Depositional setting and taphonomy of a skin-bearing hadrosaur specimen, Dinosaur Park Formation, Alberta

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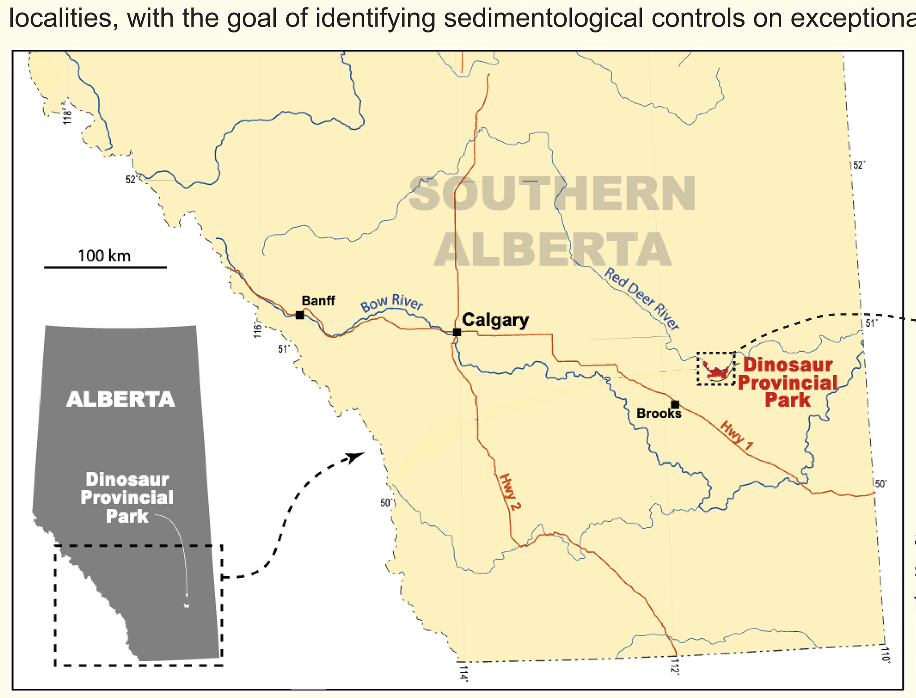
Introduction

Fossils are preserved primarily within sedimentary successions, where burial and early diagenetic processes allow biological remains to persist in the geologic record (Holland 2016). Preservation quality is not random, but instead reflects the interaction of physical, chemical, and biological processes that vary systematically among depositional environments (Holland 2016). As a result, different depositional systems impose preservation biases that influence both fossil abundance and the types of tissues retained in the fossil record.

Soft-tissue preservation, including fossil skin, is exceptionally rare compared to skeletal remains and requires rapid burial coupled with early chemical stabilization. Preservation rates are spatially and temporally variable, as demonstrated by non-homogeneous Poisson process models, underscoring the importance of depositional context in controlling fossil occurrence (Holland 2016). Studies of hadrosaur skin further suggest that preservation is influenced by the internal architecture of dermal tissues rather than skin thickness alone, highlighting the role of biological structure interacting with sedimentary and diagenetic conditions (Fabbri et al. 2020).

Depositional environments therefore act as preservational filters by governing sedimentation rate, oxygen exposure, substrate composition, and pore-fluid chemistry. Although fluvial systems are dynamic and commonly associated with erosion and reworking, they preserve both terrestrial and aquatic organisms and exhibit pronounced internal variability in preservation potential. However, the specific sedimentary processes and architectural elements within fluvial systems that favor soft-tissue preservation remain poorly constrained. Within fluvial systems, channel belts and point bars record repeated depositional events and preserve sedimentary structures that influence burial dynamics, permeability, and post-depositional fluid flow.

Dinosaur Provincial Park (Fig. 1) exposes Upper Cretaceous fluvial deposits of the Dinosaur Park Formation with exceptional fossil abundance and three-dimensional exposure, providing an ideal setting to evaluate how fluvial depositional processes influence fossil skin preservation (Lowi-Merri and Evans 2020). This study uses lithofacies analysis, stratigraphic relationships, and channel-belt architecture to examine the depositional context of a skin-preserved juvenile hadrosaur and associated fossil localities, with the goal of identifying sedimentological controls on exceptional preservation within a meandering fluvial system.



