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

Greg J. Dean
Department of Geoscience, University of Calgary, Calgary, AB, Canada
gjdean@ucalgary.ca

Deborah A. Spratt
Department of Geoscience, University of Calgary, Calgary, AB, Canada

Charles M. Henderson
Department of Geoscience, University of Calgary, Calgary, AB, Canada

Introduction

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 was 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 1. This study will focus on fractures measured at the Ganoid Range in the southeast portion of the field area.

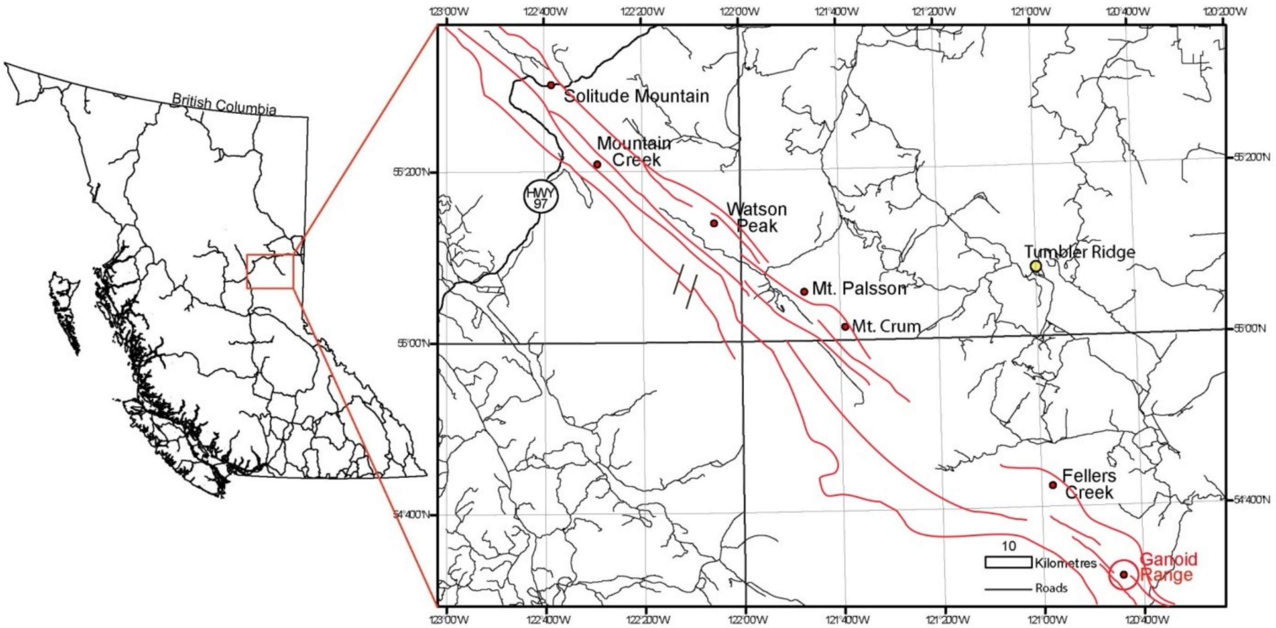

Figure 1: Map of study area with field locations denoted by red dots (modified from Henderson *et al.*, 2010). Red lines represent locations of thrust faults (modified from Stott, 1983, McMechan, 1994 and McMechan and Thompson, 1995), showing that several thrust sheets have been sampled.

Fracture Analysis Data

Understanding the influence of fractures generated within the fold-and-thrust belt on reservoir quality is of major significance. Fractures are the representation of a surface or zone of failure by any non-sedimentary mechanical discontinuity. The use of outcrop data for analysis of these features aides in their characterization through the use of orientation, size, density and intensity (Feltham, 2005). The same analysis has been applied to fracture data collected at all field sites noted in Figure 1.

Fracture results from linear scanlines show eight main fracture sets within the Ganoid Range (Figure 2). The 329° Set is oriented parallel to the regional fold axis trend (154°) and the local fold axis trend (162°), the 290° Set is oriented oblique to the 329° Set and formed as a conjugate. 310° and 350° trending fractures formed conjugate to the σ_2 direction and also oblique to the 329° Set. Fractures within the 030° and 089° sets are oriented at high angles to the regional fold axis trend and conjugate to the principal stress direction (σ_1). Those fractures oriented parallel and conjugate to the regional and local fold axis trends generally appear on the limbs of the folds whereas fractures oriented normal to σ_1 dominate in the hinge zones.

Fractures within studied outcrop of the field area, including those from the Ganoid Range, were not for the most part perpendicular to bedding and are therefore not thought to be related to early folding or bed flexure, but rather to later stage fold tightening (Feltham, 2005). Subsurface fractures from wells 12-20 km to the east do not show this relationship however. Fractures from these wells show domination by two main sets oriented conjugate and at high angles to the σ_1 direction (030° and 008°). 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 rather than fold tightening as in outcrop.

