# Joint Analysis Along the Junction of the Quetico and Wawa Structural Belts, Quetico Provincial Park, Canada

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## INTRODUCTION

For nearly three weeks, we studied areas near Yum Yum Lake in Quetico Provincial Park, Ontario. This area straddles the proposed Quetico-Wawa belt junction (Woodard and Weaver, 1990). This junction is the boundary between two different lithologies which are thought to be two Archean terrains. These terrains consist of various metavolcanic and metasedimentary rocks. The boundary between the terrains crosses the Minnesota- Ontario border west of United States Point and trends 20 km to the northeast to the Yum Yum Lake area. A map of the study area appears in the project's summary, written by Dr. Henry "Chief" Woodard (Fig. 1, this volume) (Woodard, 1992).

For our individual project, we wanted to test for systematic differences between joint sets on either side of the proposed Quetico-Wawa boundary. We tried to find relationships between joint sets and possible faults, between joint sets and lineaments on aerial photographs, and between joint sets and geological structural settings. These observations were then geometrically related to the Quetico-Wawa junction in search of a common origin.

## METHODS

Our process of collecting data was to measure the strike and dip of systematic, dominant joint surfaces in outcrops along the lakeshores. These lakeshore outcrops were the most useful because the more inland outcrops were covered by a thick surface of lichen which made it difficult to measure jointing.

We measured the joint surfaces which were aligned in parallel sets and clearly opened. We recorded the measurement of one representative joint of each set. A set of ten joints at one outcrop translated into one data entry, as did a set of three joints at the same outcrop. If the distiction was as obvious as the above ten to three ratio, we would note which joint set was the strongest. However, no matter how strong or weak a joint set was at a particular outcrop, it received a single data entry. This imbalance constitutes a problem because the overall data is not weighted towards the most prominent joints. For example, in a stereonet graph, every joint set, despite relative prominence, would recieve a single plot. In order accomplish a more accurate representation, we would have had to measure and record every joint at every outcrop, and this would not have been feasible given our time constraints. Another problem in measurement was that some of the outcrops were cliff faces. In order to obtain a measurement, one of us had to lean out of the canoe and, while trying to balance and keep from capsizing, hold the Brunton compass steady enough to take an accurate reading before the wind blew the canoe away from the outcrop.

We used the Macintosh computer program *Stereonet v. 3.75 KW* to combine data from specific areas, looking for concentrations of points over a more general geographic area.

## DATA

We have divided our measurement area into five major geographic zones- Southwest Yum Yum Lake, Northeast Yum Yum Lake, "No-Name" Lake, McNiece Lake, and Grey Lake (Fig 1, Woodard, 1992). A N20E lineament runs through the approximate center of Yum Yum Lake. We arbitrarily used this lineament to split the lake into two geographic sections: northeast Yum Yum Lake and southwest Yum Yum Lake. All the areas are further broken down according to their location relative to the Wawa-Quetico belt boundary.

The figures used here are 1% area contours, the shaded areas indicate the highest concentration of points on a stereonet and thus represent the poles to major joint sets. All joint sets are listed in order of prominence.

The strikes of the major joint sets near the southern end of Yum Yum Lake, in the Quetico side, are approximately N40W, N40E, N75E, N15W, and N80W . The joint sets in the WaWa belt in the same area are N40W, N50W, and N55E .

The joint sets near the northern end of Yum Yum Lake, northeast of the N20E lineament which represents the boundary between the Quetico and Wawa belts, are approximately N45W, N75W, N40E, and N50E (Figure 1) . On the Wawa side, the joint sets are approximately N65W, N40W, N50W, N45E, and N35E .