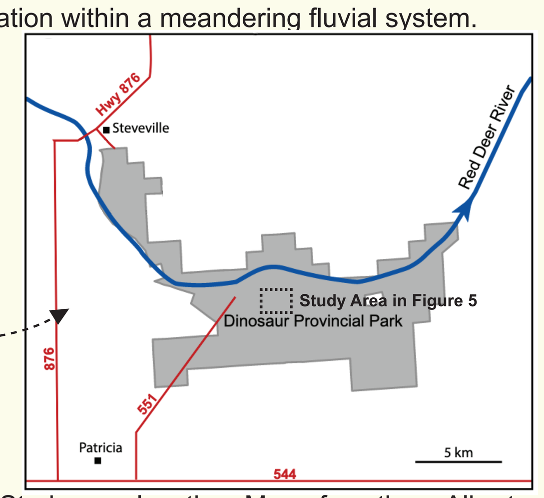


Figure 1. Study area location. Map of southern Alberta and the location of Dinosaur Provincial Park. Local study area map of Dinosaur Provincial Park and the field site located just south-east of the Dinosaur Provincial Park Visitor Centre, Alberta and east of Evac C (modified from Durkin et al. 2020).

Geological Setting

The study area is located within Dinosaur Provincial Park (DPP), southern Alberta, and lies within the Western Canada Sedimentary Basin. The exposed stratigraphy belongs to the Belly River Group, an eastward-thinning continental clastic wedge up to approximately 280 m thick in the study area (Dawson et al. 1994; Eberth 2005). Deposition occurred during the Late Cretaceous, coincident with peak stages of the Laramide Orogeny and subsequent tectonic relaxation, which influenced sediment supply and basin subsidence patterns (Dawson et al. 1994).

Stratigraphically, the Belly River Group comprises, from oldest to youngest, the Foremost Formation, Oldman Formation, Dinosaur Park Formation (DPF), and Bearpaw Formation (Fig. 2; Dawson et al. 1994). The Foremost Formation represents coastal to shallow marine deposition, overlain by the fluvial Oldman Formation. The DPF disconformably overlies the Oldman Formation and is gradationally overlain by marine shales of the Bearpaw Formation, reflecting the onset of a regional marine transgression associated with the Western Interior Seaway (Dawson et al. 1994; Eberth 2005).

The Dinosaur Park Formation consists of fluvial channel-belt and floodplain deposits, with the lower portion dominated by sandy alluvial paleochannel facies and the upper portion characterized by mostly overbank deposits capped by the Lethbridge Coal Zone (Fig. 2; Eberth 2005). These deposits were laid down during the initial stages of the final major transgression of the Western Interior Seaway and include alluvial, estuarine, and paralic facies (Eberth and Hamblin 1993; Eberth 2005). Outcrops are characterized by laterally extensive, meter- to decameter-scale, single- to multi-storied paleochannel bodies composed of trough cross-bedded sandstone, inclined heterolithic strata, carbonaceous drapes, and authigenic siderite (Eberth 2005).

Paleocurrent data indicate a dominant southeast- to east-directed paleoflow, consistent with regional drainage patterns during DPF deposition (Fig. 3; Eberth and Hamblin 1993). The distribution and quality of DPF exposures within DPP are influenced by regional bedrock structure, with the most complete stratigraphic sections preserved along the eastern margin of the park near the Sweetgrass–Bow Island Arch, a Laramide-age structural high (Eberth 2005).

