Fracture Analysis of Upper Paleozoic Carbonates: East-Central British Columbia

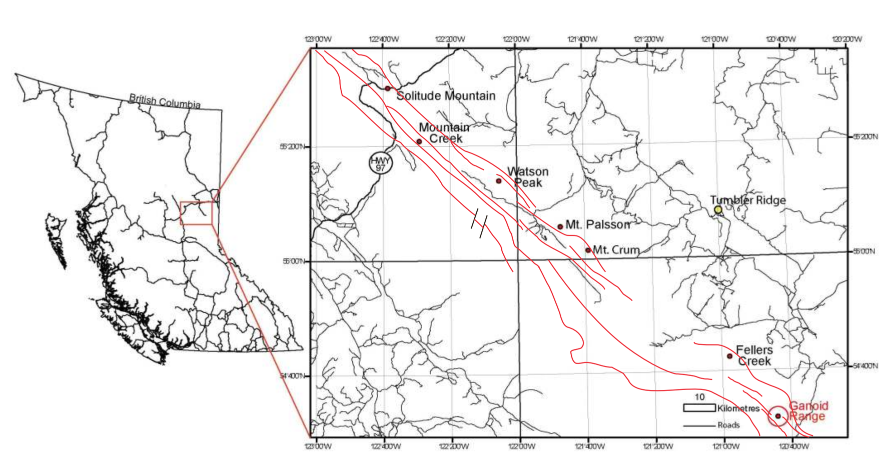
CABS
CENTRE FOR APPLIED BASIN STUDIES

Greg J. Dean, Deborah A. Spratt and Charles M. Henderson - Department of Geoscience, University of Calgary, Calgary, Alberta

UNIVERSITY OF CALGARY

Introduction & Geologic Background

Active normal block faulting occurred during the Pennsylvanian to Permian creating sub-basins that affected stratigraphic distribution and preservation. Reactivation of these faults during Late Cretaceous Laramide thrusting compartmentalized reservoir distribution throughout the east-central British Columbia Foothills and surface analogues within the Front Ranges. In this study, regional fracture patterns were examined in outcrops within the Hannington, Belcourt and Fantasque formations (Bamber and Macqueen, 1979) to determine the effect lithology and Laramide reactivation played on the origin and density of fractures. The effect of local structures on such fracture patterns is being used to create an applicable subsurface model. Image logs were used to define fracture properties within the subsurface and correlate them with outcrop and core. The locations where outcrop fracture data were collected are depicted on Figure 2. This poster presentation focuses on fractures measured at the Ganoid Range in the southeast portion of the field area.