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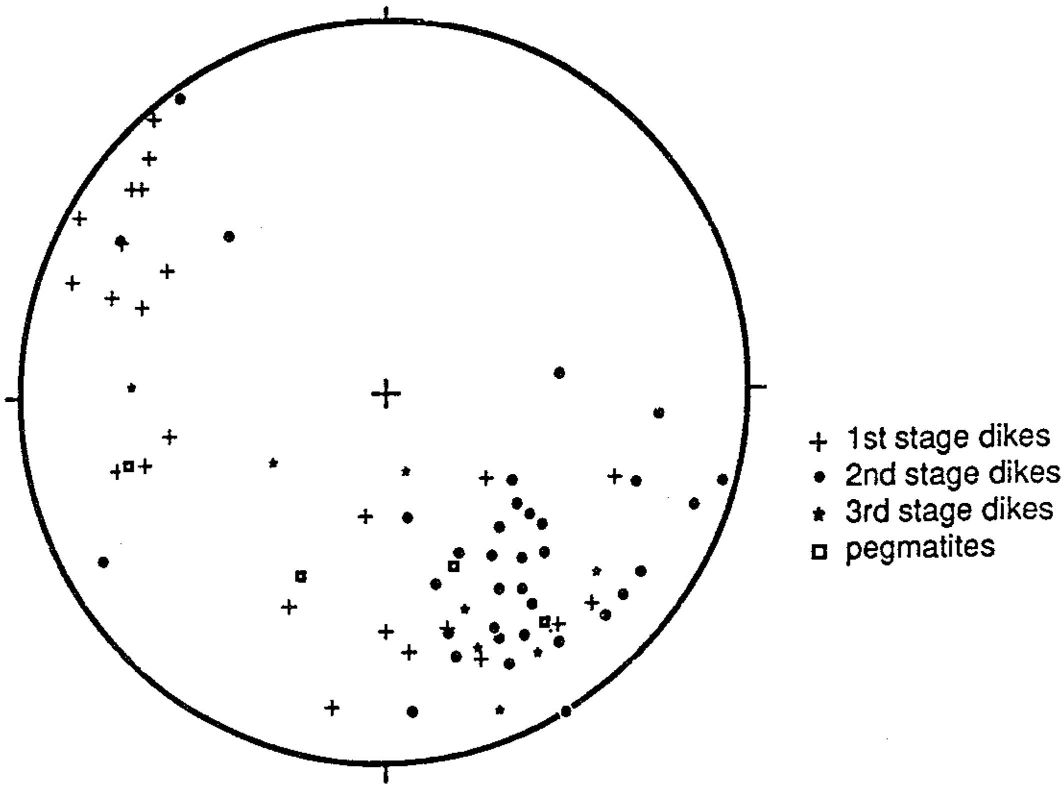


Figure 1. Stereonet showing the equal area lower hemisphere projections of the poles to planes of the trondhjemite dikes and pegmatites. Different generation of dikes were determined by observed cross-cutting relationships, composition, and groupings on this stereonet.

"No-Name" Lake is located to the northwest of Yum Yum Lake and, with Yum Yum Lake, forms a part of a major lineament, N45E. The joint sets on the Quetico side of the boundary are approximately N40E, N30E, N40W, N25W, and 65W (Fig. 2). The joint sets on the Wawa side are approximately N65W, N55E, N50W, N70W, north-south, and east-west.

McNiece Lake is located to the northwest to "No-Name" Lake entirely in the Quetico belt. Here there are four major joint sets (N50W, N65W, east-west, and N05W).

Grey Lake is located to the east of Yum Yum Lake, entirely within the Wawa belt. Here there are four major joint sets (N45W, N60E, N30E, and N80W) (Fig.3).

In each of the study areas there is a high-angle (65-80 degrees) northwest trending joint set, a mid-angle northwest (40-50) trending joint set, and a mid-angle northeast (40-50) trending joint set..

The major lineaments of the area are the Quetico-Wawa boundary (N50E) and the Burntside Lake Fault zone (N25E). There are numerous smaller lineaments which trend in directions that are subparallel to the two major lineaments. There is a minor lineament south of Yum Yum which trends at N85W and is thought to be a fault (Godfrey and Jennings, 1991). A small set of N45W lineaments are above Grey Lake. There is a N60E trending lineament in the northeast bay of "No-Name" Lake.