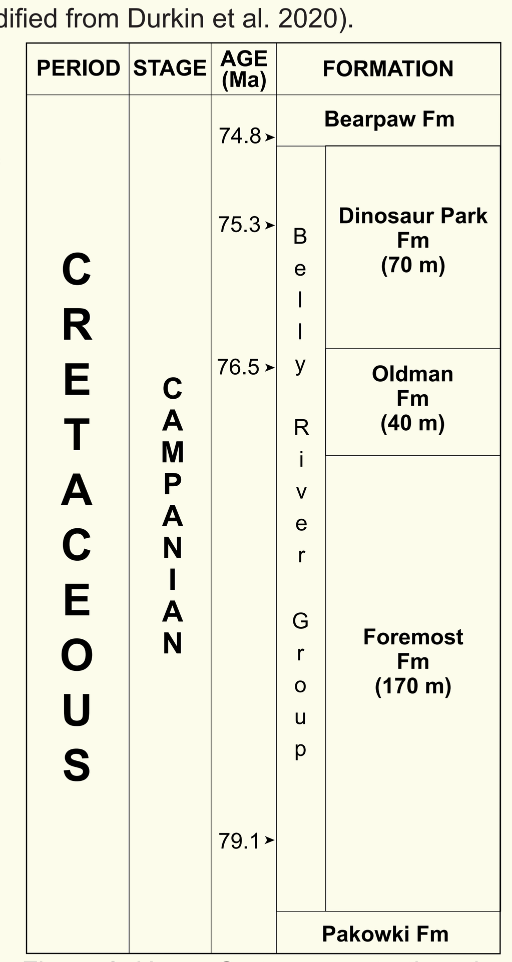


Figure 2. Upper Cretaceous stratigraphy of the Alberta Foreland Basin in the eastern plains, including the stratigraphic position and age of the Dinosaur Park Formation (modified from Eberth, 2002 and Durkin et al. 2020).

Methods and Study Area

Fieldwork for this project was conducted over a two-week period in the summer of 2025 in the area surrounding the specimen of interest within the Dinosaur Park Formation. Twelve detailed stratigraphic sections were measured using a Jacob staff, grain-size card, and hand lens, with the base and top of each section recorded using a Trimble differential global positioning system (dGPS). Paleoflow data were collected with the Clino app, utilizing exposed bedding surfaces on sandstone units, resulting in 36 rose diagrams generated in Stereonet software to visualize flow directions. In addition, reference photographs were taken for each section to aid later analysis and interpretation (Fig. 4).

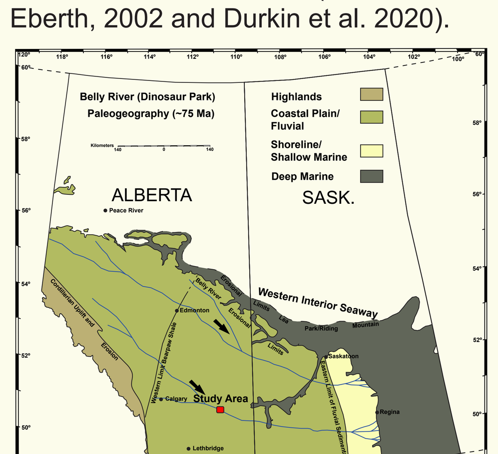


Figure 3. Palaeogeographic reconstruction of the Dinosaur Park Formation at ~75 Ma, showing east- to southeast-directed palaeoflow and fluvial channels incising sand-rich coastal plain deposits (modified from Leckie and Smith, 1992 and Durkin et al. 2020).