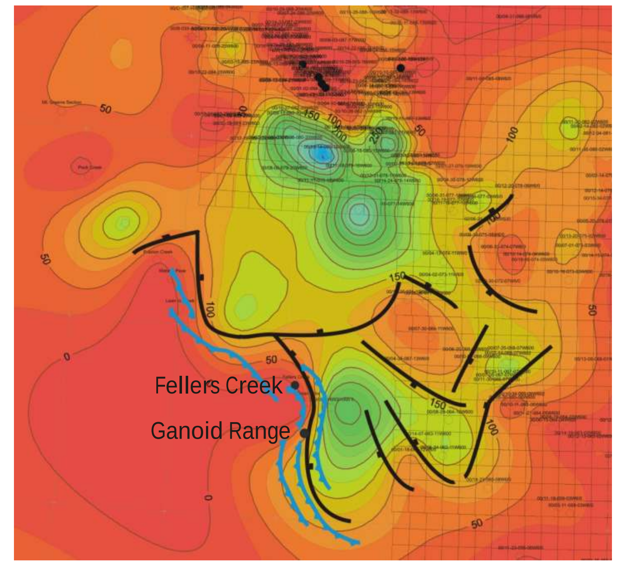
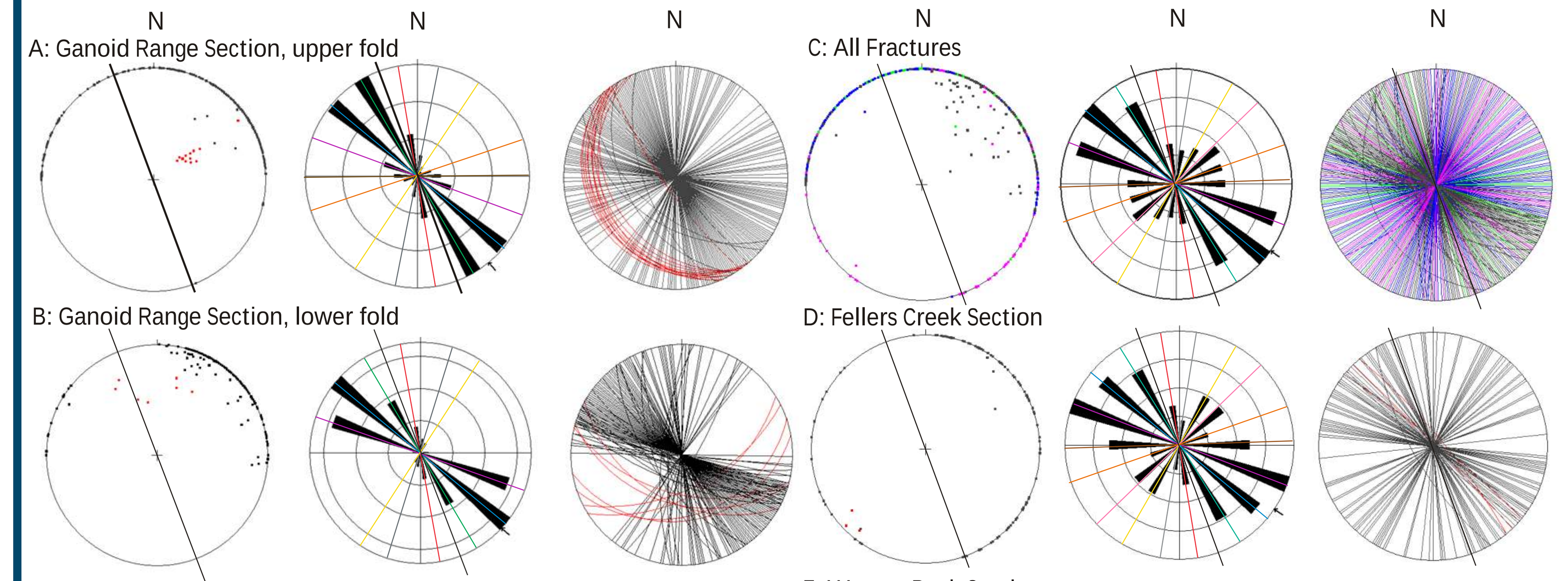


Figure 1: Map of study area with field locations denoted by red dots. Red lines represent locations of thrust faults (modified from Stott, 1983, McMechan, 1994 and McMechan and Thompson, 1995), showing that several thrust sheets have been sampled modified from (Henderson *et al.*, 2010). Figure 2 (right): Moscovian isopach (Mid-Pennsylvanian), illustration relative positions of Pennsylvanian-Permian normal faults (black) and Laramide thrust faults (blue) (modified from Dunn, 2003)

Outcrop Fracture Orientations



Fractures from linear scanlines show nine main fracture sets. Fractures oriented parallel and conjugate to the regional and local fold axis trends generally appear in the hinge of the folds whereas fractures oriented parallel and conjugate to s_1 dominate on the limbs. Fractures within studied outcrop of the field area were not for the most part perpendicular to bedding and dipping near 90° and are therefore not thought to be related to early folding or bed flexure (non-Stearns type) , but rather to later stage fold tightening.