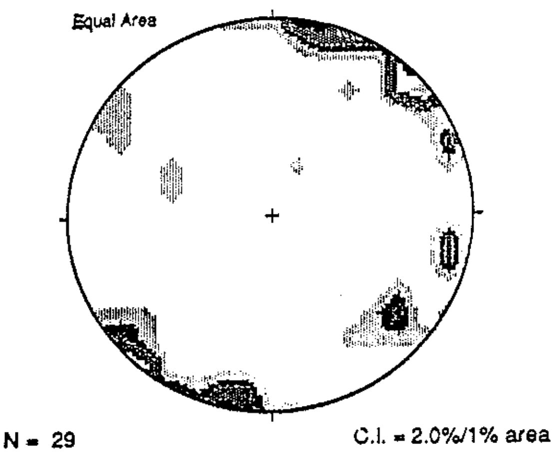


**Figure 1.** 1% Area Contour summarizing joint data collected in the Quetico belt in northeast Yum Yum Lake

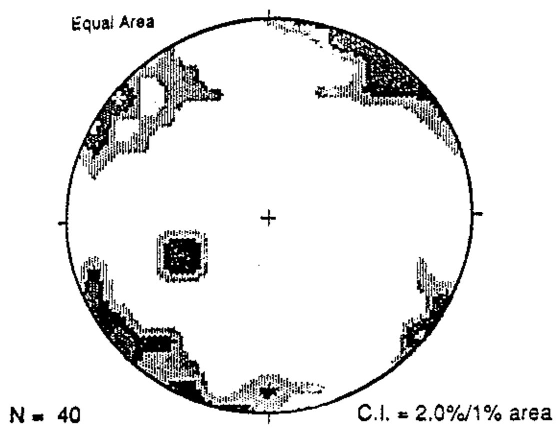


**Figure 2.** 1% Area Contour summarizing data collected in the Quetico belt in "No-Name" Lake

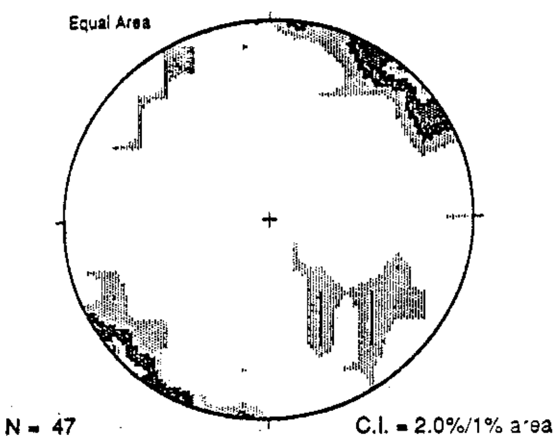


**Figure 3.** 1% Area Contour summarizing joint data collected in the Wawa belt in Grey Lake

## INTERPRETATIONS

Joints, while being the most common structure in geology, are the most poorly understood (McClay, 1987). They are generally thought to be products of brittle deformation (Pollard and Aydin, 1988).

Assuming that joints are exclusively the product of brittle deformation, the joint sets in the Yum Yum Lake area are relatively young. Evidence of brittle deformation is usually eradicated by subsequent ductile deformation. In our area of study, evidence of two, possibly three, major ductile deformative events exist (Chastain and Kolinski, 1991). The joints had to have opened, if not formed, at a later time.

The joints also opened after all intrusive events. The joints cut all dikes and veins as cleanly as they cut the country rock. Possibly, the reason why there are no well-formed joints older than the dikes and veins is that the dikes and veins intruded into the older joints, forming along the past fracture surfaces.

From the above relative chronology and the nature of jointing, we know that the joints result from late stage brittle deformation. The largest source of late-stage brittle deformation in the area is the Burntside Lake fault system. It is a logical assumption that at least some of the jointing was produced by stress and strain related to the Burntside Lake Fault zone.

The Burntside Lake fault extends from northern Minnesota into the Ontario portion of the Canadian Shield. The fault and its numerous splays are characterized by a red stain, the product of hydrothermal alteration. The Burntside Lake fault has had a large influence on topography and geography. For example, Kashiapiwi Lake, elongated for 9 km., occurs along the fault zone (Woodard and Weaver, 1990).

