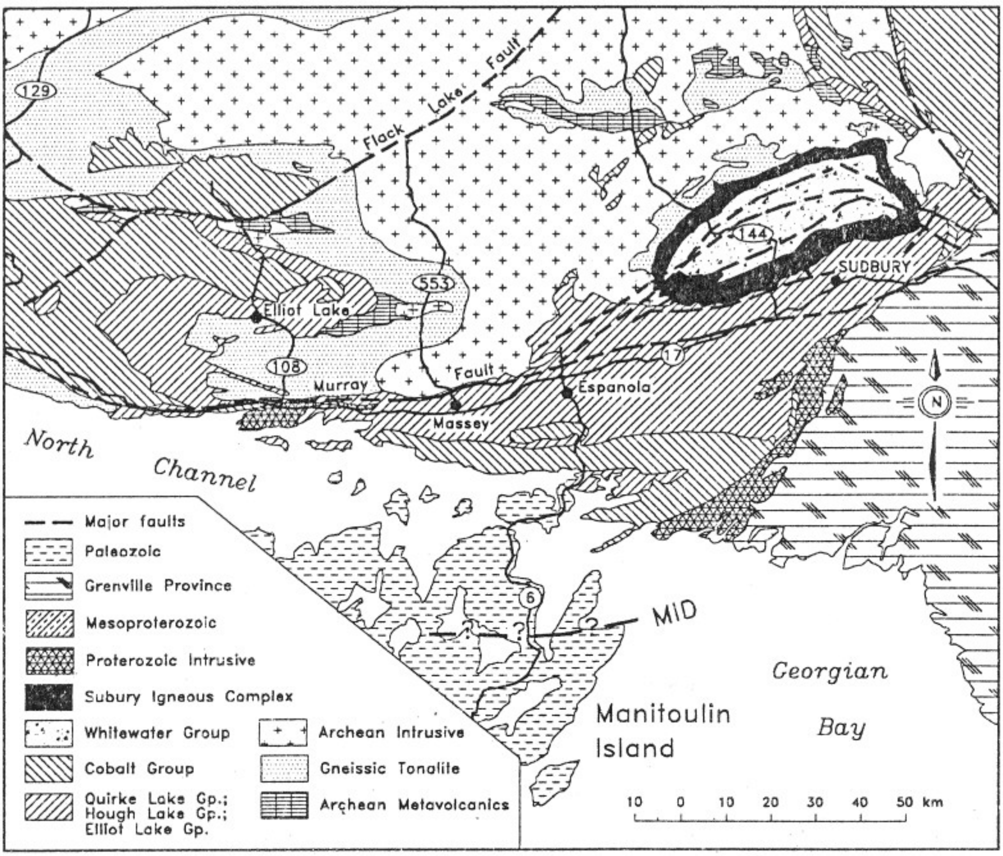
CTG 1993

Friday Oct. 15 - Sunday Oct. 17



Espanola, Ontario

CTG 1993 Abstract Volume

Talks, Saturday Morning

8:15 - Official welcome (time for stragglers to find seats)

8:20 FABRIC ANALYSIS OF ORIENTED 'LINE SEGMENTS' IN A PLANE AND APPLICATION TO SECTIONAL STRAIN ANALYSIS
Pierre Robin

8:40 COMPUTER ASSISTED PETROGRAPHIC ANALYSIS
John Starkey and Abani Samantaray,

9:00 GEOPHYSICAL EVIDENCE FOR THE TECTONIC TRANSPORT OF A THIN GABBRO-ANORTHOSITE SHEET: GRENVILLE PROVINCE
Richard Kellett

9:20 MAGNETIC FABRICS IN THE DINKEY CREEK PLUTON, SIERRA NEVADA, CALIFORNIA
Cruden, A. R. & Launeau, P, Tobisch, O.T.