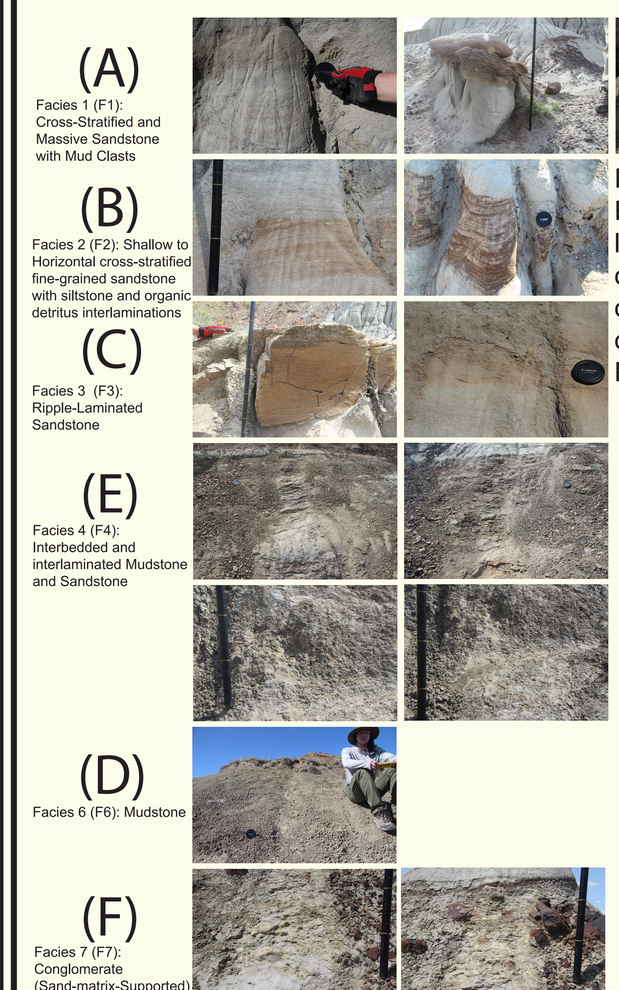


Figure 4. Representative lithofacies observed in outcrop sections of Dinosaur Provincial Park.

The later stage of the research focused on integrating and synthesizing the field data. Stratigraphic sections were digitized in Adobe Illustrator, and lithofacies identified in outcrop were described, condensed, and grouped into facies associations to interpret depositional environments (Fig. 5). Paleoflow data has been mapped and refined in QGIS to better understand channel geometry and flow dynamics.

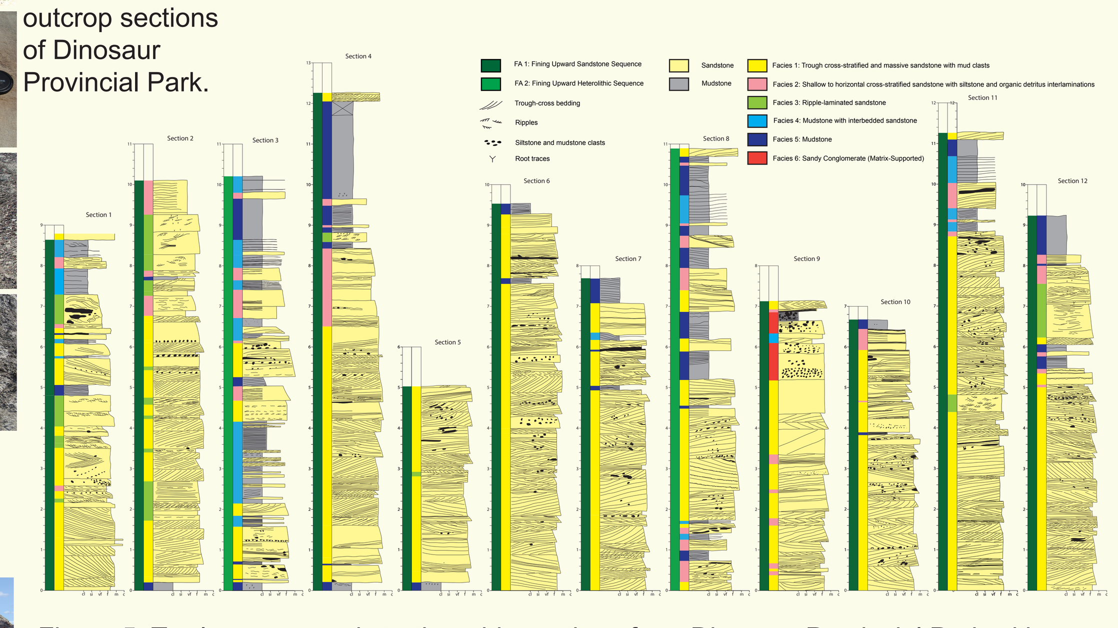


Figure 5. Twelve measured stratigraphic sections from Dinosaur Provincial Park with interpreted lithofacies and facies associations. Locations of measured sections are shown in Figure 7.

