THE TEACHING OF STRUCTURAL GEOLOGY

PARTICIPANTS

Edward Beutner, Franklin & Marshall College
David Bice, Carleton College
Robert Burger, Smith College
Peter Crowley, Amherst College
Tekla Harms, Amherst College
Paul Karabinos, Williams College
Julie Maxson, Carleton College
Kevin Pogue, Whitman College
Samuel Root, College of Wooster
Christene Smith, Colorado College
Edward Spencer, Washington and Lee Univ.
Richard Stenstrom, Beloit College
Robert Varga, College of Wooster
Donald Wise, Franklin & Marshall College

GUESTS

W. D. Means, SUNY Albany
Rolfe Stanley, University of Vermont
Barbara Tewksbury, Hamilton College
Michael Williams, University of Massachusetts

Keck Workshop on the Teaching of Structural Geology

Smith College
3 - 5 March, 1995

H. Robert Burger, Department of Geology, Smith College, Northampton MA 01063

On the weekend of 3 - 5 March, 1995, eighteen structural geologists will gather at Smith College to discuss what materials should be included in a modern course in structural geology and how best to transfer this information to their students. Fourteen of the workshop participants are from Keck Geology Consortium colleges and four are guests. Prior to the workshop all participants are contributing a course syllabus, several of their favorite structural problem sets, a list of resources used in the classroom, and a catalog of materials not currently available that would be most useful in meeting instructional goals.

The plan for the workshop sessions are:

Session 1 - Topics: What should a modern structural geology course look like? What are the important skills, concepts, techniques we should be teaching? What do students need to know to compete well in the current job market?

Session 2 - Presentation: W. D. Means (SUNY Albany) "A Shear Zones Approach to Teaching Undergraduate Structural Geology"
Topics: Continuation of Session 1. What is a proper mix of topics, skills? How do we now convey this information?

Session 3- Presentation: Barbara Tewksbury (Hamilton College) "Structural Geology Without Lectures- - Strategies for a Hands-On, Investigative Structural Geology Course"
Topics: Improving pedagogy. Strategies for teaching structure lectures and laboratories. What are our best efforts? What works? What doesn't?

Session 4 - Presentation: Rolfe Stanley (Univ. of Vermont) "A System Dynamics Approach in Teaching Structural Geology"
Topics: Continuation of Session 3. What would one like to do if no external or internal restraints? What is the promise of cooperative learning and inquiry-oriented teaching?

Informal Session - Computer software demonstrations and hands-on opportunities. Other volunteered demonstrations.

Session 5 - Topics: What supporting materials would be useful to us? How to acquire them? Do they even exist? Are there any initiatives we can undertake? Planning for future initiatives.

Session 6 - Topics: Summaries. Conclusions? Wrap-up.

Based on the success of other Keck workshops addressing teaching of disciplines in geology and the pre-workshop enthusiasm and cooperation of all participants, this workshop promises to be equally exciting and rewarding.

STRUCTURAL CONTROL OF TOPOGRAPHIC LINEAMENTS LOCATED NEAR THE JUNCTION OF THE QUETICO AND WAWA STRUCTURAL BELTS, KAWNIPI LAKE AREA, QUETICO PROVINCIAL PARK, ONTARIO

FACULTY

Henry H. Woodard, Beloit College
Samuel Root, The College of Wooster
Daniel Askren, Georgia Southwestern College

STUDENTS

Kevin Allen, Virginia State University
Kia Keynse Baptist, Ohio Wesleyan University
Soyini Baten, Amherst College
Martha Burrows, Georgia Southwestern College
Angela Dalke, College of William and Mary
Erin Endsley, Beloit College
Shannon Hayes, Beloit College
Jennifer Houghton, College of Wooster
David Kinner, Amherst College
Dawn James, Franklin & Marshall College
Willard Morgan, Williams College
Karl Wegmann, Whitman College

STAFF

J. Luke Blair, The College of Wooster
Jeff Cook, Beloit College
Robert Masters, The College of Wooster
Peter Parham, Camp Manager

STRUCTURAL CONTROL OF TOPOGRAPHIC LINEAMENTS LOCATED NEAR THE JUNCTION OF THE QUETICO AND WAWA STRUCTURAL BELTS, KAWNIPI LAKE AREA, QUETICO PROVINCIAL PARK, ONTARIO