The northwest end of McNiece Lake is a series of cliff faces which roughly parallel Kashiapiwi Lake. The faces of the cliffs are slickensided, stained red, and oriented at N25E. The cliffs are cut by an extensive, dominant joint set which strikes at N70W, almost perpendicular to the cliff faces. This high angle northwest-trending joint set is ubiquitous throughout the McNiece Lake area and it is always the most prominent of the joint sets in outcrop. But, nowhere does it appear as strongly than at the northwest end of McNiece Lake. We believe that the cliff face at the northwest end of McNiece Lake is the trace of a splay from the Burntside Lake fault and that the N70W trending joints found at the cliff face are direct results of the Burntside Lake fault. We labeled this joint set J1. We assert that the high angle northwest trending joint sets throughout the area are also related to the Burntside Lake fault zone and are possibly all part of the same joint set. J1 can be seen on Figure 1 as two black bulges almost on the vertical extremes of the stereonet.

In Grey Lake in the Wawa belt, as in the entire study area, a high angle (80 degrees) northwest-trending joint set is present. We believe the joint set correlates to a lineament (observed on an aerial photograph) which occurs south of Yum Yum Lake. The lineament roughly trends N85W. If the joint set around Grey Lake is indeed J1, the lineament evidences the large scale deformation caused by the Burntside Lake Fault.

In the McNiece Lake area we observed another joint set. It strikes to the northeast and appears on the stereonet with only the slightest of traces. But, at a few outcrops, we judged it to be cleanly opened and prominent. Thus, we gave the northeast trending joint the name J2. At all of our field stations, we consistently found a mid angle northeast striking joint set. Just as we used its pervasiveness to hypothesize that J1 trends throughout the region, we assert that J2 is a major regional joint set (J2 is strong in Figure 2).

The strongest lineament or topographic feature which has a strike parallel to J2 is the belt boundary. Perhaps a relationship exists. If the docking of the belts was brittle-ductile and the joints opened after the ductile deformation, then the mid-angle northeast trending joints could be the result of the belts' junction.

Besides J1 and J2, a possible third joint exists. In each of our geographic sub-sections, there is a joint set which has a mid angle (high thirties to high forties) northwest strike. We call it J3 (Fig. 3 represents J3 the best). J3 occurs roughly at a 90 degree angle to J2. This perpindicular relationship hints that J2 and J3 may be congugate joint sets.

The major joint set in Grey Lake strikes N45W. On an aerial photograph of this area, we observed lineaments which trend parallel to this joint set. At the outcrops where we measured the joint set, we found no evidence suggesting faulting. We suspect that the lineaments are also not faults as we can detect no offset on the aerial photograph. If, indeed, there is no faulting in the area, it is possible that these joints are related to the Quetico-Wawa boundary which forms the Yum Yum Lake-"No-Name" Lake lineament. We have no evidence for this other than the fact that these joint sets form lineaments which are perpendicular to the boundary and that the lineaments do not seem to cross the boundary. Similar to our assertion about J2's relatioship to the belt boundary, our speculation about J3's genetic history rests on dubious evidence. In order to find a definitive answer, further research needs to be done.

Two of our geographic sub-areas, "No-Name Lake" and South Yum Yum Lake on the Quetico side, presented problems to our J1, J2, and J3 hypothesis. Both sub-areas gave stereonet contours which showed that J1, J2, and/or J3 were not the major joint sets within the particular sub-areas.

However, we believe that J1, J2, and J3 have a strong presence in the "No-Name" Lake area. Around the "No-Name" Lake's northeasternmost bay, there is a curved lineament which trends at approximately N60E. Without the measurements from northeast "No-Name" Lake, the stereonet contour plot derived from the measurements taken around the rest of the Quetico side of the lake clearly and only shows J1, J2, and J3. Across this lineament, the strikes of the joint sets change radically. Perhaps the lineament occurs along a fault.

The zone with the most diffuse stereonet contours is the one from the South Yum Yum Lake area, in the Quetico side. In this geographical zone, there are numerous, low-angle northeast-trending lineaments (possible splays of the Burntside Lake fault?) and a fault which is roughly parallel to the belt junction (Godfrey and Jennings, 1991). Furthermore, the zone is sandwiched between the two major lineaments. One might expect that the diverse stresses from the different generations of folding and faulting would produce chaotic jointing.

