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# Paleoecology and sedimentology of a vertebrate microfossil assemblage from the easternmost Dinosaur Park Formation (Late Cretaceous, Upper Campanian,) Saskatchewan, Canada: Reconstructing diversity in a coastal ecosystem

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## ABSTRACT

A ~42 m section of Late Cretaceous Upper Campanian sediments in Saskatchewan Landing Provincial Park, southwestern Saskatchewan, Canada, represents the easternmost outcrop of the Dinosaur Park Formation in the Western Interior Basin. Herein we document a new microvertebrate locality from the upper part of this formation that shows high diversity in a mixed coastal and marine assemblage. Palynology, ichnology, sedimentology, and vertebrate palaeontology are integrated to determine paleoenvironmental and paleoecological conditions in the region. The site is interpreted as having been deposited under marginal-marine conditions near a shoreline undergoing transgression by the encroaching Bearpaw Sea. Though well studied and sampled in Alberta, the Dinosaur Park Formation is poorly exposed with little known associated vertebrate assemblages in Saskatchewan. These discoveries from the new microvertebrate site offer new insights into Late Cretaceous ecosystems near paleocoastlines, allowing for future studies of spatial diversity patterns relative to Albertan faunas. Herein is also presented the first published occurrences of several Late Campanian vertebrate taxa in Saskatchewan.

## 1. Introduction

Changes in faunal composition and depositional environments in the alluvial and coastal plains flanking the Western Interior Seaway of North America have been widely documented in Late Cretaceous Campanian (76.9–75.8 Ma) deposits from southern Alberta (Dodson, 1971; Wood et al., 1988; Eberth, 1990, Brinkman, 1990; Brinkman et al., 1998, 2004, 2005a, b; Brown et al., 2013). Fossil-bearing Campanian deposits are also present in Saskatchewan (the province to the east of Alberta), holding a similar potential for the study of paleoecosystems at the time. However, the deposits have been far less well studied than in Alberta, and it is not known if and how the paleofaunas of the two provinces vary. It is reasonable to suggest that fauanas from the two might vary, given that the ecosystems in Saskatchewan, being closer to the paleoshoreline of the Western Interior Sea, would have experienced a greater marine influence for a greater period of time. Herein, we describe a fossil locality from Saskatchewan, presenting one of the first descriptions of the Campanian-aged terrestrial paleobiodiversity from the province.

Vertebrate microfossils ('microvertebrates') have played an important role in understanding paleoecology and community succession through the stratigraphic record (Shotwell, 1955; Estes and Berberian, 1970; Dodson, 1973; Sankey, 2008). Vertebrate microfossil assemblages (referred to here as 'microsites') are concentrations of fossilised vertebrate remains, including small bones, scales and teeth of multiple taxa, of which more than 75% are 5 cm in size or smaller (Rogers and Kidwell, 2007). These accumulations may be considered both thanatocoenoses (accumulations of in situ fossils in a single locality) and biocoenoses (biological communities at a single locality), providing a 'snapshot' of biodiversity over the period that the microsite was formed. These fossil deposits afford higher resolution information about paleocommunity structure than is available from any other geological or macro-paleontological source.

Campanian-aged (72.1–83.6 Ma) deposits of the Belly River Group (BRG) in southern and central Alberta include (from oldest to youngest), the Foremost, Oldman, and Dinosaur Park formations. In Montana, the BRG is equivalent to the Judith River Formation and upper portion of the Two Medicine Formation (Rogers, 1998). All

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group-equivalents yield rich microsite assemblages (Eberth, 2015; Rogers and Brady, 2010). While the BRG in Alberta is well exposed and represented in core, BRG outcrops and associated microsites in Saskatchewan are generally sparse and poorly known. This lack of knowledge is problematic because Saskatchewan contains the eastern- and northeasternmost occurrences of this group in Canada (Eberth et al., 1990).

During the Campanian, Saskatchewan was situated at a slightly higher latitude than today, near the paleocoastline of the Western Interior Seaway. Based on climate-leaf analysis, the paleoclimate is suggested to have been warm temperate to subtropical, with a mean annual temperature of around 12.0 °C ( ± 2.1) and a growing season precipitation of 1586 mm ( ± 280) (Golovneva, 2000). In modern environments, salinity has been shown to be a primary factor in controlling the distribution and abundance of organisms (Remane and Schlieper, 1972; Basan and Frey, 1977; Dunson and Mazzotti, 1989; Dunson and Travis, 1991; MacEachern and Gingras, 2006; Buatois and Mángano, 2011; Torres-Dowdall et al., 2013). Therefore, the easternmost deposits in Saskatchewan offer an opportunity to increase understanding of faunal turnover across the coastal and alluvial plains in response to marine transgression. Because they were nearer paleocoastline, paleocommunities in Saskatchewan should have been more influenced by temporal fluctuations in sea level than those in more inland locations in southern Alberta (Eberth et al., 1990).

In this paper, we describe the sediments and vertebrate palaeontology of a fossil-rich locality at Saskatchewan Landing Provincial Park in southwestern Saskatchewan, Canada (Fig. 1), and interpret the depositional environment and associated microvertebrate assemblage. Interpretation of the depositional environments has been aided by ichnological analysis. The fossil taxa in this site constitute the easternmost occurrence of a late Campanian terrestrial microvertebrate locality in the Western Interior Seaway. The fossil locality on Lake Diefenbaker ('Lake Diefenbaker site': LD) provides a rare opportunity to study the fauna in an ancient marginal-marine environment that responded to a sea-level rise.