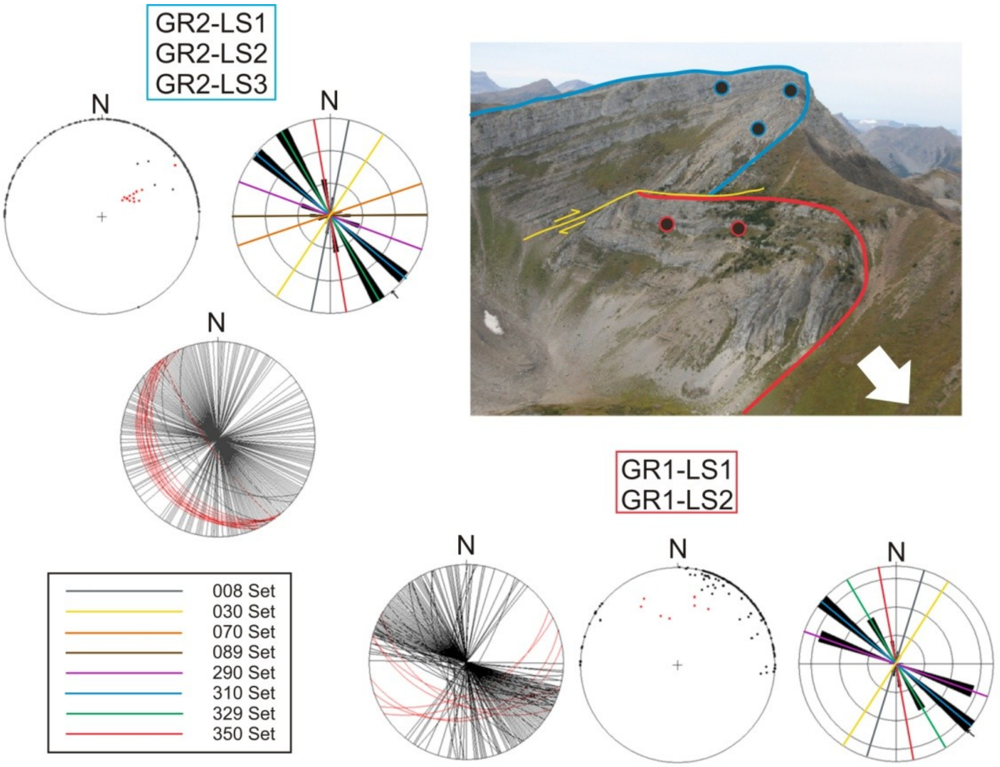

Figure 2: Ganoid Range structure (white arrow points north), with linear scanline fracture orientations; note GR1 measurements from lower fold and GR2 measurements from upper fold.

Fracture densities were calculated from both linear scanlines and circular window scanlines using the equations derived from Mauldon *et al*., 2001. The Terzaghi correction was applied to these data from linear scanlines to calculate true fracture densities and was normalized against densities from circular window scanlines. Sample fracture set density and interval fracture densities (0.5 and 1.0 m) are represented in Figure 3. Fracture densities were widely variable across the linear scanline. Many intervals along the 0.5 and 1.0 metre spacing lines are dominated by 310° fractures with maximum frequency of 44 (0.5 m) and 33 (1.0 m) fractures per metre.

Sample normalized fracture densities can be found in Figure 4 and demonstrate the large increase in fracture density and intensity near the hinge zone (4A) when compared to that from a limb of a fold (4B). Additionally the 350° and 310° fracture sets dominate in the hinge zone scanlines as they did within linear scanlines.