9:40 THE ANATOMY OF THE SUDBURY IGNEOUS COMPLEX
E.J. Cowan and W.M. Schwerdtner

Coffee Break

10:30 STRUCTURAL ANALYSIS OF THE LIVELY GREENSTONE BELT (LGB), EASTERN PENOKEAN OROGEN
Ulrich Riller and W.M. Schwerdtner

10:50 STRUCTURE AND TIMING OF POST-TIMISKAMING DUCTILE DEFORMATION ALONG LARDER LAKE - CADILLAC DEFORMATION ZONE IN THE KIRKLAND LAKE AREA
Wilkinson, Lori and Cruden, Alexander,

11:10 ANALOGY BETWEEN STRETCHING FAULTS AND STRAIGHT BELTS IN DEEPLY ERODED OROGENS
W.M. Schwerdtner

Talks II:

Depending on the weather these talks will either be held on Saturday afternoon (if the weather is bad) or on Sunday morning (our preference). We'll announce the choice Saturday morning.

8:00 STRUCTURAL STUDIES IN THE EASTERN SEGMENT OF THE FLIN FLON-SNOW LAKE GREENSTONE BELT, TRANS-HUDSON OROGEN, SNOW LAKE, MANITOBA
Kraus, Jürgen and Williams, Paul. F.

8:20 KINEMATIC ANALYSIS OF A COMPLEX SHEAR ZONE IN THE ELBOW LAKE AREA, FLIN FLON-SNOW LAKE GREENSTONE BELT, CENTRAL MANITOBA
J.J. Ryan and P.F. Williams

8:40 STRUCTURAL ANALYSIS OF THE BIRCH RAPIDS STRAIGHT BELT, TRANS-HUDSON OROGEN, SASKATCHEWAN
M.L. Coté

9:00 MODEST MOVEMENTS, SPECTACULAR FABRICS IN A INTRACONTINENTAL DEEP-CRUSTAL STRIKE-SLIP FAULT: STRIDING-ATHABASCA MYLONITE ZONE, SASKATCHEWAN-NWT
Simon Hanmer

9:20 DEFORMATION MECHANISMS IN THE EAST ATHABASCA MYLONITE ZONE, NW SASKATCHEWAN
Dazhi Jiang

Coffee Break

10:00 HIGH-STRESS AND HIGH-STRAIN-RATE DEFORMATION OF CONTINENTAL LITHOSPHERE
Joseph Clancy White

10:20 HIGH_GRADE, HIGH_STRAIN ROCKS OF THE KRAMANITUAR COMPLEX, BAKER LAKE AREA, NORTHWEST TERRITORIES
M. Sanborn-Barrie,

10:40 STRATIGRAPHY AND STRUCTURE ALONG THE WEST FLANK OF THE MONASHEE COMPLEX, SOUTHEASTERN CANADIAN CORDILLERA.
Johnston, Dennis H. and Williams, P.F.

Posters on Display:

THE INTRA-CRATONIC PALEOPROTEROZOIC FORWARD OROGENY, AND IMPLICATIONS FOR REGIONAL CORRELATIONS, NORTHWEST TERRITORIES, CANADA
Cook, D.G. and Maclean, B.C.

ANALYSE STRUCTURALE PRéLIMINAIRE DU SILLON VOLCANIQUE DE BELLETERRE.
Jean Goutier and Ghislain Tourigny

STRUCTURAL STYLES IN THE ABERDEEN AND MASSEY-WEBWOOD AREAS OF THE SOUTHERN PROVINCE
Steven L. Jackson

FABRIC ANALYSIS OF ORIENTED 'LINE SEGMENTS' IN A PLANE AND APPLICATION TO SECTIONAL STRAIN ANALYSIS

Pierre-Yves F. Robin
Tectonic Studies Group, Department of Geology
University of Toronto, Erindale Campus
Mississauga, Ontario
Canada L5L 1C6

Line segments within a planar section of a rock can contain fabric information in their lengths as well as in their orientations. A new eigenvector method, called the 'line segment' tensor method, uses both directions and lengths to quantify that fabric. Furthermore, whenever these line segments can be assumed to have been initially isotropically distributed, in both orientation and length, and to have been passively deformed by a strain, the line segment tensor calculated is proportional to the quadratic strain tensor. The method thus provides a particularly easy method of strain analysis requiring no plot and very little calculation. A semi-empirical analysis of the errors associated with sampling is also given.

