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Sedimentological and ichnological analysis of fluvial, fluvial-tidal and estuarine channels, Dinosaur Park Formation, Alberta

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Summary

We used ichnology and detailed sedimentology of measured stratigraphic sections and core to interpret the environmental conditions (e.g., salinity) and sedimentological processes within meandering channel systems of the Campanian Dinosaur Park Formation, Alberta. Although the Dinosaur Park channels contain abundant inclined heterolithic stratification in point bar deposits, tides and brackish water appear to have only periodically affected deposition of the sediments and the trace fossil assemblages throughout the majority of the succession. Trace fossils are either absent, form low diversity assemblages in deposits from freshwater channels, or form moderate diversity assemblages in deposits from brackish water channels. Stratigraphic packages 5 to 20 m in thickness fine upwards from cross-stratified sandstones and commonly contain muddy heterolithic deposits with trace fossils in the upper portions of the packages, even within the lower part of the Dinosaur Park Formation. Point counts of sand-sized framework grains showed variability in the proportion of quartz vs. lithics and feldspars, which may be attributed to variability in the degree of sediment reworking or changing provenance from upstream to mixed upstream/downstream. These patterns are evident on the scale of 4th to 5th order allomembers/parasequences and also on the 3rd order scale of the Dinosaur Park to Bearpaw transgression. The uppermost portion of the Dinosaur Park Formation in the Dinosaur Provincial Park area preserves sedimentological and ichnological evidence of wave-influenced shorelines at the mouths of broad estuarine channels formed during transgression of the coastal plain. The trace fossil assemblage, which lacks *Cylindrichnus* and diminutive *Gyrolithes* characteristic of other IHS-dominated fluvial-tidal and estuarine channels (e.g., McMurray Formation), is dominated by *Planolites* and *Palaeophycus,* but also contains *Teichichnus*, *Arenicolites*, *Thalassinoides* and *Asterosoma* in some facies. We interpret the sedimentology and ichnology to represent the fluvial to fluvial-tidal and estuarine transition of a wave-influenced shoreline on an unconfined coastal plain. We suggest that the evidence from the Dinosaur Park Formation contrasts with tide-influenced estuarine channels in confined valleys by showing less ichnological evidence of brackish water in the channels and fewer clayey deposits in the inclined heterolithic stratification of point bars.

Introduction

Meandering fluvial systems and their deposits contain abundant inclined heterolithic stratification representing point bars, and are common in low-lying areas adjacent to marine shorelines (e.g., Thomas et al., 1987). Muddy inclined heterolithic beds are common in tidally influenced channels in areas with brackish water as evidenced by trace fossils (e.g., McMurray Formation) (e.g., Wightman and Pemberton, 1997; Musial et al., 2012). In the Dinosaur Park Formation, however, most of the evidence suggests that the channels were not tidally influenced and contained freshwater in channels in the alluvial plain well landward of the shoreline (e.g., Eberth, 2005).

Large-scale reconstructions of fluvial systems and their associated deposits are needed to accurately map and predict the geometry of sandstone and mudstone sediment bodies in the subsurface, and to predict the probable distribution, dip, and geometry of heterolithic beds that affect the movement of fluids through the

sediments. Detailed studies that include ichnology help to determine the connectivity and distance between marine environments and sandstones of the channel systems of estuarine, fluvial-tidal, and upstream fluvial areas, and they help to predict the type, size, and distribution of adjacent mud deposits by contributing to the overall environmental interpretation. This study investigates the ichnology, sedimentology, and stratigraphy of the fluvial to estuarine transition in the unconfined coastal plain setting of the Campanian Dinosaur Park Formation, for the purpose of developing an ichnological and sedimentological model that can be compared to other IHS-dominated channel systems. The results and interpretations contribute to more detailed predictions of facies distributions in different types of estuarine systems (e.g., confined vs. unconfined; wave-dominated vs. tide dominated) deposited during transgression of channels.

Methods

An integrated approach to the analysis of the Dinosaur Park Formation of the upper Belly River Group and the lower Bearpaw Formation in the Dinosaur Provincial Park and area included facies analysis, detailed sedimentology (e.g., petrography, grain-size analysis with Sedigraph), ichnology, and stratigraphy. Point counts included quartz (monocrystalline), quartz (polycrystalline), feldspar, opaque lithics, chert, and intraformational clasts (e.g., pellets). Sedigraph analyses measured grain-size distribution of the < 63 micron fraction of sediment samples. Sediments were disaggregated using an ultrasonic bath.