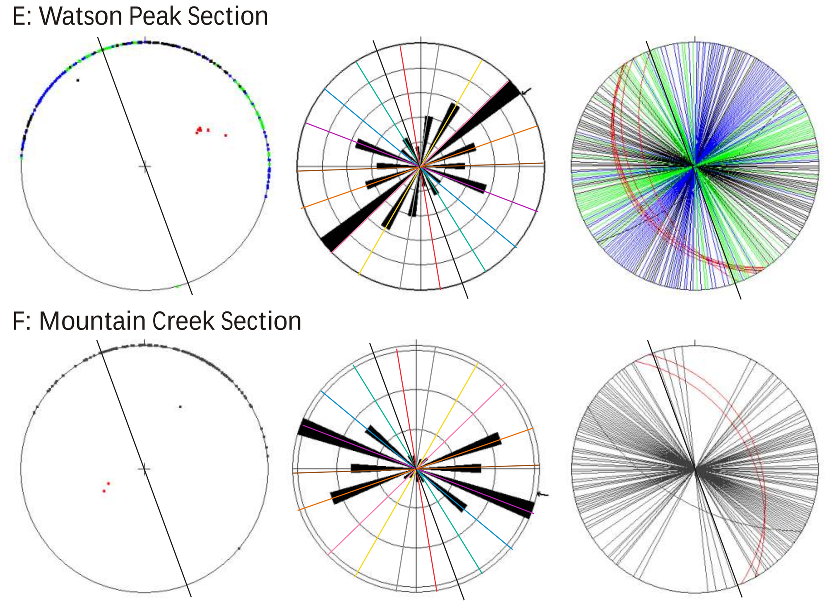
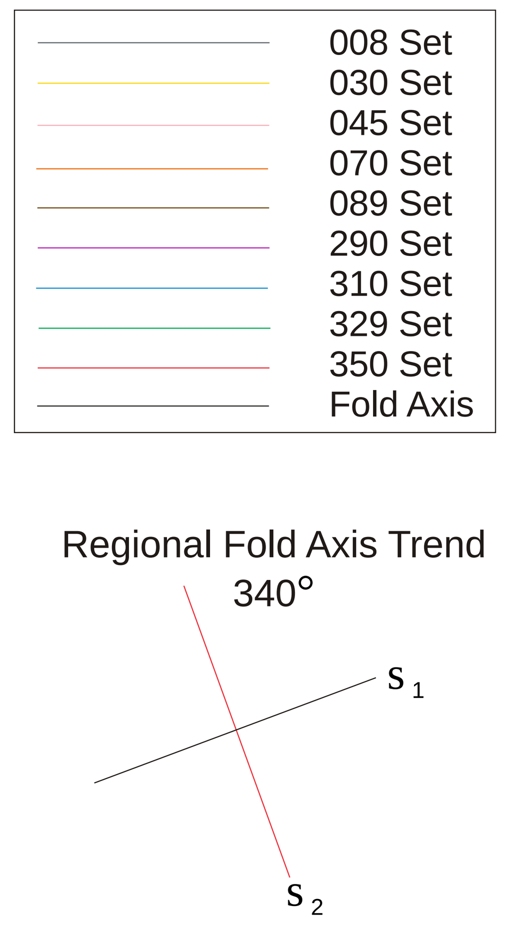


Figure 2A-F: Linear scanline fracture orientations; A: lower fold of Ganoid Range structure; B: upper fold of Ganoid Range structure; C: All fractures from all field collection sites (Ganoid Range in black, Watson Peak in blue, Fellers Creek in pink and Mountain Creek in green); D: fracture orientations from Fellers Creek section; E: fracture orientations from Watson Peak section; F: fracture orientations from Mountain Creek section. Red dots represent poles to bedding whereas black dots represent poles to fractures, see Figure 3 for legend.

