geoconvention
Virtual Event
September 21-23 2020
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Link between sedimentary fabric and fracture distribution of the Montney – key insights from a world class outcrop using UAV photogrammetry

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Summary

The Montney Formation has been studied in detail over the last several decades as it has become the predominant gas and gas-condensate play in Western Canada. Despite the surge of research, several key questions remain unanswered or poorly understood. Two of these areas of inquiry are: 1) the lateral variability of sedimentary facies and facies architecture on a 10s to 1000s of metres-scale i.e. single well-pad scale, and 2) the distribution and variability of the height and intensity of natural fractures, and the influence of sedimentary fabric on this distribution. By studying an extraordinarily large and well exposed Montney equivalent outcrop in the Canadian Rockies, this study has provided key insights into these issues.

Theory / Method / Workflow

A detailed digital outcrop model has been created of a ~1.5-kilometer-long well-exposed Montney equivalent outcrop located near Canmore, Alberta in the front ranges of the Canadian Rocky Mountains. The model was created using UAV (drone) photography and photogrammetry, with an average resolution of 2.7 cm per pixel. Sedimentary fabric has been analyzed primarily using UAV photographs and orthomosaic images generated from the digital outcrop model. Depositional line drawings reveal increasing bed thickness, fabric complexity and lateral variability towards the top of the outcrop, and zones of distinctive sedimentological fabric have been defined (figure 1). Detailed sedimentological measured sections, including XRF and spectral gamma ray measurements, have also been collected at this outcrop, allowing sedimentary fabric observations to be related to core and well-log data.

Natural fractures were assessed using the digital outcrop model and output orthomosaic images. The primary dataset of digital fracture traces was generated by an edge-detection script written to automatically detect and digitize fracture traces on orthomosaic images (McKean et al., 2019). Select windows and scanlines on the digital outcrop were also manually interpreted to confirm the validity of the automated fracture detection dataset. Supplementary fracture datasets were manually collected in the field to assess and validate the digitally derived data (figure 2).

Automation of fracture detection is far faster, results in a larger number of data points, and eliminates interpreter bias and drift compared to manual interpretation of a digital outcrop models or orthomosaic images. In practical terms, automation is the most accurate way to collect a robust dataset over such a large area, as manual interpretation would take far too long and be too inconsistent. The 2D fracture traces collected in this study are used to assess fracture height distributions and both areal fracture intensity (p21) and linear fracture intensity (p10) across the outcrop.

Results, Observations, Conclusions

The depositional line drawing clearly indicates that this formation is not “layer cake” geology, even on the scale of a single horizontal well length of 1 to 3 km. Sedimentological fabric varies both vertically, with the upwards increase in complexity, and laterally in bed thickness within some zones. Comparing results from the sedimentological fabric and fracture distribution reveals that the two are closely related. Many fractures observed in this formation are strata-bound, and sedimentary facies appears to have a strong control on fracture height. Discrete weak interfaces caused by thin mudstone beds or sharp lithology contrasts coincide with the termination of fractures above and below, possibly representing a fracture barrier or baffle. However, it is also apparent the sedimentary fabric is not the only control on fracture distribution, as intensity also varies greatly laterally, independent of sedimentary fabric or facies (figure 2,3). These observations offer key insights into the metre-scale details of Montney reservoir and could help to explain variable or anomalous well behavior (figure 4).

Acknowledgements

This work was made possible through funding from the Tight Oil Consortium (TOC) and the Robert K. Goldhammer Memorial Grant (provided by the AAPG). All work was done with written permission from Alberta Parks in the form of a Research and Collection Permit.