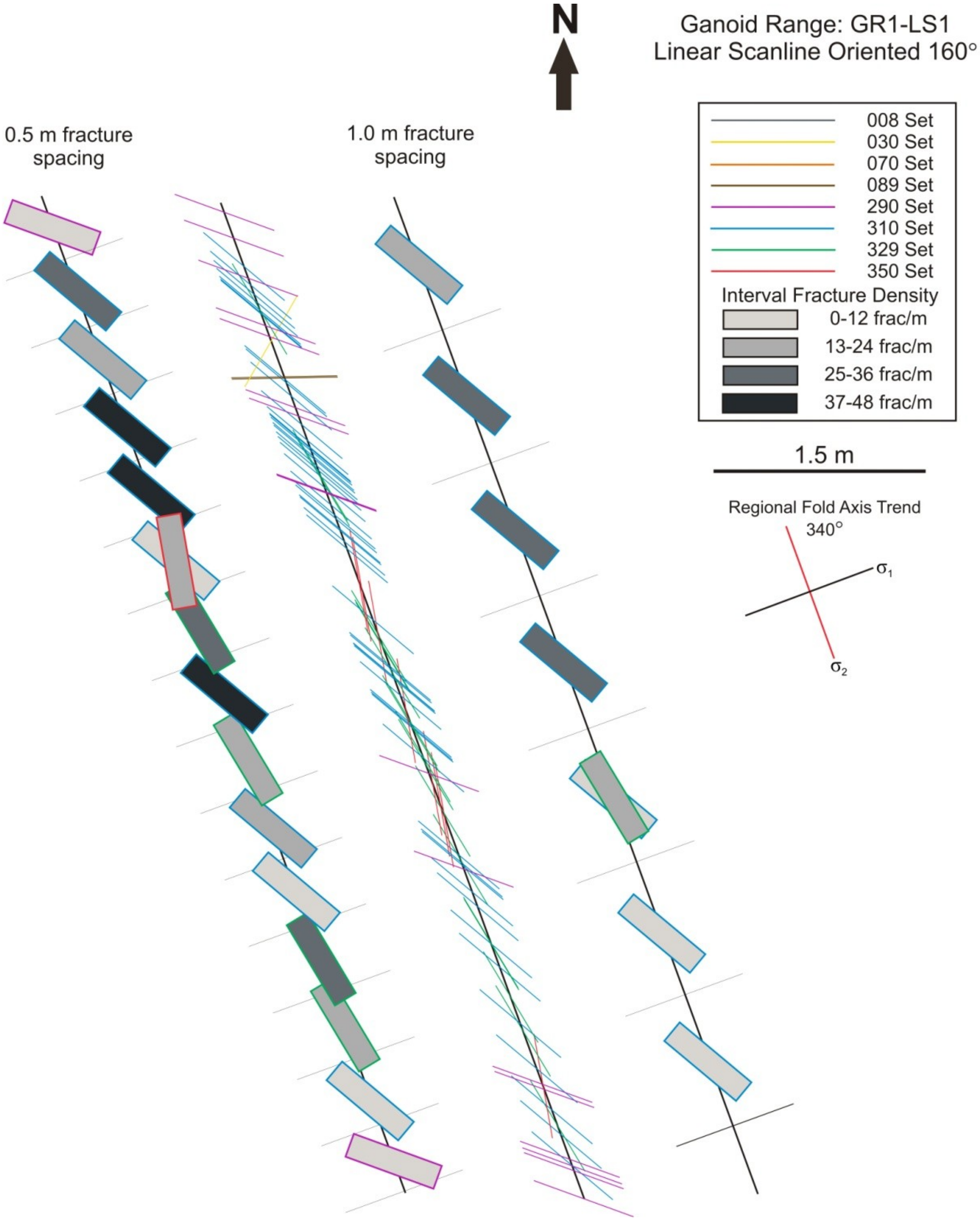

Figure 3: Fracture distribution and interval fracture densities along a linear scanline (GR1-LS1); note the rectangular box outlines of fracture spacings show the dominant fracture orientation for that interval.

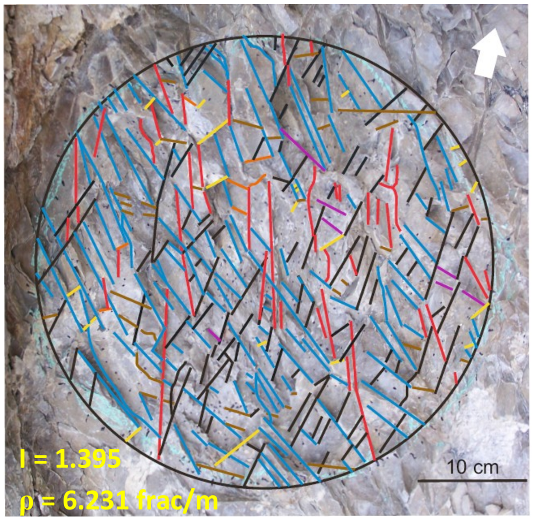

Figure 4A: Circular window scanline (GR2-CSL2) from the hinge zone of the upper fold, demonstrating increased fracture density and at high angles to σ_1 fractures; white arrow points north.

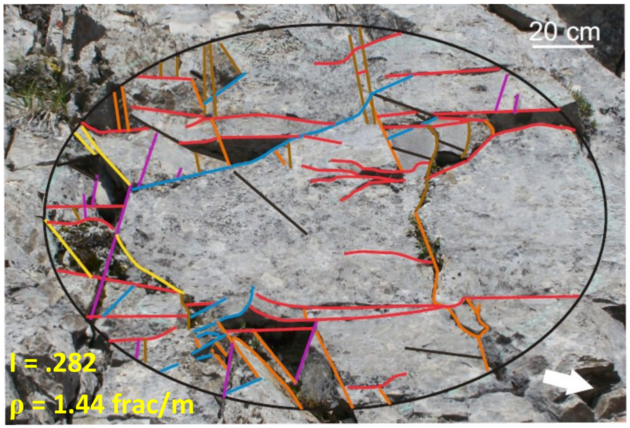

Figure 4B: Circular window scanline (GR1-CSL1) from the limb of the lower fold showing lower fracture density and fractures parallel to regional fold axis tend.

Conclusions

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.

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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, 26 pp.

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

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., 1995, Geology, Wapiti Pass, West of the Sixth Meridian, British Columbia: Geological Survey of Canada, Map 1872A.

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.