Outcrop Fracture Density



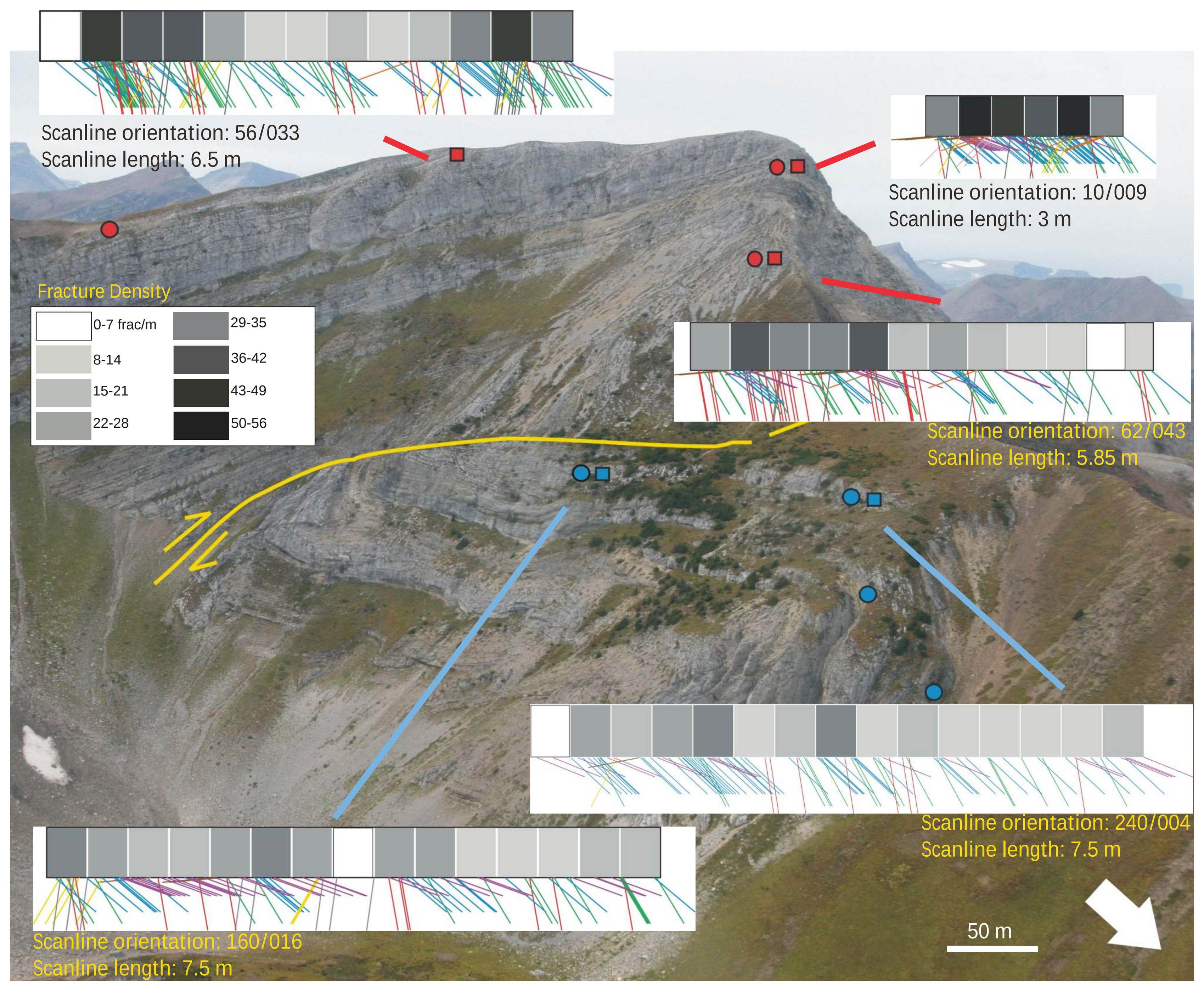


Figure 3: Ganoid Range structure (photo by S. McLellan), circles represent circular window scanline locations, squares represent linear scanline locations. Fracture density bars show 0.5 metre interval total line densities (see legend). The coloured lines represent fracture orientation and relative spacing. Note that fracture orientations are relative to up being north and scanlines are not in true orientation.

Subsurface Fractures

Subsurface fractures from wells 12-20 km to the east do not show the same relationship as fractures from outcrop locations to the west. Fractures from these wells show domination by two main sets oriented conjugate and at high angles to the s_1 direction (030° and 008°) (Figure 4A and 4B).

This pattern is possibly related to the change in fold style (tight folds in outcrop vs. open folds in the subsurface) and the decreased amount of deformation away from the detachment and thin-skinned thrust provinces (Cooper, 2000). This relationship between outcrop and subsurface fractures implies that subsurface fractures may be related to flexure of the crust during regional compression (Sterns-type) rather than fold tightening as in outcrop.