COMPUTER ASSISTED PETROGRAPHIC ANALYSIS

John Starkey and Abani Samantaray,
Dept. of Earth Sciences,
University of Western Ontario,
London, Ont.
N6A 3B7

The ready availability of inexpensive video cameras and frame grabber boards for IBM compatible micro-computers makes possible the application of micro-computers to petrographic analysis. Unfortunately, commercially available software is scarce, is mostly written for dedicated instruments and is not designed for petrographic use. An image analysis system has been developed to address petrographic needs. This has necessitated the evaluation and development of digital filters, edge finding operators and feature extraction algorithms for use with petrographic images. The result is an image analysis system which can be adapted to specific geological problems.

As far as possible standard petrographic techniques have been emulated. Thus, the analysis of a thin section can be conducted by rotating the planes of polarization of the polarizer and analyzer in a manner analogous to the rotation of the specimen, and data can be combined from observations in plane and crossed polarized light. Mathematical functions are applied to interpolate discontinuous grain boundaries in a way analogous to visual interpretation.

The system determines the x-y co-ordinates of the points along continuous grain boundaries. From these data a variety of parameters can be obtained including the lengths and orientation of the long and short axes of the grains, the lengths of the perimeter of the grains, their areas and centres of gravity and thus their locations. Shape parameters can also be calculated, including the best fit ellipses, cubic splines and amplitude spectra of finite fourier series.

The analysis proceeds by the selection of operations from a menu displayed on the computer monitor and the data are obtained automatically. Tests on a variety of thin sections indicate a high success rate in the identification of grain boundaries. For those cases where user interaction is required or desired the system includes an extensive, interactive editor.

GEOPHYSICAL EVIDENCE FOR THE TECTONIC TRANSPORT OF A THIN GABBRO-ANORTHOSITE SHEET: GRENVILLE PROVINCE

Richard Kellett
Department of Geology, University of New Brunswick, PO Box 4400, Fredericton, New Brunswick, E3B 5A3

Proterozoic gabbro-anorthosite complexes make up some 17% of the exposed surface area of the Grenville Province. They occur in a variety of different terranes and tectonic settings. The relationships between the gabbro-anorthosite intrusions and the surrounding terranes are poorly understood. The Lac Bouchette Intrusion lies some 60 km southeast of the Grenville Front in western Québec. It is situated at the northern edge of an allochthonous terrane composed of metasediments. The terrane to the north comprises granulite grade orthogneisses and paragneisses of the Parautochthonous Belt. The intrusion is dominated by meta- gabbro with a minor amount of gabbroic anorthosite. The southern margin of the intrusion is marked by a major thrust fault, but the northern margin is poorly exposed. A detailed high-frequency magnetotelluric survey was performed across the intrusion as part of the Abitibi-Grenville Lithoprobe transect. The electrical resistivity structure of the intrusion and its margins has been determined by analysis of the electric current flow in the region, combined with 1D and 2D inverse modelling. The intrusion and the terranes to the north are highly resistive. The thrust at its southern margin is evident as a major zone of low resistivity. The geometry of the intrusion at depth has been determined from the depth extent of a minor low resistivity layer interpreted to be the thrust fault at the base of the intrusion. The intrusion extends to a depth of 1500 m in the south. Magnetic modelling has defined this southern portion to be composed of highly magnetic gabbro. The northern portion of the intrusion is thinner and is composed of a less magnetic rock. The anorthositic core is confined to the top 500 m in the centre of the complex. The intrusion has been overthrust by the allochthonous metasediments to the south, but is itself a thin sheet faulted against the granulite grade terranes to the north.

MAGNETIC FABRICS IN THE DINKEY CREEK PLUTON, SIERRA NEVADA, CALIFORNIA.