In early October, Drone-based structure-from-motion multi-view stereo (SfM-MVS) photogrammetry was acquired to construct a digital outcrop model and measure stratigraphic surfaces using the Pix4Dmapper method outlined in Nesbit et. al (2018) (Fig. 6). Measurement of more than 300 stratigraphic surfaces including accretionary, point bar tops, and point bar bases of several point bars enable strata correlation across the study area. Surfaces measured in Pix4Dmapper were exported to ArcGIS to interpolate the average dip direction using the trend tool. the potential to incorporate bentonite ash layer data and historic quarries, where available, to constrain the relative age and locations of the fossil-bearing deposits.

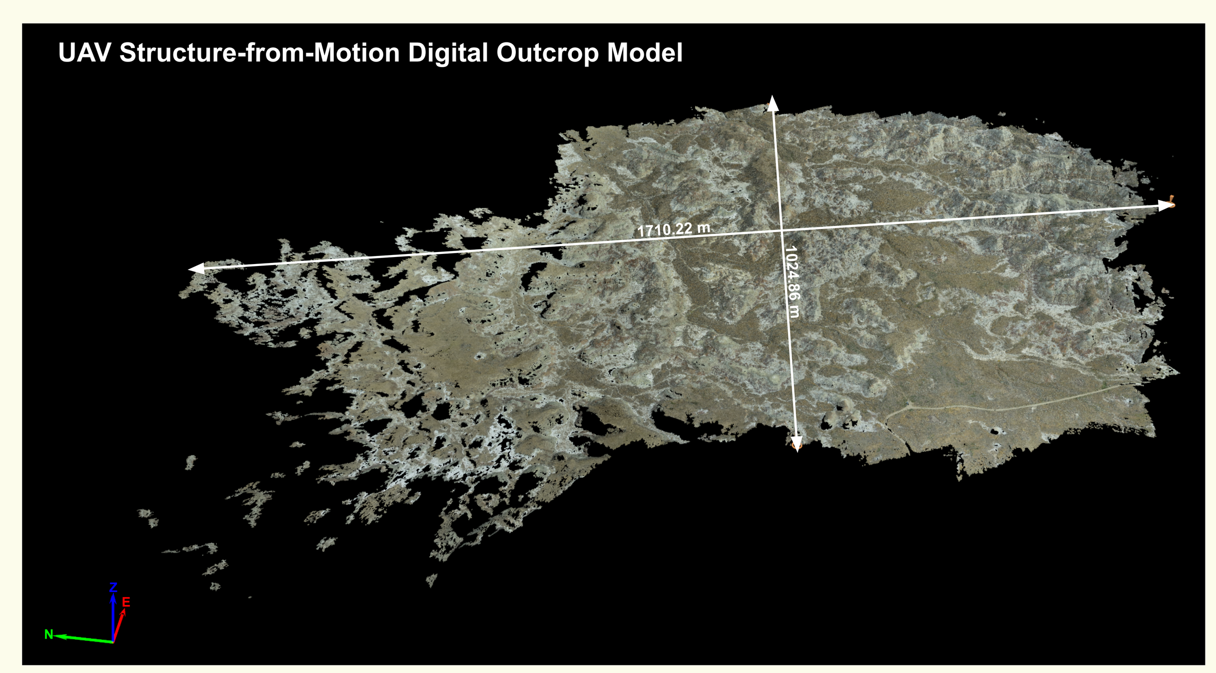


Figure 6. Three-dimensional digital outcrop model (DOM) derived from Unmanned Aerial Vehicle (UAV) photographs and Structure-from-Motion photogrammetry. Resolution of the model is ~3 cm per pixel, with a bed detection limit of ~10 cm. The model covers ~1.2 km² and provides the basis for extensive stratigraphic surface mapping. See Nesbit et al. (2018) for further detail on DOM construction and stratigraphic mapping.