HENRY H. WOODARD
Department of Geology
Beloit College
Beloit, Wisconsin 53511

SAMUEL ROOT
Department of Geology
The College of Wooster
Wooster, Ohio 44691

DANIEL ASKREN
Department of Geology and Physics
Georgia Southwestern College
Americus, Georgia 31709

Kawnipi Lake occupies a 22 km. long, northwest southeast-trending, S-shaped depression which transects the regional structural grain of the underlying Archean rocks (Fig. 1). In a traverse southeastward from the northwest end of Kawnipi Lake the following major structural lineaments are encountered: 1) Side Lake shear zone, 2) Burntside Lake fault, 3) Quetico-Wawa subprovince junction, 4) A possible extension of the Isabella Lake-Silence Lake fault, represented by a band of mafic and ultramafic rocks, and 5) Dack Lake-Kawa Bay ductile shear zone (Fig. 1). All of these lineaments trend northeast-southwest in the vicinity of Kawnipi Lake. The northwest end of Kawnipi Lake basin is fault controlled while the central section is eroded along the crest and flanks of tight F_1 folds which have been bent and rotated into their present position by a process which is here called "backshoving" (see following description).

The Side Lake shear zone was originally recognized by Woodard and Weaver (1990) and described more fully by Woodard and Root (1993) in the area along Kahshahpiwi Lake. Although no mapping has been done along the zone between Keefer Lake on the southwest and Kawnipi Lake on the northeast, the Kahshahpiwi drainage between these two lakes forms a well-defined lineament on aerial photos. Where this lineament crosses the northwest end of Kawnipi Lake there exists a well-developed shear zone. This shear zone differs from the Side Lake shear zone further southwest at the type locality. At Kawnipi Lake the zone is only a few hundred meters wide (Wegmann and Allen, this volume), is steeply dipping to the northwest, exhibits left-lateral sense of shear, and lacks the pervasive slickensides and slickenlines so characteristic of the Side Lake shear zone further to the southwest. If the aerial photo interpretation connecting the two areas ultimately proves to be correct, then it is clear that the Side Lake shear zone in the Kawnipi Lake area has changed from a gently dipping zone of more brittle deformation with a consistent left-lateral sense of shear, to one of steep dip and more ductile deformation, but still with left-lateral shear sense. In the vicinity of Side Lake the shear zone cuts the post-folding Lac La Croix leucogranite (2662±5 Ma) and appears to terminate against the junction of the Quetico and Wawa belts (Woodard and Weaver, 1990). In the Kawnipi Lake region the northeast strike of the shear zone progressively bends toward the east until it reaches an approximate east-west position. This strongly suggests that the shear zone may again intersect the Quetico-Wawa junction further to the northeast in the vicinity of Cache River and Ferguson Lake.

The Burntside Lake fault can be traced continuously from the type locality in Minnesota northeastward for approximately 60 km, where, just south of Rose Island in Kawnipi Lake, it terminates against the older Quetico-Wawa junction (Baptist, Baten and Houghton, this volume) (Fig. 1). Everywhere along its trace the fault shows evidence for brittle rupture with the common development of porous fault breccias, slickensides, and slickenlines. The dip of the fault is always steep but in the vicinity of Point Lake it dips 70°SE. Sense of shear within the brittle deformation is consistently right-lateral along the entire length of the fault. Hydrothermal alteration is common with characteristic development of red hematite staining and epidote and quartz vein formation. As far as we know this is the most brittle rupture in the region and cuts other major structural features, including the Quetico-Wawa junction (Woodard and Weaver, 1990). On the south shore of the small island just southwest of Rose Island in Kawnipi Lake (Fig. 1), a basaltic dike crops out. The unmetamorphosed character of this dike indicates that it is