Cruden, A. R. & Launeau, P.,
Dept of Geological Sciences, University of Toronto, Mississauga, Ontario L5L 1C6, Canada;
Tobisch, O.T.,
Earth Science Dept., Univ. of California, Santa Cruz, CA95064.

The Anisotropy of Magnetic Susceptibility (AMS) has been determined at 80 evenly distributed sites in the 102 to 104 Ma. old, tonaltic to quartz monzonitic Dinkey Creek pluton, central Sierra Nevada batholith, California. The pluton has an elliptical (50 km x 14 km) outcrop pattern with its longest dimension parallel to the strike of the batholith. A large (15 km x 7 km) SW trending lobe projects from the western margin of the pluton. Most outcrops of the Dinkey Creek pluton display a variably developed planar Shape Preferred Orientation (SPO) of the main mineral phases and elliptical Mafic Microgranular Enclaves (MME's). Microstructural criteria indicate that, for most sites, the mineral SPO was formed by the rotation of grains during magmatic flow.

The samples show an average bulk susceptibilty of 5.2 x 10-3 SI indicating that the AMS is mainly due to the SPO of magnetite grains. The average anisotropy degree is 13% and susceptibility ellipsoids are dominantly oblate, in agreement with the shape of MME's measured in outcrop. Magnetic foliations (Kmax/Kint plane) are usually very well defined and sub-parallel to the magmatic foliations measured in the field. Magnetic lineations can also be defined at most sites as vector means of Kmax directions with alpha95 = 1í - 30í. Preliminary image analysis work shows that the magnetic fabric orientations and intensities are a good measure of the SPO's of the main, early crystallizing, mineral phases. Furthermore, obliquities between the subfabrics of plagioclase, mafic minerals and late-crystallizing k-feldspar on Kmax/kmin (or XZ planes) of some samples can be used to infer shear-sense during the flow of magma as it cooled through the critical melt-percentage interval.

Magnetic foliation trajectories show a relatively simple pattern, being generally steep and parallel to the long axis of the pluton except within the lobe structure where they are curved and symmetrical about the lobe axis. The magnetic lineation data indicates a more complex flow pattern. For example, in the lobe they converge towards the lobe axis, possibly indicating a linear feeder zone at depth. Lineation trajectories also suggest the presence of several other, isolated linear feeder zones or flow cells in the pluton.

THE ANATOMY OF THE SUDBURY IGNEOUS COMPLEX

E.J. Cowan and W.M. Schwerdtner
Department of Geology
University of Toronto.

The layered Sudbury Igneous Complex is described by various workers as a funnel folded sheet intrusion or more recently an impact-melt sheet. Although the tripartite layered nature of the Ignous Complex (in ascending order: norite gabbro and granophyre) has been documented nearly 100 years ago there is little information regarding the detailed igneous structure or internal fabric of this igneous body. The internal fabric of the Ignous Complex will likely help to resolve the emplacement history of the Sudbury Igneous Complex and hopefully eliminate some of the emplacement hypotheses. We have documented the spatial variation in the magnetic fabric by measuring the low field anisotropy of magnetic susceptibility (AMS) of hand samples at ~300 sites on the East North and South Ranges.

The AMS lineation is consistently in oriented within the granophyre and is normal to the inclined base of the Igneous Complex in the North and East Ranges. The AMS lineation in the gabbro and the norite plunges down dip on the AMS foliation which is commonly parallel to the base of the Sudbury Igneous Complex. The two contrasting AMS fabrics can be also seen in the shape of the AMS ellipsoids plotted on a Flinn diagram (gabbro/norite is more oblate than granophyre). The orientation of the AMS fabrics appear to correspond to the magmatic fabric expressed by the alignment of silicate minerals and this is confirmed by image analysis of oriented thin sections. The granophyre is characterized by plagioclase laths with extreme aspect ratios in places up to 1:20 while the minerals in the gabbro and norite are typically stubby with lower aspect ratios. The extreme aspect ratios of the plagioclase crystals and their layer-normal orientation is attributable to crystallization rather than magmatic strain. This contrasts with the layer-parallel magmatic fabric of the gabbro and the norite which may have resulted from magmatic flow. Most AMS foliation poles are distributed in a great circle about the magnetic lineation in the North Range but are more highly clustered in the East Range and in the bend between the North and East Ranges. The AMS foliation appears to be axial planar to this fold-like bend and its orientation is similar to the tectonic foliation developed in the core of Sudbury Basin. To what extent this AMS foliation reflects synfold magmatic foliation is unknown. The examination of magmatic fabrics with the identification of magnetic carriers from individual sites will help to resolve this problem.

