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Stratigraphic investigation of the McMurray Formation along the Steepbank River using LiDAR and UAV Data

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Summary

The Steepbank River outcrops of the Cretaceous McMurray Formation have been extensively studied over the last several decades (e.g., Mossop and Flach, 1983; Flach and Mossop, 1985; Wightman and Pemberton, 1997; Langenberg et al., 2002; Ranger and Gingras, 2003; Musial et al., 2012; 2013; Jablonski and Dalrymple, 2016; Hayes et al., 2018). To build on these studies, a new data set has been collected that consists of a large-scale LiDAR survey combined with local, high-resolution uncrewed aerial vehicle (UAV) photogrammetry surveys to compile an integrated digital outcrop model (DOM) of the Steepbank River outcrops. The objectives of this study are to (1) integrate the outcrop exposures into the recently refined and extensively mapped stratigraphic framework of the McMurray Formation (e.g., Horner et al., 2019), and (2) digitally map internal stratigraphic surfaces of meander-belt deposits to reconstruct depositional element architecture and facies distributions.

The LiDAR data set along the Steepbank River extends from 30-92-9W4 (Outcrop 3) southeastward to 23-92-9W4 (Fig. 1a); the UAV surveys collected in 2019 focus on Outcrop 3 (Fig. 1B, C). The LiDAR survey is a georeferenced framework where we compile published data from previous studies (e.g., Musial et al., 2012; 2013; Jablonksi and Dalrymple, 2016; Hayes et al., 2018) and build upon those results with additional data collected for this study. Stratigraphic surfaces identified in measured sections, the DOM, and wireline logs from surrounding boreholes integrate the outcrop exposures with the stratigraphic framework for the McMurray Formation. Key surfaces include the regionally correlative upper McMurray coarsening-upward units, as well as channel-belt bases and the sub-Cretaceous unconformity. We demonstrate the refined stratigraphic position of the key reservoir interval meander-belt deposits. Utilizing the high-resolution UAV surveys, internal stratigraphic surfaces are mapped to reconstruct point-bar accretion and internal erosion surfaces. Three-dimensional projection of theses surfaces demonstrates point-bar geometry and distribution of meander-belt elements. Future work includes collecting additional UAV surveys and measured sections, and the construction of a 3-D geocellular model of meander-belt deposits exposed along the Steepbank River.

Methods

The LiDAR data set was collected in August 2017 and additional UAV data was collected in August 2019. The LiDAR data point density is 44 points per m^2. UAV structure-from-motion was used to created 3-D point cloud data in Pix4Dmapper. We followed the methods outlined in Nesbit et al. (2018) for DOM construction and generated an average 0.027 m point-spacing point cloud. In ArcGIS, LiDAR and UAV point cloud data are integrated and georeferenced. Measured stratigraphic sections were collected during the 2019 field season, which documented grain size, bedding, sedimentary and biogenic structures, and colour. Measured section data from this study as well as previous studies was digitized and integrated into the DOM data set. A series of paleoflow measurements were taken as the maximum forset dip direction of trough-cross stratified sandstones. Stratigraphic surfaces were mapped in a series of points along the outcrop exposure and then extrapolated in 3-D as a surface plane. Stratigraphic surfaces are correlated with surfaces identified through wireline log interpretation in nearby boreholes.

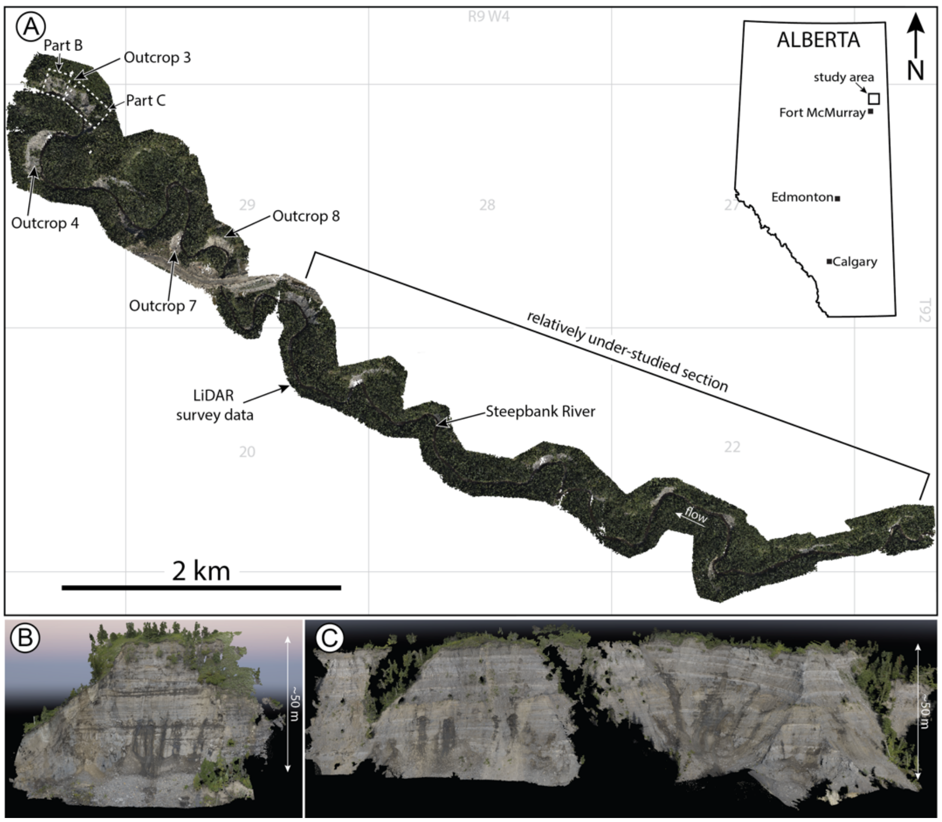

Figure 1: Data sets and location of Steepbank River study area. A) Map of LiDAR data, location of outcrops, and Parts A and B. Location of study area is shown on inset map of Alberta. B) and C) UAV-photogrammetry point cloud data from Outcrop 3A (Part B) and 3B-C (Part B).

Future Work

Initial results have highlighted key areas to be studied during the 2020 field season. High water levels in 2019 limited outcrop accessibility to Outcrop 3, however, future field work will cover Outcrop 4 and key under-studied outcrops further upstream (to the southeast) that are captured in the LiDAR survey (Fig. 1). Post-field work objectives include integrating wireline log interpretations with outcrop data in a 3-D modelling software (e.g., Schlumberger's Petrel) to construct a geocellular model. The results of this study will improve our understanding of the stratigraphic context of the well-studied Steepbank River outcrops and provide a high-resolution well-constrained window into the 3-D architecture of McMurray Formation meander-belt deposits.

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