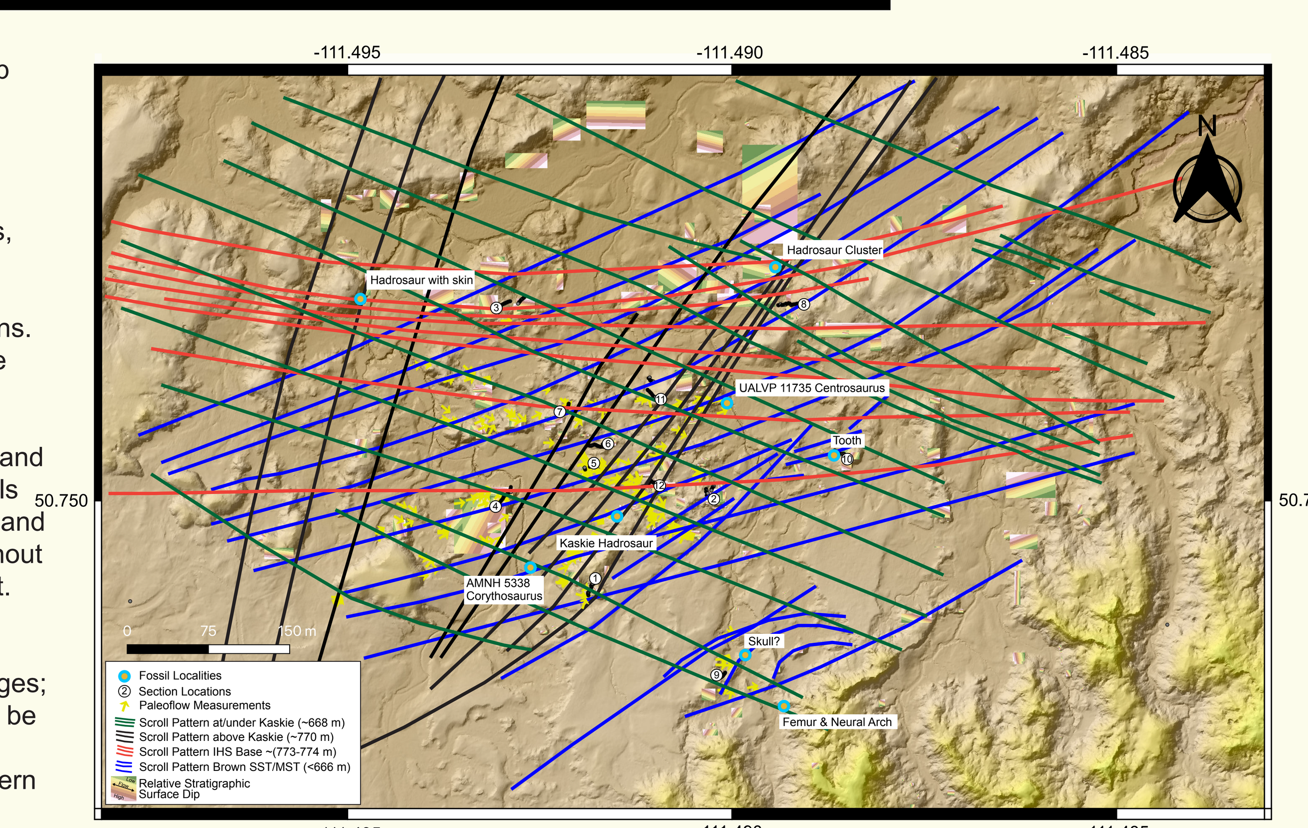


Figure 7. Study area map showing measured stratigraphic section and fossil locality locations, palaeoflow directions, stratigraphic surface dips, and interpreted scroll patterns preserved at multiple outcrop elevations. Palaeoflow directions are derived from trough cross-bed foresets and ripple crest orientations, and accretion-surface symbols indicate depositional dip and palaeoflow strike throughout the meander-belt deposit. Scroll patterns represent deposition at different elevations and relative ages; fossil localities appear to be preferentially associated with the green scroll pattern at ~668 m elevation.

These datasets will be combined to construct cross sections, map point bar architecture, and generate a stratigraphic framework that reconstructs the paleoenvironmental setting and evaluates the conditions that may have contributed to exceptional fossil preservation.

