FRACTURE SYSTEM ANALYSIS, QUETICO AND WAWA BELTS, KAWNIPI LAKE REGION, ONTARIO CANADA

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INTRODUCTION

Kawnipi Lake is located in the Quetico and Wawa belts of the Superior Province in Quetico Provincial Park, Ontario. The Quetico belt contains four lithologies in the Kawnipi Lake area, including granitic-rich migmatite (Agx), biotite-rich migmatite (Ap), Williams Lake quartz monzonite (Agp) and biotite schist rich migmatite (Apq). The Wawa belt has major alternating units of biotite schist and tonalite (At) as well as minor amphibolite inclusions and ultramafic units. Major structures found in the area include (from northwest to southeast) the Side Lake shear zone (Woodard and Root 1993), Williams Lake pluton (Wegmann and Allen, 1994), the Burntside Lake fault (Baten, Baptiste and Houghton, 1994), and several recently identified shear zones and folds including the continuation of the Dack Lake shear zone (Endsley and Hayes 1994). Kawnipi Lake's length, orientation and wealth of displayed structural features that might influence fracturing make it ideal for fracture analysis on a large (20km) scale. The outcrops lie vulnerable to the yearly thaw and freeze of the lake which helps expose and accentuate fractures for identification and measurement.

The breadth of this study goes beyond surveying systematic or regional fracture arrays. Other key issues include the examination of joints in various lithologies in both the Quetico and Wawa belts and the determination of how localized structures like shear zones influence the pattern of fractures. This study attempts to link prominent fracture sets in the area of Kawnipi Lake to regional tectonic events. Establishing such links is a difficult task, dependent upon sampling technique and ability to establish definite sets and age relationships, but this analysis offers some possible causes for fracturing in the Kawnipi Lake region.

METHODS

In conducting this study, it was necessary to establish methods which would identify and describe the systematic joint systems of the Kawnipi Lake area while minimizing bias. The methodology instituted for this analysis attempts to overcome bias in measuring and to provide a sufficient amount of data by measuring all of the fractures in a given area, not simply the "prominent" sets. At each outcrop, every systematic fracture in an area averaging 20m^2 was measured. This survey generally yielded forty to fifty measurements per station. The only fractures which were excluded were those which were obviously non-systematic, joints which were rounded due to erosion or curved due to exfoliation. The measurement of strike and dip of the fracture surface was taken with a Brunton quadrant compass and recorded. By using 1% contours of pole density, systematic, prominent sets were later distinguished from fractures which were non-systematic.

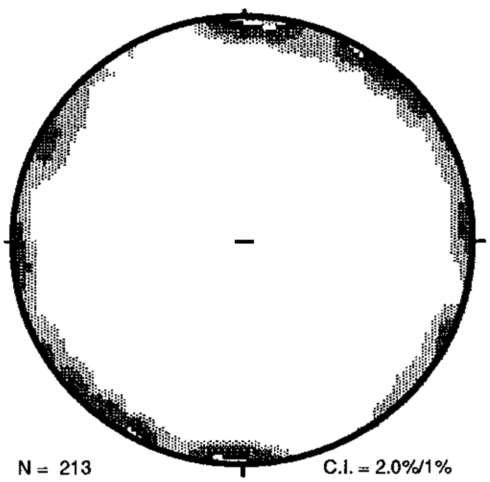
Additional observations about the character of the fractures and the outcrops were indispensable in studying Kawnipi Lake's fracture systems. In an attempt to establish the existence of distinct sets, crosscutting relationships were identified at each station. Additionally, structures associated with fracturing were examined. Slickenside surfaces, quartz veins and igneous dikes all provide essential information about the dynamics and age of the fracturing, so their presence was noted at each outcrop. Finally, information about the lithology and foliation, essential for establishing a regional geologic history was recorded.

Because the study hoped to gain a regional perspective of fracture systems, data had to be collected across the entire Kawnipi Lake region. Ideally, an analysis such as this would measure fractures at every outcrop, but time constraints made this impossible. Instead stations were set on a northwest to southeast transect at approximately one kilometer intervals. Outcrops were chosen on the basis of accessibility, presence of joints and the size constraints outlined above. Usually outcrops which afforded a three dimensional view of the fracture surfaces were chosen in order that the true strike and dip of the fracture planes could be determined. Where unusual structures existed, extra stations were utilized to obtain a more accurate picture about the nature of fracturing in the area. These areas include Kawa Bay where rocks were sheared, south of Rose Island near the Burntside Lake fault and Quetico-Wawa junction, and north of Kasie Island where the strike of foliation locally changed dramatically from N35E.to approximately N80E. Since the study also examined the affect of lithology on fracturing, stations were located whenever the transect appeared to cross lithologic boundaries.

