Structural Geology and Fracture Analysis of Grotto Canyon, Alberta

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Summary

Grotto Canyon was chosen because the large variety of structures, fracture data, lithologies, veins types, and different temperature regimes within this area make it an important analog for what may be occurring in the foothills of compressional belts around the world. This study analyzed a variety of different features that were ultimately used for three different purposes. The first goal of the project was to test the validity of the new Circle-Window method by comparing it to the traditional Scanline technique at the same location on the outcrop.

The second goal of the project was to determine the controls of the basement structure in this area on the surface geology, subsurface geology, and on the density and orientation of the fractures. Balanced cross-sections and the fracture data analysis were used to look for correlations that are not consistent with the surface structural geometries.

The third and most important goal was to produce a predictive model that can be used to locate naturally fractured reservoirs in compressional tectonic belts.

Introduction

Grotto Canyon near Canmore, Alberta has good exposures that illustrate many structurally complex features and fracture systems within the Palliser Formation, making this area useful for creating a predictive model for the nearby Foothills. The area illustrates a variety of fabrics and structural features that range from the brittle to the ductile regime. Within this area there is a fault-propagation fold that dies out along strike, as well as primary and secondary folding, faulting, and shear zones.

In order to better define the relationship between these structural features, the lithology, and controls on the distribution and intensity of fracturing, the area was mapped during the summer of 2007. The mapping focused on three major aspects. The first aspect was to delineate the changing geometry of the fault-propagation fold as it dies out along strike along with a number of associated detachment faults. The second aspect involved using the Scanline and the Circle-Window fracture analysis techniques to quantify and describe fracturing in the area. Data collected included fracture filling, size, orientation, density, intensity, and cross-cutting relationships between different veins and in different lithologies. The third aspect of the project involved collecting a number of samples representing fault breccias, shear zones, fracture fillings, and lithologies for analysis in more detail in thin sections to determine their fabrics.

Theory and/or Method

The area between Grotto Mountain and the ridge of Gap Peak was mapped down to Highway 1A. This area is roughly 5 km in length and about 1 km wide. An entire summer was spent mapping dominantly within the Palliser Formation, but the Banff and Exshaw formations, the Rundle Group, and the Alexo Formation were also seen. The main features of interest were the structures, the locations and densities of the fractures in different layers of the Palliser Formation, the brittle and ductile features, and the collectable data for fracture analysis in the well exposed parts of Grotto Creek and Steven Creek.

Two methods of fracture analysis are used in this study area. The traditional Scanline method involves laying a tape along the length of an outcrop and determining its orientation. Then the position along it where each fracture intersects the tape, the orientation, length of the fracture, and the type of fracture are recorded. The Circle-Window method involves drawing a circle on the outcrop that encompasses at least 30 different fractures to make sure that the results are unbiased and statistically significant. Once the circle is on the outcrop, one counts the number of fractures that intersect the circle and the number of fractures that terminate within the circle. These two measurements should provide an accurate density and intensity of the fractures.

In order to test this new method of fracture analysis, the Circle-Window technique was used at the same location as the Scanline technique. The Circle-Window technique was also used in specific and various locations throughout the area where the Scanline method could not be used due to the limited size or accessibility of the outcrops. The specific locations were chosen to allow determination of the change in density and intensity of the fractures nearing different structural features, such as faults and shear zones, and on differently oriented surfaces, for instance horizontal and vertical surfaces, that were near each other.

Examples

The following two figures illustrate a few of the results gained from the fracture analysis done in the southern part of Grotto Creek. The first figure shows the densities (fractures/metre) calculated by the Scanline technique over four metre intervals. The blocks' colours represent the fracture densities within that area and their orientations are parallel to the dominant fracture strike within that interval. There is a clear trend in the southernmost part of the creek showing the regular orientation of the blocks and the location of a swarm (higher density area). The northern part of the creek shows no obvious pattern of fracture orientations or locations of swarms. This is most likely due to a number of shear zones and faults at this location. These trends indicate the dependence of the fracture systems on the local structures in the study area.

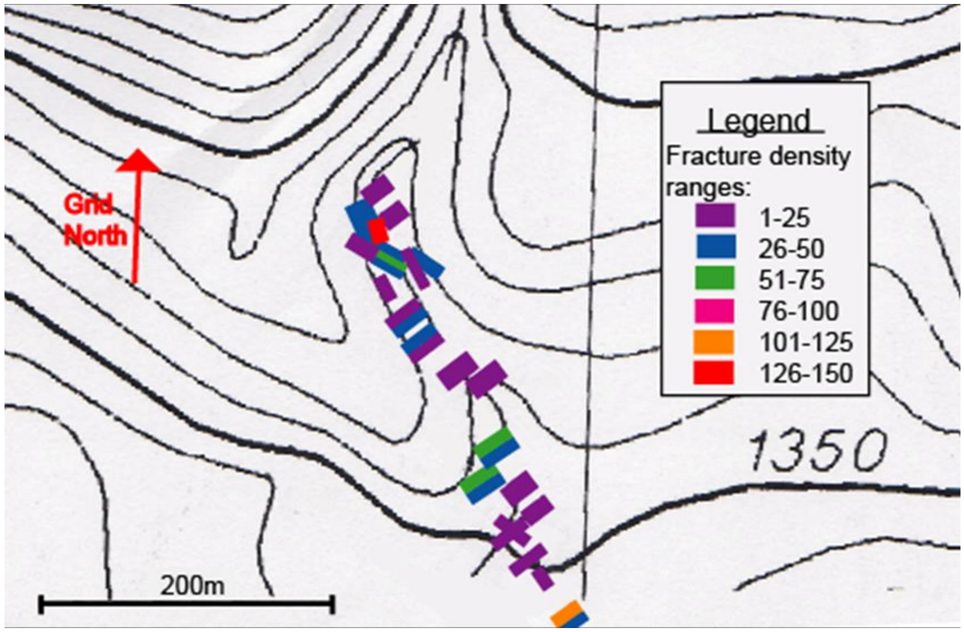

Figure 1: Densities (fracture/m) calculated from the Scanline technique over 4 m intervals. White areas represent no measurements or no outcrop. Rectangles are aligned parallel to the dominant fracture strike over that interval.