We have developed a relative chronology for the joint sets in this area based upon observations made around McNiece Lake. J1 and J3 are clearly the youngest of the joint sets, they cut J2 at numerous outcrops . We were not able to tell which of J1 or J3 was older, therefore we assume that they formed at approximately the same time. Our observation that J2 and J3 formed at different times seems to contradict the possibility that J2 and J3 are a conjugate set. Finally, we found a late-stage fault, which trends at N15W and cuts J1 and puts an upper boundary on the occurance of the area's jointing.

## CONCLUSIONS

We chose a particularly difficult topic to research. Though joints are common and easy to locate in the field, they are near impossible to interpret. We only know a few things for certain-

The joints are relatively young.

The joints opened post-ductile deformation.

In McNiece Lake, J1 and J3 are younger than J2.

We can make a few assertions with some confidence-

J1, in McNiece Lake, is associated with the Burntside Lake Fault.

The N75W joint set in Grey Lake is the result of a minor fault.

The joint set orientations change when crossing a topographic lineament in northeast "No-Name" Lake in the Quetico belt.

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**The Relationship of Lithological Structures to the Quetico-Wawa Juncture, Area of Southwestern Yum Yum Lake in the Quetico Provincial Park, Ontario Canada**

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## Introduction

Yum Yum Lake, located in Quetico Provincial Park, is transected by the Quetico-Wawa belt boundary. The Archean Quetico and Wawa metamorphic belts of the Superior province are in contact along an obvious northeast-southwest lineament, along which Yum Yum lake has developed. The Quetico -Wawa belt boundary may represent two docked terrains (Percival, 1989). Sills of quartz monzonite, dated at 2656 Ma, intruded into the sedimentary and volcanic rocks of the Quetico belt. About the same time, tonalite sills were intruded into the sedimentary and volcaniclastic rocks of the Wawa belt. Following this was a period of folding and migmatization in both belts, with development of trondhjemite leucosomes, folds and foliation. They may be synchronous with the docking of the two belts (Woodard and Weaver, 1990).

The Vermillion Batholith (a leucogranite which is post-folding and post-migmatization, and later than the above noted quartz monzonite sills) was intruded into the Quetico Belt (Woodard and Weaver, 1989). The rocks in both the Quetico and Wawa belts are potassium metasomatized along the boundary (Woodard and Weaver, 1990). The potassium metasomatism found in the Wawa belt rocks is also related to the batholith. The Quetico belt may have a slightly higher grade of metamorphism than the Wawa belt rocks. There is a disagreement over the time it took from the sedimentation to intrusion of the batholith; Woodard and Weaver (1990) time the events as taking 200 to 300 million years, while Percival (1989) concludes that it took 15 million years.

The Burntside Lake Fault system, a brittle deformational event, crosscuts both belts and the belt boundary (Woodard and Weaver, 1989 and 1990). At Yum Yum Lake, the main trace of the system lies 2.5 km to the northwest in the Kashahpiwi Lake area.

The purpose of this project was to map in detail the various lithologic units across the Quetico-Wawa belt boundary, as well as to delineate the faulting possibly attributed to the Burntside Lake Fault system. The distribution of these units relative to the belt boundary may lead to a better understanding of the tectonic nature of the boundary.

## Methods

A beginning study of the area was done by canoe because of the easy access to lakeshore outcrops. This was to identify the varying rock units and to find problem areas such as brecciation zones and rock units in places where they were not expected. The next step was to look at these problem areas on an aerial photograph to see if there were lineaments in or near the areas. Then a pace and compass traverse was made perpendicular to the structural trends. Rocks on both sides of lineaments were studied and records of rock types, breccia, and fault surfaces (including slickensides), and other evidence, such as displacement to identify the lineament, were taken. Additional traverses by canoe and foot were made to follow contacts along strike and to follow at least one very large dike-like body of (Sg) located on the peninsula between the southernmost and middle bays on the southern part of Yum Yum lake. Stations were located on aerial photographs and information recorded in a notebook. At each station along traverses, as well as on lakeshores, the rock types were identified, and strikes and dips of the S1 and S2 foliations were measured. Also recorded were strikes and dips of the fault surfaces, joints, and closely spaced fracture sets, and bearing and plunge of slickensides. Descriptions of mineralogical change, grain size change, degree of migmatization, and amount and types of dikes were also included.