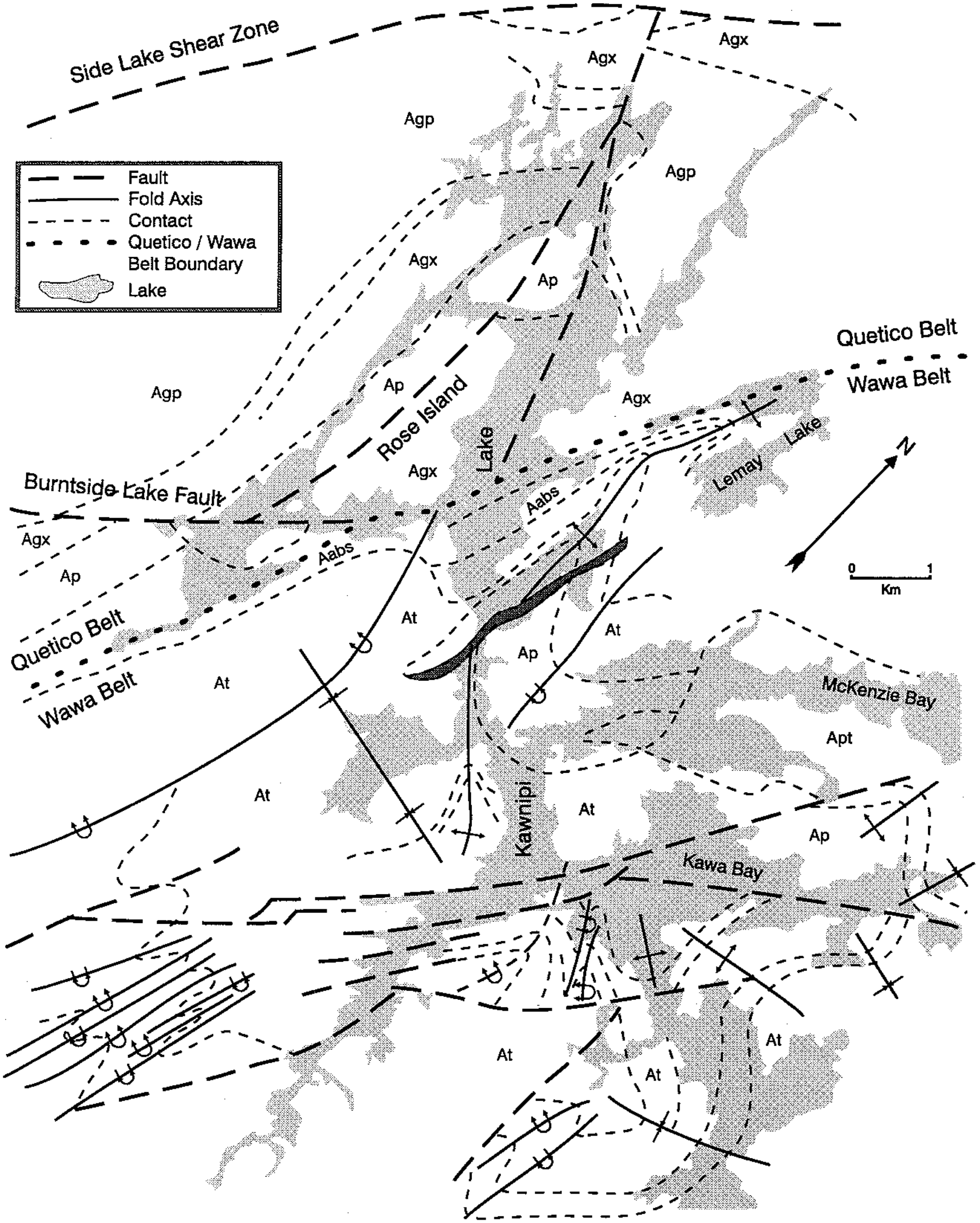

Figure. 1 Fold Configurations, faults, and Quetico - Wawa Junction, Kawnipi Lake Area.

Late Precambrian Keeweenawan in age. The NW-SE strike of the dike makes it lie approximately at right angles to the strike of the adjacent Burntside Lake fault. The dike can be traced southeastward on the opposite lake shore (and across the Burntside Lake fault) and shows no offset by the fault. This is the first time, along almost 50 km. of mapped fault trace, that a minimum age can be assigned the Burntside Lake fault. It is pre-Keweenawan in age.