STRUCTURAL ANALYSIS OF THE LIVELY GREENSTONE BELT (LGB), EASTERN PENOKEAN OROGEN

Ulrich Riller and Fried Schwerdtner
University of Toronto, Department of Geology, Earth Sciences Centre
22 Russell St., Toronto, M5S 3B1

Lower Huronian metavolcanics and intercalated metasediments of the eastern Penokean Orogen occur in a well-defined belt, the Lively Greenstone Belt (LGB), which borders on the South Range of the Sudbury Igneous Complex (1.85 Ga). A detailed, field-based structural analysis was conducted along the central portion of the LGB, which contains two suboval granitoid plutons, the Creighton Pluton (2.38 Ga) and Murray Pluton (2.33 Ga). Depositional layering and foliation in supracrustal rocks of the LGB are vertical or dip steeply to the northwest. The SE-younging in the supracrustal rocks contrasts with the NW younging in the rocks of the South Range.

The presence of prestrained fragments in deformed Sudbury Breccia dikes indicates two periods of ductile deformation in the LGB. Deformation prior to Sudbury Brecciation created tight kilometre-scale folds with axes plunging moderately to steeply to the west, and a mechanical discordance with stratigraphically overlying sediments. The Creighton Pluton is composed of two major magmatic phases enveloping supracrustal enclaves. The solid-state strain of these phases varies greatly with position, and reaches a maximum in the oldest rocks. Magmatic foliation is locally preserved in the younger phase indicating two synorogenic pulses of magmatism. Monophase granitoid rocks of the Murray Pluton recorded only the solid-state deformation, and define a sigmoidal foliation pattern that cuts across the pluton boundaries. Emplacement of both plutons was apparently facilitated by (1) large-scale folding and (2) ductile flow of host rock. Evidence for the second process is provided by subvertically elongated volcanic structures such as stretched vesicles, varioles and lapilli. Post-Sudbury Breccia deformation (Penokean) imparted moderate strains to the metavolcanics and parts of the Creighton Pluton. The mechanism of solid-body rotation of vertical to overturned strata remains to be established.

STRUCTURE AND TIMING OF POST-TIMISKAMING DUCTILE DEFORMATION ALONG LARDER LAKE - CADILLAC DEFORMATION ZONE IN THE KIRKLAND LAKE AREA

Wilkinson, Lori and Cruden, Alexander,
Dept. of Geology, University of Toronto, Mississauga, Ontario, L5L 1C6;
Krogh, Tom,
Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario, M5S 2C6

The E-W trending Au-bearing Larder Lake-Cadillac Deformation zone (LCDZ), is defined in Ontario by carbonate alteration and structures which are related here to two main ductile deformation events (D_1, and D_2), developed within 2677-2685 Ma old Timiskaming metasedimentary rocks. D_1 is most significant, and is interpreted as a N-S shortening event which is recorded predominantly as transpression within the LCDZ.

The syenitic Murdock Creek (MCS) and Lebel (LS) stocks contain D_1 fabrics where they abut the LCDZ. However, internal magmatic structures indicate their emplacement was controlled by a pre-D_1 "proto-LCDZ". Zircon and two potential generations of titanite (large, blocky, brown, titanite and small, euhedral yellow titanite), from both stocks were dated using the U-Pb method.