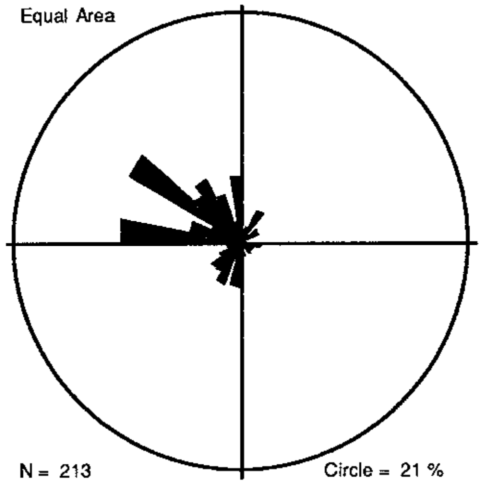
DATA AND OTHER RESEARCH

Data were collected at 78 stations along the 20km transect in an area of approximately 75 km^2. S_1 foliation is consistently N30E- N50E except for local variation at the northwest and southeast ends of Kawnipi Lake. A total of 2932 fracture plane measurements from 67 stations were recorded for evaluation. To facilitate analyzing data on the scale of Kawnipi Lake, the stations were divided into six sectors based on regional structures and topographic expression. Data within each sector was summarized for interpretation over the large study area. Virtually all sets dip sub-vertically which indicates that dip is not a significant factor for interpretation. Therefore, Rose diagrams may be used in conjunction with 1% contour plots for interpretation at a larger scale.

When the fracture data from each of these regions is compiled into a plot which covers the whole study area, two orientations of strike dominate: a set which strikes northwest-southeast at N60W and an east-west, N85W set. Sets striking N00E and N30W also appear throughout the Kawnipi region. The only substantial set which trends to the northeast in the Kawnipi fracture system is oriented at N30E.



1% Contours of Poles, Major Structure Sets
Kawnipi Lake, Ontario Canada



Rose Diagram, Major Structure Sets
Kawnipi Lake, Ontario Canada

These results are further substantiated by other work done to the south. Research at Keewatin Lake in 1993 found "two well developed sets of fractures" including a "N60W striking joints set" and a "N35E striking fault zone."(Sak and Humm, 1994) Work done farther to the southwest in Kashipiwi and Keefer Lakes determined "two joint sets(N60W and N30W)" were younger than the side lake shear zone(Troolin and Sanchez, 1993). A previous fracture study completed by Parkin and Ishimatsu (1992) near Yum Yum Lake, reported the existence of N50W, N40W, N80W, N30E, E-W and N-S sets.

DISCUSSION

The primary goal of this study was to describe and interpret the fracture system of the Kawnipi Lake region. Through a painstaking process of data collection and processing, the major fracture sets in the Kawnipi system were determined: N60W, N30W, N85W, N00E and N30E with sub-vertical dips. This information must be examined in light of known lithologies, structures and deformational events for further description and interpretation of causation and chronology.

The fracture system remains largely consistent across the Quetico-Wawa belt junction, the Burntside Lake fault, the Williams Lake pluton and the shear zones in Kawa Bay. One might expect that the trends would be somewhat altered in these areas, but there is no evidence in our analysis that any change occurs. As with structure, lithology has very little influence on the fracture system. The major constituent sets of the system cut across all lithologies and are found in both belts. Because the sets are present in all rock types, one would surmise that the fracture systems observed in the Quetico were created by stresses after emplacement of all the major lithologies. The one notable exception would be the diabase dikes found around Kawnipi Lake which exhibit joints perpendicular to their cooling surface but lack the regional sets found in the country rock.

While the sets of Kawnipi's fracture system propagate in all lithologies, some fracture sets are more prevalent in a specific lithology. The regional foliation strikes about N30E, coincident with the orientation of a major fracture set. This association is generated by units of biotite schist where well defined fractures dominate the outcrops and occur sub-parallel to the primary foliation. Similarly, horizontal to sub-horizontal irregular jointing occurs exclusively in outcrops of tonalite in Murdoch and McVicar Bay. A closer examination of the outcrop shows that a moderately developed, sub-horizontal S_2 foliation exists in the stacked tonalite. The sub-horizontal fractures could be related this secondary foliation and vertical extension during exhumation of the Canadian shield. The fracturing in these rocks appears to exploit planes of weakness along foliation as do shear structures in the region.