Four stratigraphic sections were measured at the decimetre scale in Dinosaur Provincial Park through the entire exposed succession (up to ~80 m thickness) of the formation. Sediment and trace fossil samples were collected during measuring, and the position within the stratigraphy noted at the decimetre scale. One long core obtained from southwest of the Park was measured at the decimetre scale (ARC 1-83, “Princess” core; NE 35-T19-R12 W4 or 1-2-T20-R12-W4). The studied thin sections were made from the ARC 1-83 “Princess” core and from samples collected in the field.

Findings

Although inclined heterolithic stratification (IHS) is prevalent as point-bar deposits of the channels of the Dinosaur Park Formation, the channels are interpreted to be dominantly freshwater with only periodic brackish incursions. Rhythmic bedding without thick clay laminae provides evidence of minor tidal influence in the fluvial-tidal zone landward of saline water in the channels. Trace fossil assemblages are dominantly low diversity in silty IHS deposits, but muddy IHS–dominated facies interpreted to represent both point bars and counter point bars contain moderate diversity trace fossil assemblages (e.g., *Teichichnus*, *Planolites*, *Arenicolites*) that suggest these facies were deposited in association with brackish water. Although roots are present in point-bar tops and muddy overbank deposits adjacent to the channels, the DPF lacks meniscate backfilled burrows that indicate drainage of the sediments above the water table. These deposits were emplaced during a transgression, and the coastal plain system had high water tables not conducive to bioturbation by terrestrial invertebrates.

Stratigraphic packaging of the Dinosaur Park Formation below the Lethbridge Coal Zone suggests that stacking of several fining-upwards packages, from trough cross-stratified sandstones through silty and muddy IHS and mud-filled channels, represent retrogradational allomembers (or parasequences) deposited during the overall transgression to the overlying marine Bearpaw Formation. The trace fossil assemblages are closely related to the sedimentary facies throughout the succession below the Lethbridge Coal Zone, and support the interpretation that muddier IHS deposits are related to flooding of the coastal plain. In the Dinosaur Park area of southeastern Alberta, even the flooding events appear to be represented by fresh to low-salinity brackish water in the channels. Nevertheless, there is an overall decrease in grain-size in the fine-grained IHS beds and an increasing abundance of simple trace fossils (e.g., *Planolites*) moving upwards through the DPF. Point-counts and petrography of the channel sandstones also indicate slight variability in the proportion of quartz to lithics and feldspars, as well as the bentonitic clay content versus calcite cement. Some of the channel sandstones also contain glauconite,

which may indicate either a provenance of reworked marine Cretaceous sediments exposed in the west near the thrust belt. Alternatively, the provenance of framework grains varied as the channel systems changed within the allomembers/parasequences from fluvial-dominated with an upstream sediment source to fluvial-tidal with a mixed upstream and downstream sediment source.

Above the Lethbridge Coal Zone, point-bar deposits comprise clayey heterolithics that contain trace fossils such as *Palaeophycus* and *Asterosoma*, which are typically associated with brackish to fully marine salinities (e.g., MacEachern and Gingras, 2007). Muddy estuarine channels at the top of the Dinosaur Park Formation above the Lethbridge Coal Zone also preserve large *Skolithos* and *Thalassinoides* along the lowermost contacts with the underlying IHS, which may represent a ravinement surface. Small, uncommon *Phycosiphon* burrows are preserved in the muddy channel fill. Sandstones interpreted as wave-dominated barrier bars at the mouth of the estuarine system contain glauconitic pellets and trace fossils such as *Rosselia and Asterosoma*.

Conclusions

The results of this study indicate that the Dinosaur Park to Bearpaw transition, which represents a marine transgression, is an ideal example of the fluvial and fluvial-tidal to estuarine transition on a broad, unconfined coastal plain with limited tidal influence in the channels in the Dinosaur Provincial Park area. Freshwater to slightly brackish salinities appear to have dominated the water in the channels throughout the majority of the Dinosaur Park Formation. The trough cross-stratified sandstones and abundant inclined heterolithic stratification are typical of meandering channel deposits found in other fluvial to estuarine channel systems. However, the trace fossil assemblages notably lack ichnotaxa such as *Gyrolithes* and *Cylindrichnus*, which are important indicators of brackish water in the meandering channel systems of other IHS-dominated fluvial to estuarine transitions of Alberta (e.g., McMurray Formation). Based on our integrated analyses, we suggest that these findings could be related to the unconfined nature of the Dinosaur Park system and wave-dominance at the transgressing shoreline in the Dinosaur Park area, in contrast to systems with tide-dominance in relatively confined valleys such as the McMurray system.

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