The junction of the Quetico and Wawa subprovinces strikes N23°E in the area of Keewatin Lake to the southwest, and along strike toward the northeast, through a distance of 12 km., swings progressively toward the east to reach N30°E near the north shore of Lemay Lake. Aerial photos indicate that this progressive easterly change in strike continues toward the northeast and ultimately passes through an E-W orientation where the Quetico-Wawa junction is folded into the McKenzie Lake antiform. Percival (1988) has the junction improperly located on his Geologic Map of the Quetico quadrangle, as does Thurston, and others (1991) on their map #2542 and #2576. These authors extend the belt junction across the middle of Kawnipi Lake in an arcuate line to the mouth of the Wawiag River. Their displayed junction is as much as 15 km. southeast of the actual location along the north shore of Lemay and Ferguson Lakes. Northeast of Keewatin Lake the junction is flanked on both sides by schist-rich migmatites. Within the Wawa belt the schists contain significant interlayers of amphibole-rich schists while within the Quetico belt the adjacent schists contain chiefly biotite (Dalke and James, this volume). West of Rose Island (Fig. 1) in the Quetico belt the Williams Lake quartz monzonite (Agp) is surrounded by granitic-rich migmatite (Agx) and biotite schist-rich migmatite (Ap) which grade, through a distance of 1/2 km., from well-layered gneisses into the massive porphyritic quartz monzonite of the pluton (Wegmann and Allen, this volume). Within the Wawa belt the rock sequence is dominated by thick sills of tonalite (At) interlayered with biotite-amphibole schists (Aabs) and, at the mouth of McKenzie Bay, by thick-bedded quartz-plagioclase-mica-garnet schists (Ap). Much of McKenzie Bay (Fig. 1) is underlain by an intrusive porphyritic tonalite (Atp) (Endsley and Hayes, this volume). Although cross-cutting relationships demonstrate that this unit is younger than other Archean rock types in the Kawnipi Lake portion of the Wawa belt, it is cut by the regional northeast-striking and westerly-dipping ductile foliation.

All the tonalites in the Wawa belt within several kilometers of the Quetico-Wawa junction show significant quantities of secondary K-feldspar (Endsley and Hayes, and also Burrows, this volume). In many outcrops and thin sections these rocks technically classify as granodiorites. Endsley and Hayes (this volume) observe that the amount of K-feldspar present in the tonalites increases toward major ductile shear zones (for example the Kawa Bay fault [Fig. 1]) which cut the tonalites. This suggests that the shear zones acted as conduits for the distribution of potassium to the rocks.

At least twelve outcrops of Keeweenawan Age basalt dikes have been recognized in the Kawnipi Lake area (Dalke and James, this volume). They cut both Quetico and Wawa belt rocks and at two localities, on either shore of Kawnipi Lake, thick dikes were intruded along the belt junction. Overall there is no apparent preferred orientation of these dikes. They are fresh and unaltered, range from fine- to coarse-grained, and show well-formed chill zones. All these dikes are similar to Keeweenawan basalt dikes which are exposed in areas closer to the Mid-continent Rift System, which lies many kilometers to the southeast. The Kawnipi Lake area has the largest number of these basalt dikes recognized along more than 55 km. of mapped Quetico-Wawa junction.

Within the Wawa belt in the central portion of Kawnipi Lake there occurs a 200 m. wide band of amphibolites and serpentinites (see Fig. 1, black band). The amphibolites are strongly layered and megascopically resemble the amphibolites described by earlier workers along the Isabella Lake-Silence Lake fault (Sak and Humm, 1994). The serpentinites show relict poikilitic textures resulting from pyroxene enclosing olivine. Many of the pyroxenes are as large as 6 cm. in diameter. The serpentinites are remarkably undeformed. Detailed observations made for 4 km. along strike of the band indicate that the unit cuts across the crest of a bent and deformed F_1 anticline (see Fig. 1), which suggests that it is a complex mafic-ultramafic dike. Along strike to the south it appears to terminate against tonalite and no extension could be found which would link it to the amphibolite in the Isabella Lake-Silence Lake fault zone, which lies on strike, but at a distance of 10 km. to the southwest on the shore of Agnes Lake.

Woodard, Root and Askren (1994) speculated that the S-shaped form of Kawnipi Lake might be related to left-lateral shear associated with the Quetico-Wawa junction which rotated a pre-existing fault to produce the S-shaped lake. Although further work has proven this suggestion to be overly simplistic, nevertheless the S-shaped form of Kawnipi Lake appears related to left-lateral "backshoving" of the core of a major, very tight synform which lies northeast of the Kawnipi Lake area, and flanks on the southeast the McKenzie Lake antiform. As the large ductile McKenzie Lake antiform moved generally northeastward and overrode its adjacent synform to the southeast, the trough of the synform was pinched-off from its limbs and moved backward (southwest and up-plunge) under the overriding antiform. The rocks of the Wawa belt which flanked the pinched-off synform to the southwest are shoved southwestward. This process of "backshoving" caused intense rotation and dismemberment of previously formed F_1 anticlines and synclines within the Wawa belt in the central and eastern portions of Kawnipi Lake) (see Fig. 1), and a complex sequence of F_2 fold axes can be recognized. The central portion of Kawnipi Lake trends west and northwest across the regional structural trends, and is eroded along the crests and flanks of several of these rotated F_1 folds.