For the LS, 5 of 6 analyses (1 zircon, and 4 high quality titanite fractions; 2 yellow and 2 brown) are near concordant (0.3, 0.37, 0.07, 0.02, and 0.75% discordant, respectively) to 0 Ma and have a mean $^{207}Pb/^{206}Pb$ age of 2673 ± 2 Ma. The sixth analysis of a poor quality, turbidic yellow titanite is 8% discordant on a line projecting from 1350 Ma to 2679 +8-4 Ma. Th/U ratios are consistent with magmatic crystallization for all fractions. Data for four high quality fractions of titanite; 2 brown titanite and 2 yellow, and one zircon from the MCS are 0.61, 1.22, 0.24, 0.86% and 6.85% discordant, respectively to 0 Ma and have a mean $^{207}Pb/^{206}Pb$ age of 2673 ± 2 Ma, with a 78% probability of fit. A sixth fraction of yellow, slightly turbid titanite has a slightly younger apparent $^{206}Pb/^{207}Pb$ age (-0.1% discordant) of 2665 ± 4 Ma, and a Th/U ratio of less than 1, and hence probably formed after magmatic crystallization, possibly during D_1 deformation. The age of this event may be younger still if the fraction contained some of the magmatic, older grains of titanite.

The timing of D_1 deformation was previously only poorly constrained by the age of the Timiskaming Assemblage (2677-2685 Ma), the youngest assemblage containing D_1 structures. The data from this study allows a much tighter constraint on the timing of D_1, and possible related gold-forming events. D_1 deformation must be at least 2673 ± 2 Ma, the age of emplacement of stocks cut by D_1, but is likely 2665 ± 4 Ma, the age of reset titanite in MCS. Late Archean sedimentation, pluton emplacement and subsequent ductile deformation associated with the LCDZ in the Kirkland Lake area therefore took place over 24 Ma to as little as 8 Ma.

ANALOGY BETWEEN STRETCHING FAULTS AND STRAIGHT BELTS IN DEEPLY ERODED OROGENS

W.M. Schwerdtner
Department of Geology
University of Toronto, Toronto, Ontario, M5S 3B1

Stretching faults are dislocations whose walls extend ductilely during slip (Means 1989). Opposing walls of type 1 faults stretch at the same rate, those of type 2 faults at markedly different rates (Means 1980). This results in type 1 structures with constant net-slip magnitude. Type 2 structures are characterized by systematic changes in net-slip magnitude, along the fault plane (Duebendorfer and Black 1992), and expected to be most common at mid-crustal levels.

Straight belts such as the Grenville Front Tectonic Zone (Ontario) or the Birch Rapids structure (northern Sask.) are the locus of ductile flow rather than slip. Nonetheless the wall rocks of straight belts probably strain in the same manner as those of stretching faults. Because of fluid-induced strain weakening in migmatitic straight belts, which seem to represent the mid-portion of large ductile shear zones, the deformation magnitude probably increases from the host rocks toward the planar belt boundaries (Fig. 1). Several ideal fields of heterogeneous wall-rock strain may be envisaged, but the stretches on individual, boundary-parallel material surfaces cannot vary with position. By contrast the boundary-parallel shear changes systematically, in a boundary-parallel direction, if the transverse flattening increases toward the boundaries and the volume loss is relatively small.

Field-based studies are under way with the aim of identifying the ductile-deformation patterns(s) in well-exposed straight belts. Owing to their long structural history, the boundary-parallel shear at such belts will vary with time as well as position.

References Cited

Means, W. D. 1989. Geology 17:892-896.
Means, W. D. 1990. J. Struct. Geol. 12:267-272.
Duebendorfer, E. M. and Black, R. A. 1992. Geology 20:1107-1111.