Linking fractures to specific tectonic events is difficult at best. However, several deformational events in the geologic history may be eliminated as possible causes with some degree of certainty. Fractures are brittle structures which clearly post date the ductile deformation. Therefore, stresses associated with the formation of the Quetico-Wawa belt junction, the Silence Lake shear extension, and Dack Lake shear zone are unlikely explanations of the fracture sets because each involves ductile deformation. The event which produced the Side Lake shear zone may have affected the region; however, the unique characteristics and semi-ductile nature of the shear zone suggest that it would have a minor if any connection to the regional fracture sets.

Throughout the history of the Kawnipi Lake region, many stresses have been acting in a northwest-southeast orientation, potentially explaining the existence of the N30W, N60W E-W and N-S sets. It is tempting to identify major sets which trend 60 degrees apart as conjugate shear pairs, but with the limited sense of motion data available, such analysis would be speculative. Still, the prominence of the northwest-southeast fractures suggests stress acted at this general orientation. One cause of the fractures could be the Trans-Hudson orogeny which generated this stress field in the area of Kawnipi Lake. At 1.8-1.9 BA, the Hearne and Wyoming provinces collided with the Superior province(in which we find Kawnipi Lake) exerting "a northwest-southeast directed compression"(Sutcliffe and Bennett, 1294). Past studies describe small displacement northwest-trending faults associated with the Vermillion faulting event to the south. Northwest trending slickenside surfaces and joint sets are found in the Kashipiwi and Kawnipi Lake regions cross-cutting the Burntside Lake Fault and these fractures could be representative of the younger Vermillion faulting event. (Kahmbu and Russin, 1993, Troolin and Sanchez, 1993, Sak and Humm, 1994)

The northwest sets could be related to extensional tectonics as well. The most convincing evidence for this hypothesis are Kawnipi's diabase dikes, trending from N-S to N60W and cutting across the Burntside Lake fault. Because of their lack of metamorphism and mineralogy, Root and Woodard (1994, personal communication) interpret Kawnipi's the dikes as Keweenawan, related to the 1.1 billion year old Mid-continent Rift. Since rifting, the Canadian Shield has been uplifted and exhumed. The degree and mechanism of uplift is disputed, but such a doming and exhumation event would produce an extensional regime laterally and vertically as well.

The difficulty in linking the Kawnipi Lake fracture system with larger scale tectonic events is partially due to the inability of the study to develop a relative age relationship between sets. One method that was invoked was an attempt to establish crosscutting relationships. Unfortunately, in the Kawnipi Lake region, very few fractures display enough offset to hypothesize age relationships. The study also pursued an examination of hematite staining on fractures surrounding the Burntside Lake fault. Logically, the fracture surfaces which were present during the hydrothermal event would have been exposed to hematite staining while those which followed the Burntside Lake event would lack staining. Unfortunately, the outcrops in this area were flooded by hematite staining, making such analysis impossible. Age relationships may have been clarified through the use of quartz veins (Goldstein and Marshak, 1988). The presence of material in one fracture and the absence in another means the fracture flooded with quartz predates the one without it. During the analysis , this method was considered as a possibility, but never utilized effectively. In reconsidering the study, this method would have been a fairly simple yet effective way to obtain the much needed age relationships.

CONCLUSION

Through intensive data collection and analysis five statistically significant fracture sets of regional extent were identified in the Kawnipi Lake Region: N60W, N85W, N00E, N30W, and N30E. These sets do not appear to be affected by changes in lithology or regional structures. However S_1 foliation appears to influence the N30E set which exploits mineralogical planes of weakness and S2 foliation appears to direct fracturing in some tonalite. The brittle fracture sets post-date Archean ductile deformation events. Fracture set formation may be related to several brittle deformation events including the Burntside Lake Fault, the Vermilion faulting event, the Mid-continent rift and regional uplift of the Canadian Shield. Several models of fracture formation may be proposed based on conjugate pair relationships and compressional versus extensional events. Relative ages of joint sets may be undeterminable due to omission of certain essential observations in the field. Further background research and statistical analysis may support one or several of the models proposed.

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