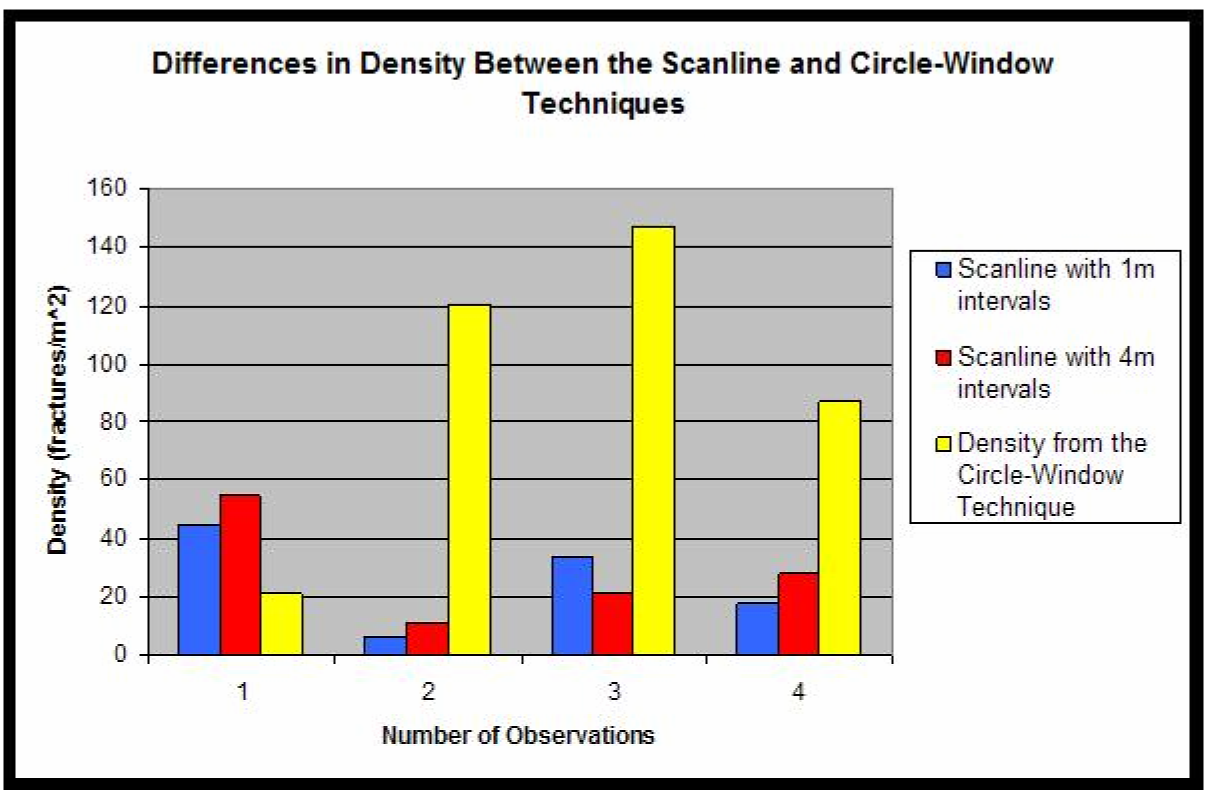

Figure 2: Densities (fracture/m) calculated for both methods were measured at the same locations on the outcrop.

The second figure displays the differences in densities calculated using the Circle-Window technique and the Scanline technique at one and four metre intervals. The Circle-Window technique is expected to have a higher calculated density (observations 2, 3 and 4) than the Scanline technique because it takes into account fractures less than 10 cm in length. Observation number one shows the opposite trend, which is most likely due to the circles being located in the lower density parts of the Scanline intervals. Overall the results are promising.

Conclusions

The deformation of the Palliser Formation, due to its burial near the brittle-ductile transition, is diverse and widespread. The brittle features range from faults to closed fractures, whereas the ductile features range from shear zones, to cleavage, to tension gashes and alteration zones, to tight folding. These features are obvious in the study area and tend to control the densities and orientations of fractures.

The fracture plane orientation data and fracture density/intensity data were used to determine the effects of compressional stresses and possible basement features on the surface and subsurface geology. Fracture data were rotated to unfold the folds so that fractures can be compared relative to folded bedding and unfolded bedding. The present day orientations of the fractures indicate a compression direction of 060 (or 230) degrees (if all fractures are related to folding) and a fold axis trend of 150 (or 330) degrees.

The fracture analysis data provided valuable information on the density and intensity of the fractures, and the frequency and structural positions of fracture swarms. The Circle-Window method increases the amount of data that can be collected within any study area. The method appears to be quite accurate and reliable and would greatly improve the efficiency and number of locations where fracture analyses can be performed. Further testing is required to determine the best circle size to use in a variety of different structural environments.

This study has increased our understanding of the deformation style of carbonate rocks in compressional environments buried to the brittle-ductile transition boundary and shows how mesoscopic structures vary as the larger scale structures change along strike.

Acknowledgements

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