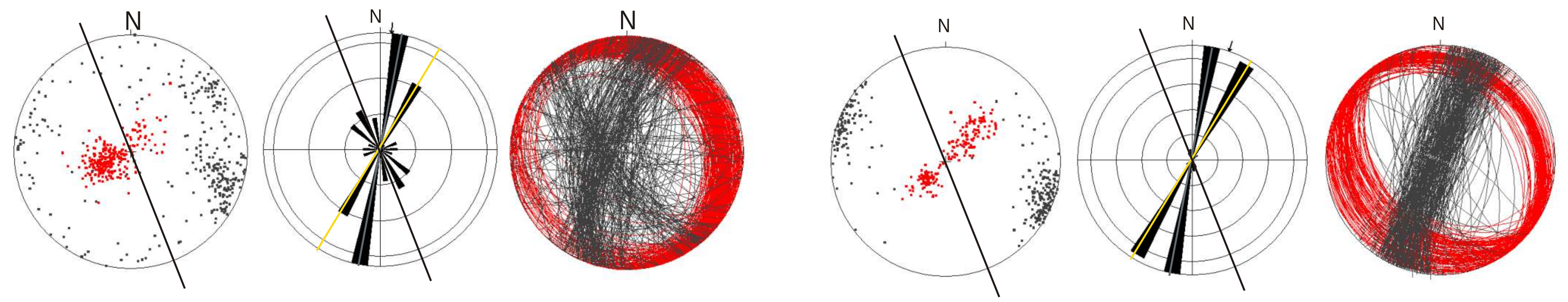


Figure 4A and 4B: Fracture orientations from subsurface wells, taken from dip-meter data. Note the domination by the 008° and 030° fracture sets. Red dots/lines are poles to/bedding planes whereas black dots/lines are poles to/fracture planes. Figure 5 (right): sample image log from subsurface well, showing fractures in pink and bedding in green. Data courtesy of Talisman Energy, Calgary, AB