## 2. Materials and methods

### 2.1. Geological setting

Deposition of Cretaceous and Paleogene sediments in the Western Canada Sedimentary Basin (Fig. 2) occurred in two depocenters separated by the Bow Island Arch: the Williston Basin to the east, and the Foreland Basin to the west (Dawson et al., 1994). During the Laramide orogeny (~70 to 80 Ma), collisional accretion of microcontinents onto the west coast of North America caused thrust-sheet loading, resulting in formation of an orogenic belt (Price, 1994). This flexed the craton to produce a deeply subsiding asymmetric foredeep fed by sediments from the tectonically induced slope (Catuneanu et al., 2000). In west-central North America, this resulted in deposition of large amounts of marine and nonmarine clastic sediments in transgressive-regressive, tectonically controlled wedge-cycles (Leckie and Smith, 1992). The Belly River Group is the fourth of five recognised cycles of foreland basin deposition (Embry, 1990; Leckie and Smith, 1992; Miall, 1991).

Deposition of the Campanian Belly River Group resulted from large sediment supply to the basin, producing an eastward-thinning paralic (interfingering marine and coastal) to non-marine clastic succession (Cant and Stockmal, 1989). Three formations from this period are recognised formally in the western Canadian Plains. In ascending order, these are the Foremost, Oldman and Dinosaur Park formations (Eberth and Hamblin, 1993). Each formation is bound by a disconformity, and has distinctive sedimentological and petrographic signatures that reflect tectonic controls of sediment supply (Fig. 3) (Eberth, 2005).

The Foremost Formation interfingers with the underlying marine Lea Park Formation, which is equivalent to the marine Pakowki and Claggett formations of Alberta and Montana, respectively, and records a period of regression. Maximum retreat of the Western Interior Seaway across Saskatchewan and Alberta is represented by the Oldman Formation. The transgressive sediments of the overlying Dinosaur Park Formation interfinger with sediments of the overlying, marine Bearpaw Formation (Eberth and Hamblin, 1993). Upper Belly River and Bearpaw exposures crop out along the South Saskatchewan River valley in Alberta and Saskatchewan, with Dinosaur Park and Bearpaw formations exposed along the western bank of Saskatchewan Landing Provincial Park. In earlier interpretations, McLean (1971) assigned the lowest terrestrial beds to the Judith River Formation, and Caldwell (1968) assigned the overlying marine sediments to the Bearpaw Formation.

Cretaceous deposits in the South Saskatchewan River valley lie at the centre of the Moose Jaw syncline (MJS), whose axis generally coincides with the Missouri Coteau, a narrow band of prairie uplands that runs through southern Saskatchewan to South Dakota (Caldwell, 1968). The MJS is a northwest-trending extension of the Williston Basin of northeastern Montana and North Dakota that flanks the Bowdoin Dome to the east (McCrossan and Glaister, 1964). The MJS is believed to have been caused by dissolution of Middle Devonian Prairie Evaporite salts, which resulted in collapse of overlying strata (McLean, 1971). Slumping and rotational-slump faulting has further complicated stratigraphy in the valley (Caldwell, 1968; McConnell, 1886). At the LD, all Cretaceous strata are laterally discontinuous making stratigraphic mapping difficult. Furthermore, construction of the Gardner Dam in 1971 led to flooding of most BRG crops out along the South Saskatchewan River valley.

The LD crops out on the north side of the river in Saskatchewan Landing Provincial Park. The Cretaceous strata dip gently at 8° to the north-northeast and strike west. Deformation of the bedrock at the site is attributed to salt-induced collapse (causing the MJS) during the Late Cretaceous to Holocene, and rotational slump faulting due to migration of the South Saskatchewan River.

### 2.2. History of fossil collection

Fossil material was originally surface collected from the Lake Diefenbaker Site in 1975 by N. Yurchyshyn. The material, which included champsosaurs, dinosaurs, turtles, crocodiles, fish, chondrichthyans, and a rare fossil of the toothed bird *Baptoris*, was assigned to the Royal Saskatchewan Museum (RSM) collection under catalogue number RSM P2306. The site was not revisited until 1990, when T. Tokaryk (RSM), D. Taylor and N. Yurchyshyn returned. Their surface-picked collection (catalogued under RSM P2199) included taxa similar to those collected in 1975, but added plesiosaur material. In 1992, the collection T. Tokaryk, J. Storer (RSM) and G. Schutte undertook (catalogued under RSM P2471), added shark and salamander taxa and elasmosaurs to the collections. Another surface collection (catalogued under RSM P2945) by W. Long (RSM) and M. Caldwell (University of Alberta) took place in 2002.

In 2012, H. Larsson (McGill University-Redpath Museum) and students visited the site. They, with two of the authors (MG, EB), excavated the microsite between 2012 and 2015. That collection (P3217 at RSM) added new taxa. One thousand one-hundred and eighty-five vertebrate fossils have been collected from the LD, and the collection is still ongoing.

### 2.3. Data collection and specimen identification

Detailed sedimentological and stratigraphic information was recorded during summers of 2012 and 2013 after outcrop surfaces were cleaned. Sediment logs included Brunton© compass and Jacob's Staff measurements. Standard sedimentological information (grain size, clast shape, sedimentary structures, paleocurrent indicators, bed geometry, bed contacts, body fossils, trace fossils) was recorded. Sediment colour was assigned using the Munsell colour chart (Munsell, 2000).

Palynology samples were collected when stratigraphic