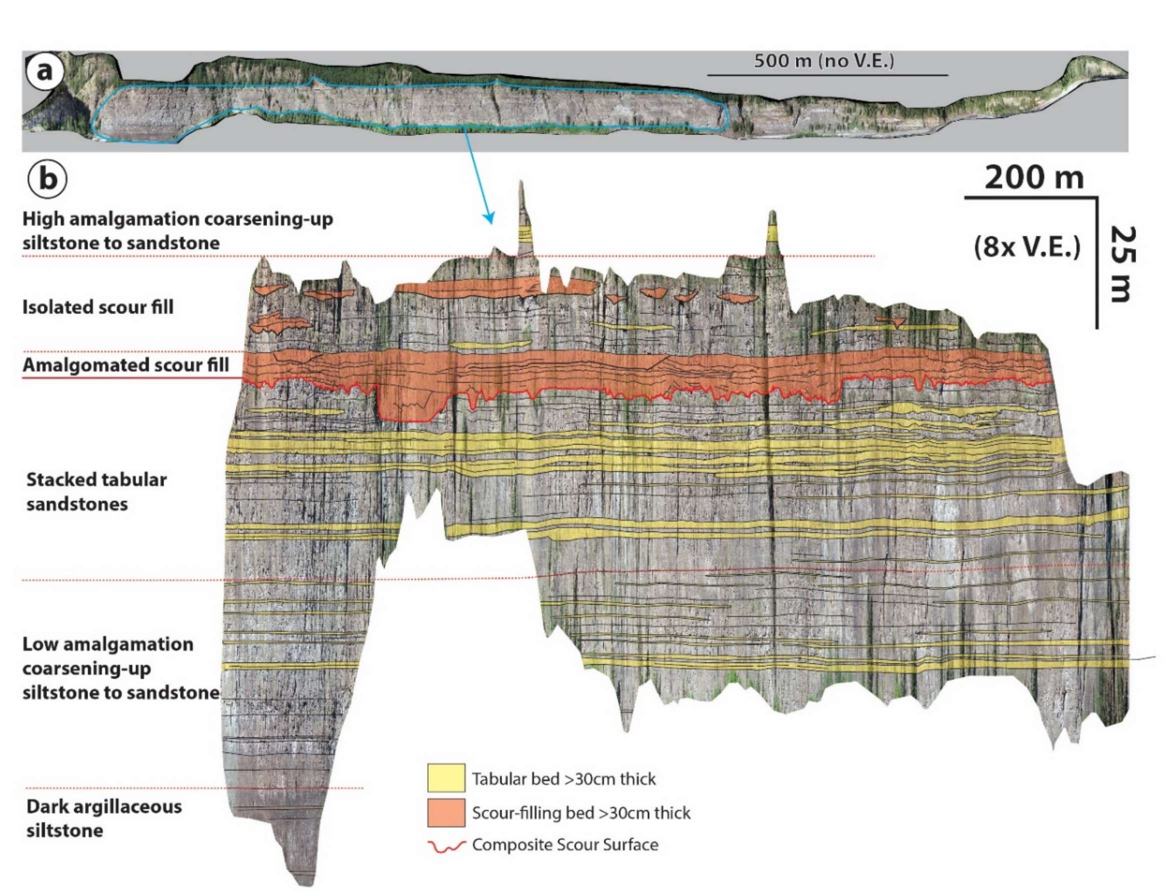

Figure 1. Orthomosaic of Montney-equivalent outcrop. Depositional fabric and geobodies are traced onto the image, with the strata split into zones with distinctive sedimentary fabric.