The primary equipment and resources for this project include the Jacob staff, grain-size card, hand lens, Canon camera, and Trimble dGPS used during fieldwork, as well as drone (RPAS) technology for (SfM-MVS) photogrammetry collection. Data processing and visualization are supported by the Clino app, Adobe Illustrator, QGIS, ArcGIS, Pix4DMapper, and Stereonet software.

Results

Table 1. Summary of lithofacies (F1–F6) identified within the Dinosaur Park Formation, including grain size, sedimentary structures, bedding characteristics, contact relationships, and interpreted depositional processes and environments.

Lithofacies	Grain Size/Sorting	Sedimentary Structures	Colour	Bedding	Upper/Lower Contacts	Process Interpretations	Depositional Setting
F1: Trough cross-stratified and massive sandstone with mud clasts	Upper very-fine– to lower medium sand; moderately to well sorted; organic detritus mud clasts (<0.3 to 5 cm), subangular–subrounded; mud node (4 to 8 cm), rounded; Dinosaur bone fragments and articulate skeleton	Trough cross-stratification, siltstone/mudstone and organic foreset drapes; graded and massive beds; elongate imbricated mudstone and siltstone clast lags at base	Sand = light grey Silt = reddish brown Mud = grey Organics = black	Unit: 30 to 83 cm thick; continuous to discontinuous	Sharp erosional base; gradational or sharp top	High-energy fluvial channel; migrating dunes	Channel thalweg or lower point bar
F2: Shallow to horizontal cross-stratified sandstone with siltstone and organic detritus interlaminations	Lower very fine- to upper fine sand; moderately to well sorted; organic detritus; frequent siltstone interlaminations	Shallow inclined to horizontal cross-stratification; wavy to planar, continuous and discontinuous siltstone, mudstone and organic laminae/drapes	Sand = light grey Silt = reddish brown Organics = black	Unit: 10 to 62 cm thick; continuous to discontinuous	Sharp erosional base; gradational top	Deposition from migrating 2D dunes; channel margin or point bar	Counter point bars, upper point bar
F3: Ripple-laminated sandstone	Lower very fine- to upper fine sand; moderately to well sorted; organic detritus; sporadic mud clasts (1 to 2 cm)	Ripple laminations with organic detritus on foresets; discontinuous	Sand = light grey Silt = reddish brown Mud = grey Organics = black	Unit: 23 to 92 cm thick; continuous to discontinuous	Sharp erosional base; gradational top	Low to moderate energy; ripple migration in fluctuating discharge	Lower to middle point bar
F4: Interbedded and interlaminated mudstone/siltstone and sandstone	Mudstone with lower very-fine– to middle fine sandstone interbeds and siltstone interlaminations; moderately sorted	Massive or laminated mudstone/siltstone interbedded with thin sandstone strata	Sand = light grey Silt = reddish brown Mud = grey Organics = black	Unit: (Mudstone: 7 to 202 cm thick; Sandstone: <1 to 10 cm) thick; continuous to discontinuous	Sharp erosional base; gradational top	Alternating overbank mud deposition and sand incursions	Overbank, counter point bar
F5: Mudstone	Mudstone; clay-rich; clay to silt sized grains	Massive or laminated	Silt = reddish brown Mud = grey Organics = black	Unit: 340 cm thick; continuous to discontinuous	Sharp erosional base; sharp erosional top	Overbank or floodplain deposits	Overbank
F6: Sandy Conglomerate (Sand-Matrix-Supported)	Granule- to cobble-sized clasts (0.3 to 6 cm; one Uvf matrix 25 cm clast w/ org fragments, lam & 3 cm mud clasts); sand matrix; matrix-supported	Trough cross-stratification	Sand = light grey Silt = reddish brown Mud = grey Organics = black	Unit: 10 to 66 cm thick; discontinuous	Sharp erosional base; sharp erosional top	High-energy channel lag or proximal braided stream deposits	Channel lag

Six lithofacies (F1–F6) were identified within the Dinosaur Park Formation and grouped into two facies associations that record spatial and temporal variability within a meandering fluvial system (Table 1.; Fig. 6). Facies Association 1 comprises trough cross-stratified and massive sandstone with mud clasts (F1), shallow to horizontal cross-stratified sandstone with siltstone and organic interlaminations (F2), ripple-laminated sandstone (F3), and is commonly capped by mudstone with interbedded sandstone (F4) and massive mudstone (F5). This association forms fining-upward successions interpreted as channel-fill and point-bar deposits, reflecting a transition from high-energy channel thalwegs to lower-energy upper point-bar and channel-abandonment conditions.