Within the Quetico belt, the more northerly-trending portion of Kawnipi Lake is fault controlled. This is demonstrated by several displaced rock units (see Fig. 1). No work has been done in the far southeastern portion of Kawnipi Lake and the reason for its orientation is still unknown. Given the extremely complex structural relationships illustrated throughout the Kawnipi Lake area, it is perhaps not surprising that the orientation of fracture sets in these rocks as measured by Kinner and Morgan (this volume) could not be easily related to the mapped geology.

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A Study of the Burntside Lake Fault At The Quetico-Wawa Junction Kawnipi Lake, Quetico Provincial Park, Ontario, Canada

Kia Baptist, Ohio Wesleyan University, Soyini Baten, Amherst College,
Jen Houghton, College of Wooster

Introduction

In the Kawnipi Lake area, the Quetico belt is generally characterized by migmatite composed of biotite schist, granitic intrusions and quartz monzonite sills. Age determinations of the igneous rocks in the Quetico range from 2.65 to 2.70 Ga (Williams, 1992). The Wawa belt is composed of greenstone, biotite schist-rich migmatite, foliated tonalite, granodiorite, and granite and is 2.70 to 2.75 Ga (Williams et. al., 1992). Convergence of these two belts resulted in a junction characterized by complex structures and lithologic melanges.

Following the development of the junction, the Burntside Lake episode of strike-slip faulting occurs in the Quetico and Wawa belts trending northeast, subparallel to the junction. The Burntside Lake Fault and the Quetico-Wawa junction intersect in Kawnipi Lake just east of Rose Island (Fig. 1). Previous research on the fault to the southwest indicates an initial period of ductile deformation followed by a later period of brittle deformation (Kambhu and Russin, 1992). Previous work on the Burntside Lake Fault indicates right lateral motion (Kambhu and Russin, 1992). No age for the Burntside Lake Fault has been determined, although relative age dating restricts it to before the Vermilion fault system (Kambhu and Russin, 1992).

As part of our research in the Kawnipi Lake area, we mapped the geology associated with the Burntside Lake fault lineament and the trace of the Quetico-Wawa junction. We also collected data on the direction and extent of displacement in the area and determined the point of intersection of the fault and the junction. We also examined the mineralogy of the Quetico and Wawa belt rocks altered by the Burntside Lake hydrothermal event.

Methods

We collected data along the shoreline by canoe and made some inland traverses to locate outcrops. At each outcrop we determined the predominant rock type and measured the foliation, strike and dip of fault surfaces, plunge of slickenlines, and the sense of motion whenever possible. We recorded the relative amount of hematite staining. All information was plotted on aerial photos of the region. Thin sections of each rock type were made to determine the effects of the hematite staining on the mineralogy of the rocks.

Lithologies along the Quetico-Wawa Junction

Within the region studied in 1994, the Quetico belt consists of granitic-rich migmatite, biotite schist-rich migmatite, small isolated units of hornblende gabbro, and Williams Lake hornblende quartz monzonite. The granitic-rich migmatite trends southwest-northeast into Keewatin Lake (Fig. 1). Biotite schist-rich migmatite is located along the channel west of Rose Island and northeast of Rose Island. Biotite schist rafts are dispersed in the granitic-rich migmatite in the area southwest of Rose Island. There are three isolated outcrops of hornblende gabbro: one along the junction northeast of Rose Island, one on a small island southwest of Rose Island, and another along the fault southwest of Rose Island. There is a peninsula of Williams Lake hornblende quartz monzonite within the belt of granitic migmatite.

The Wawa belt in this region contains granitic-rich migmatite, tonalite, and biotite-hornblende schist-rich migmatite. The granitic-rich migmatite trends northeast from Keewatin Lake along the junction. The tonalite units are found within 300 meters of the junction in areas east of Keewatin Lake, east of the portage into Kawnipi Lake, and east of the peninsula south of Rose Island. Areas of biotite-hornblende schist-rich migmatite are found east of Rose Island (Fig. 1).