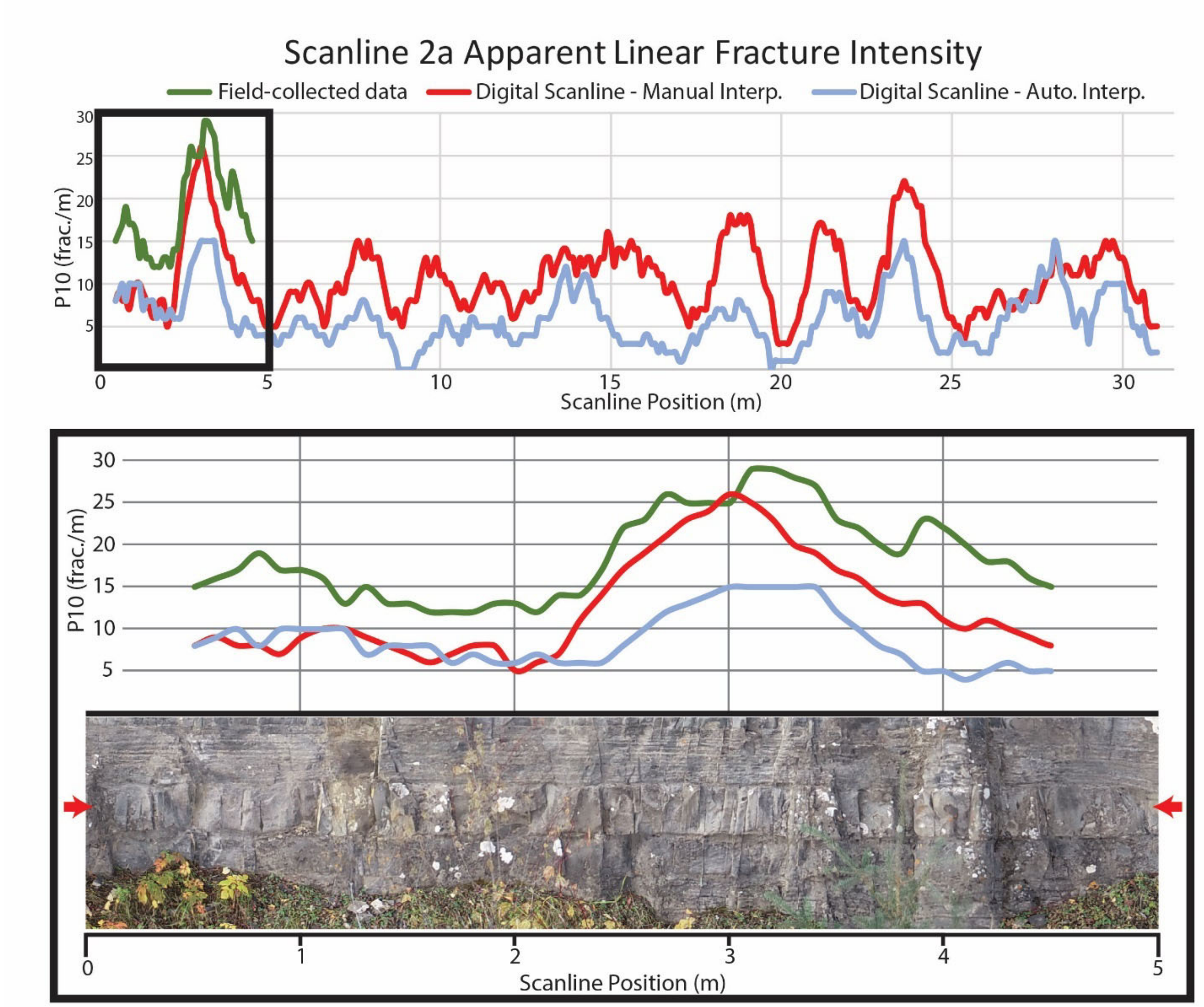

Figure 2. Comparison of linear fracture intensity collected by the different methods used in this study. The digital scanline methods generally yield a lower fracture intensity than the field-collected data, but all three datasets follow the same trend and identify the same zones of higher fracture intensity (fracture swarms).