Micro, Meso & Macroscale Fractures

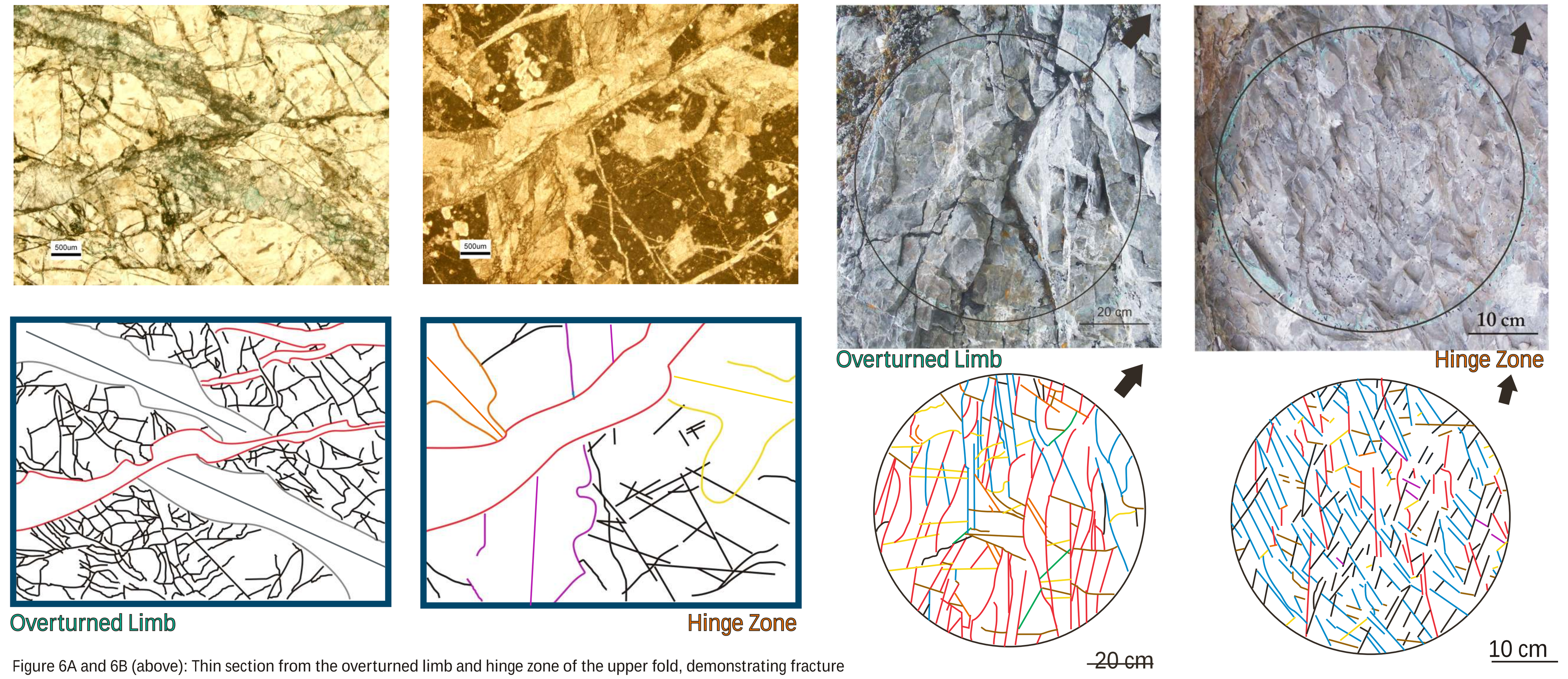
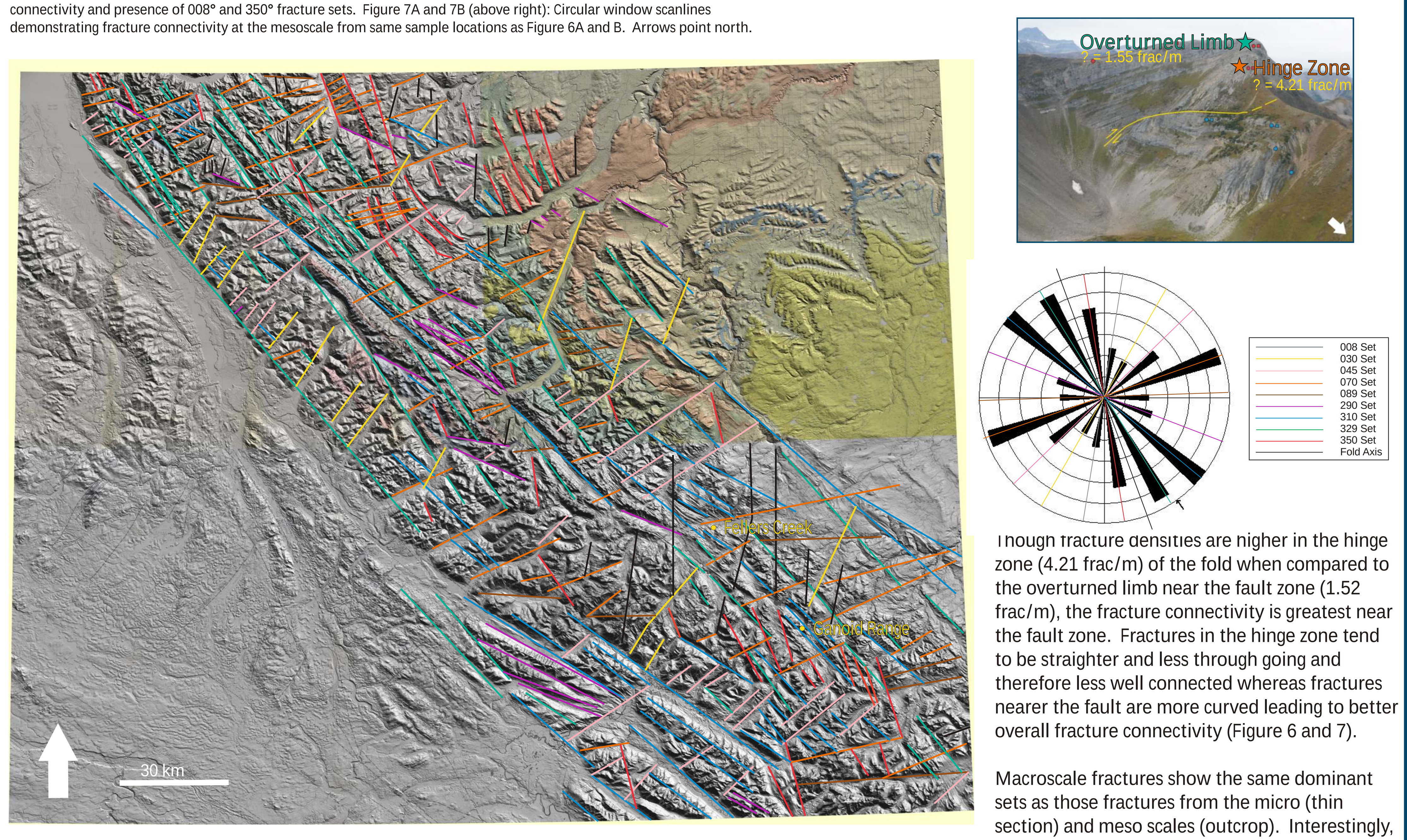


Figure 6A and 6B (above): Thin section from the overturned limb and hinge zone of the upper fold, demonstrating fracture connectivity and presence of 008° and 350° fracture sets. Figure 7A and 7B (above right): Circular window scanlines demonstrating fracture connectivity at the mesoscale from same sample locations as Figure 6A and B. Arrows point north.



