser sedimentary units. This photograph was taken in the upper Riley Creek drainage.