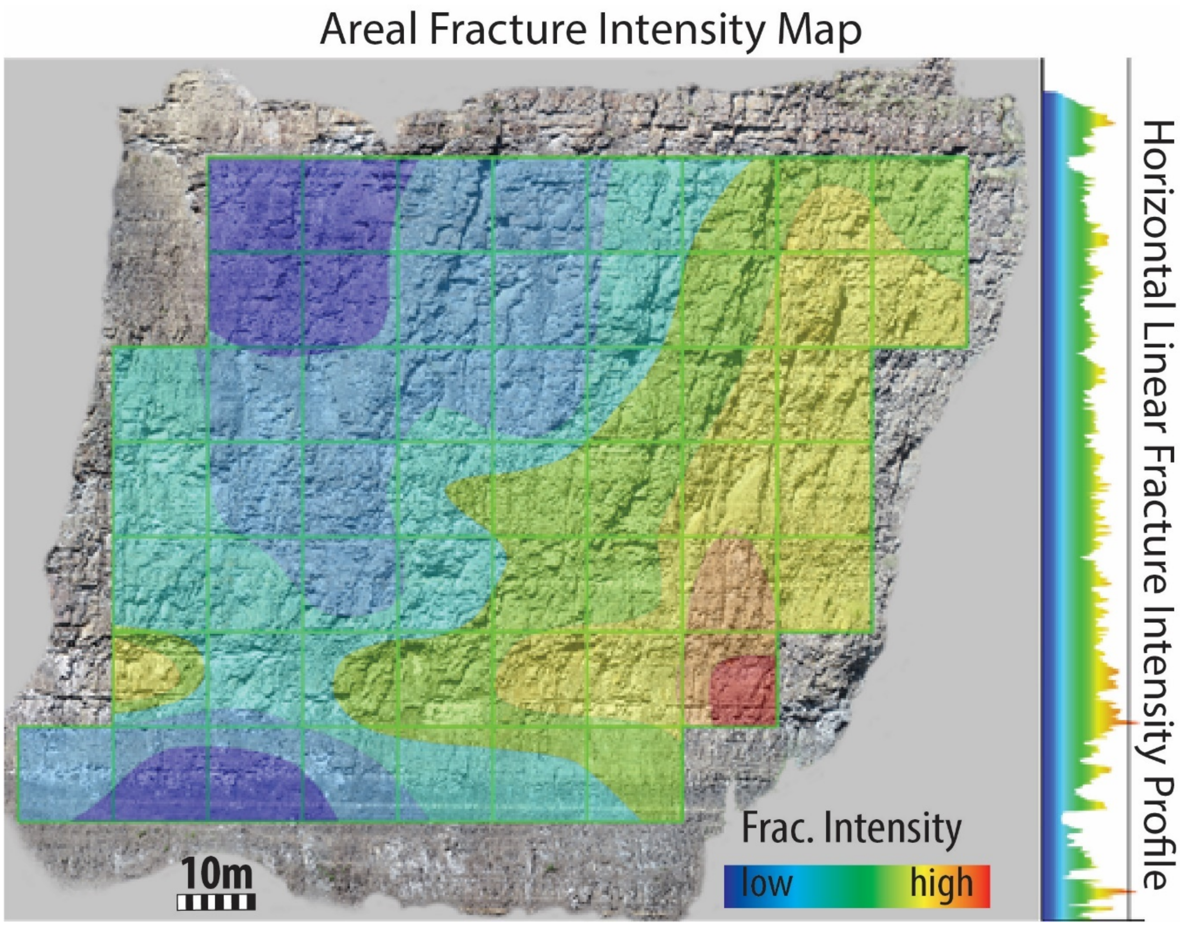

Figure 3. Areal fracture intensity (P21) map (10m x 10m sampling window) and vertical profile of horizontal linear fracture intensity (P10) demonstrate that fracture intensity varies both laterally and vertically in similar proportion.

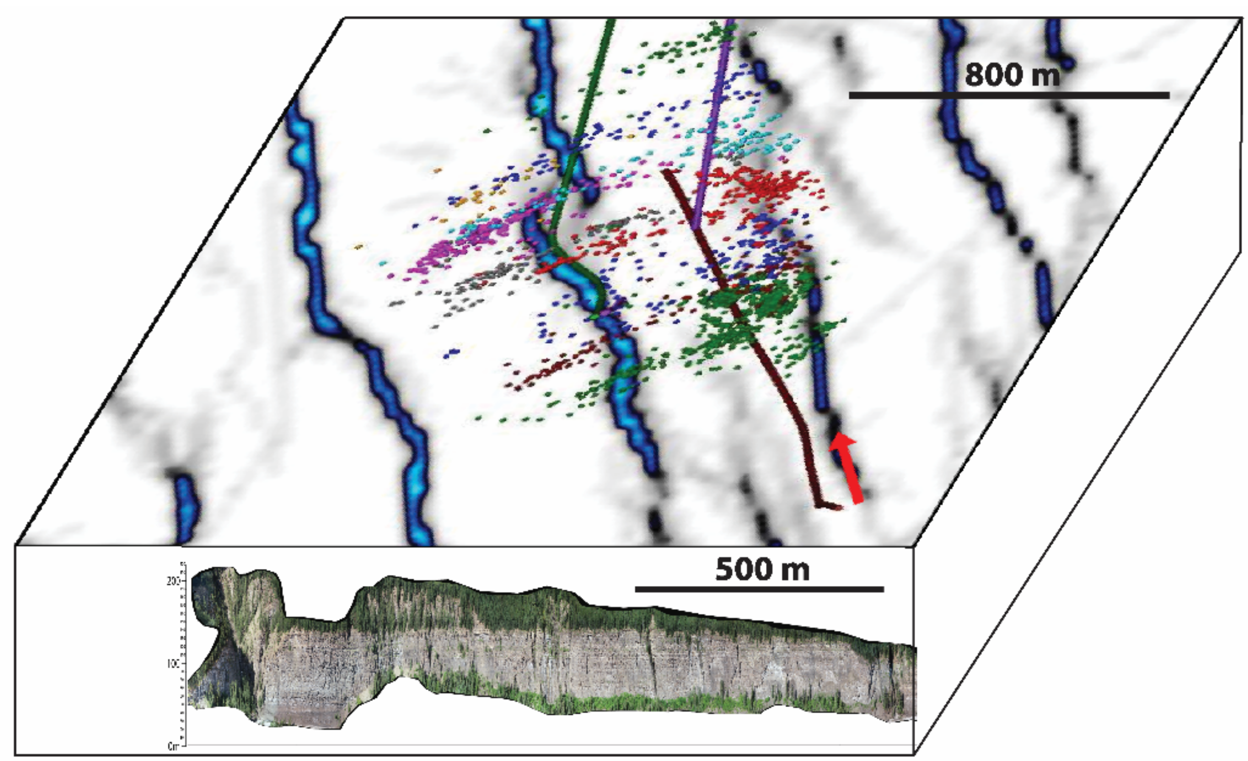

Figure 4. Comparison of outcrop scale to well-pad/microseismic/seismic scale. Sub-vertical zones of high fracture intensity observed on the outcrop may help to explain anomalous completions and microseismic responses observed in the subsurface. Modified from Maxwell et al., (2011).

References

Maxwell, S. C., Cho, D., Pope, T. L., Jones, M., Cipolla, C. L., Mack, M. G., Leonard, J. A. (2011). Enhanced Reservoir Characterization Using Hydraulic Fracture Microseismicity. Society of Petroleum Engineers. doi:10.2118/140449-MS

McKean, S. H., Poirier, S., Priest, J. A., Pedersen, P. K., Galvis-Portilla, H., Venieri, M., & Mackie, S. (2019). Induced seismicity and hydraulic fracturing insights from a fracture survey of an analogous Duvernay outcrop (Poster). In CSPG Geoconvention 2019. Calgary AB, Canada.