Facies Association 2 is dominated by shallow to horizontal cross-stratified sandstone with siltstone and organic interlaminations (F2), interbedded with mudstone (F4) and massive mudstone (F5), with trough cross-stratified sandstone (F1) present but comparatively rare. The prevalence of heterolithic bedding, organic drapes, and reduced sand content suggests deposition under fluctuating but generally lower-energy conditions, consistent with channel-margin environments, overbank settings, or counterpoint bar deposition associated with channel migration along the outer bend. Sandy conglomerate (F6) was identified only in Section 9 and is interpreted as a localized high-energy channel-lag deposit.

Paleocurrent measurements and map reconstruction indicate a dominantly eastward-flowing river system, with local deviations toward the north and south reflecting lateral channel migration (Fig. 7). Fossil localities are primarily associated with Facies Association 1, particularly within lower- to middle point-bar deposits, suggesting that channel architecture and lateral accretion exerted a strong control on burial conditions and fossil preservation potential. Vertical stacking patterns and scroll-bar geometries document repeated channel migration and abandonment, providing a stratigraphic framework for interpreting the distribution of fossil-bearing horizons.

Discussion and Future Work

Facies analysis of a skin-preserved juvenile hadrosaur and nearby fossil localities in Dinosaur Provincial Park reveals a strong stratigraphic clustering of fossils between ~668 and ~673 m elevation. Multiple fossil occurrences are concentrated slightly above 668 m, suggesting preservation may be linked to a discrete depositional interval rather than random distribution within the fluvial succession.

The skin-preserved specimen occurs immediately above an iron-rich brown sandstone–siltstone–mudstone unit that is incised by the overlying Kaskie point-bar mudstone. This relationship indicates active channel reworking, potentially associated with chute-channel formation or localized erosion into an older point bar. The fossil-bearing interval contains abundant trough cross-bedded sandstones with elevated organic content, consistent with relatively rapid burial under moderate- to high-energy flow conditions.

Slightly above the fossil horizon, a laterally continuous, iron-cemented layer cuts obliquely across underlying strata. This unit likely reduced post-depositional fluid flow and limited oxidation, creating a localized diagenetic barrier. The preserved skin itself appears to be replaced or reinforced by iron-rich mineralization, possibly siderite or an iron-rich carbonate, suggesting early diagenetic cementation played a role in stabilizing soft tissues.

The overlying presence of cemented ripples indicates waning flow energy following burial, potentially sealing the fossil beneath relatively impermeable, iron- and organic-rich sediments. Together, these observations suggest that exceptional preservation resulted from the combined effects of rapid burial, stratigraphic confinement, reduced permeability, and early iron-rich diagenesis within a dynamic fluvial point-bar setting.

This study is grounded in detailed field-based lithofacies analysis, measured sections, and mapping that establish the sedimentological and stratigraphic framework of the fossil-bearing interval. Ongoing work will focus on completing stratigraphic cross sections and refining correlations between measured sections to better resolve channel geometry, lateral accretion surfaces, and facies architecture within the channel belt. Continued development of facies associations and stacking patterns will be used to further interpret the processes governing channel migration, reworking, and abandonment, and their influence on fossil burial and preservation. While geochemical and petrographic analyses fall outside the scope of this study, such approaches represent valuable avenues for future research to evaluate diagenetic controls on soft-tissue preservation. Together, these efforts aim to strengthen process-based interpretations of fluvial dynamics and preservation within the Dinosaur Park Formation.

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