Though fracture densities are higher in the hinge zone (4.21 frac/m) of the fold when compared to the overturned limb near the fault zone (1.52 frac/m), the fracture connectivity is greatest near the fault zone. Fractures in the hinge zone tend to be straighter and less through going and therefore less well connected whereas fractures nearer the fault are more curved leading to better overall fracture connectivity (Figure 6 and 7).

Macroscale fractures show the same dominant sets as those fractures from the micro (thin section) and meso scales (outcrop). Interestingly, Ganoid Range fractures do not exhibit the 045° Set in either outcrop nor at the macroscale.

Figure 8A (above):DEM Image with macroscale fracture orientations, demonstrating a domination by the same nine sets as from the micro and meso-scales.
Figure 8B (above right): Rose diagram of dominant fracture orientations from the macroscale.

Significance

Fracture data collected from east-central British Columbia will play an important role in hydrocarbon exploitation. Outcrop data can reveal much about the orientation, density and intensity of these important features and their relationships to timing and interaction with each other. When outcrop and thin section data are combined with subsurface image log and core data, the important relationships between surface and subsurface fracturing can be interpreted. Analyzing the fractures will aid in refining the tectonic history and calculating optimal drilling directions for these important reservoir units. Creating a regional fracture model for east-central British Columbia will lead to enhanced methods of recovery in addition to more efficient exploration techniques in this Upper Paleozoic gas play.

Acknowledgements

The senior author thanks his graduate supervisors Dr. Charles Henderson and Dr. Deborah Spratt for their dedicated and continued support in the completion of this project. Thanks also go toTalisman Energy and Geoscience BC for financial and academic support of this research. This project was further supported by a Natural Sciences and Engineering Research Council of Canada Discovery Grant to Dr. Charles Henderson.

References

Bamber, E.W and Macqueen, R.W., 1979, Upper Carboniferous and Permian Stratigraphy of the Monkman Pass and Southern Pine Pass Areas, Northeastern British Columbia, Geological Survey of Canada, Bulletin 301

Cooper, M., 2000, Structural style variations in the BC foothills, GeoCanada 2000, Abstract.

Dunn, L., 2003, Sequence biostratigraphy and depositional modelling of the Pennsylvanian to Permian Belloy Formation, northwest Alberta and northeast British Columbia: PhD thesis, University of Calgary, 212pp.

Feltham, G.R., 2005, Fold-related Fractured Reservoir Analysis of the Pennsylvanian Ksituan Member of the Belloy Formation, Monkman Pass, northeastern British Columbia: Optimal Drilling Directions Determined from Image Log and Outcrop Studies: M.Sc. thesis, University of Calgary, 183 pp.

Henderson, C.M., Zubin-Stathopoulos, K., Dean. G., Spratt, D. and Chau, Y.P., 2010, Tectonic History, Biostratigraphy and Fracture Analysis of Upper Paleozoic and Lowest Triassic Strata of East-Central British Columbia (NTS 093I, O, P): Preliminary Report, in Geoscience BC Summary of Activity 2009, Geoscience BC, Report 2010, p.259-270.

Mauldon, M., Dunne, W.M. and Rohrbaugh, M.B., 2001, Circular Scanlines and Circular Windows: New Tools for Characterizing the Geometry of Fracture Traces: Journal of Structural Geology, v. 23, p. 247-258.

McMechan, M.E. and Thompson, R.I., 1994, Geology, Dawson Creek, West of the Sixth Meridian, British Columbia, Geological Survey of Canada, Map 1858 A.

Stott, D.F., 1983, Geology, Northeastern British Columbia, Geological Survey of Canada, Map 1032

Wiltschko, D.V., Corbett, K.P., Friedman, M. and Hung, J-H., 1991, Predicting Fracture Connectivity and Intensity within the Austin Chalk from Outcrop Fracture Maps and Scanline Data, Gulf Coast Association of Geological Societies, Transactions, v. XLI, p. 702-718.