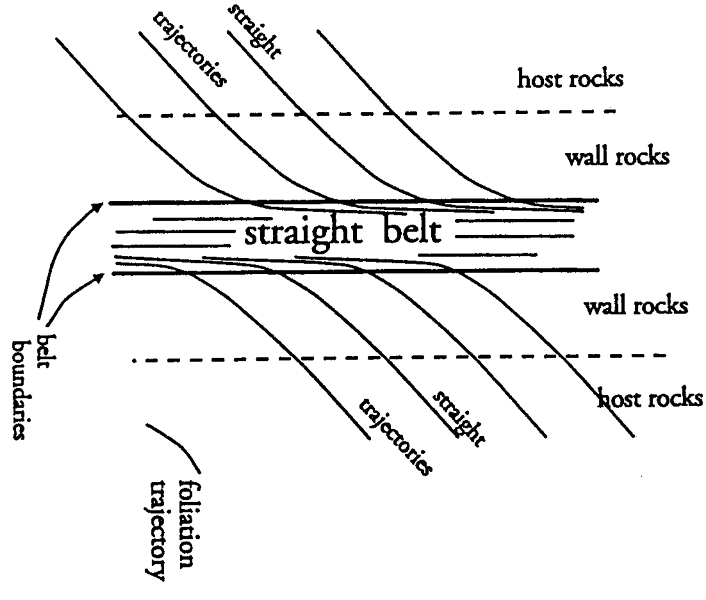


Fig. 1

STRUCTURAL STUDIES IN THE EASTERN SEGMENT OF THE FLIN FLON-SNOW LAKE GREENSTONE BELT, TRANS-HUDSON OROGEN, SNOW LAKE, MANITOBA

Kraus, Jürgen and Williams, Paul. F.
Centre for Deformation Studies in the Earth Sciences,
University of New Brunswick, Department of Geology,
University of New Brunswick, Fredericton, N.B. E3B 5A3

The Trans-Hudson Orogen is an Early Proterozoic belt separating the Archean Superior Province from the Archean Hearne Province. The Flin Flon-Snow Lake greenstone belt forms a lithotectonic domain in the Trans-Hudson Orogen. In the Snow Lake area, the greenstone belt comprises arc to back-arc assemblages of bimodal volcanic-volcaniclastic rocks (Amisk Group), which are structurally overlain by a metaturbidite sequence (File Lake Formation). Felsic Amisk volcanic rocks are dated at 1892 Ma, the youngest detrital zircon in the File Lake Formation is dated at 1850 Ma. Deformation is predated by intrusion of mafic sills. Three generations of coaxial folds (F_1, F_2 and F_3) have been recognised in the Amisk Group and File Lake Formation. Tight to isoclinal F_1 and F_2 folding ocurred during prograde metamorphism. Fold axes have a moderate to steep plunge mainly into the northeast quadrant. North of Wekusko Lake F_1 and F_2 axial-planes dip north. F_1 folds occur at all scales. An S_1 foliation in the Amisk Group rocks is defined by the alignment of biotite and amphibole and is overgrown by garnet, and, locally, by kyanite and staurolite porphyroblasts. A well-developed stretching lineation and mineral elongation (L_1) is subparallel to the fold axes. S_1 and L_1 are rare in the File Lake formation. F_2 folds appear at mesocscopic scale only and have exclusively s-asymmetry. They are typically downward facing. An S_2 is the dominant fabric in the metaturbidites at Snow Lake. It is defined by the alignment of coarse biotite and large staurolite porphyroblasts. S_2 is refracted due to differential sinistral layer-parallel shear. F_1 structures are cut at low angles by a parallel fault pair, the McLeod Road fault and the inferred Snow Lake fault. The steep north-dipping McLeod Road fault contains evidence for sinistral northside up movement. The faults are interpreted as syn-F_2. F_2 fold asymmetriy, cleavage refraction, fault movement and the abundance of sinistral tension gashes imply that F_2 has taken place in a sinistral shear regime. Open F_3 folds refold F_1/F_2 axial-planes and deform porphyroblasts. F_3 axial-planes have eastsoutheast dipping axial-planes oblique to F_1/F_2 planes. Major F_3 structures are z-asymmetric indicating shear reversal after F_2 folding. Mesoscopic F_3 folds show characteristic zig-zag to kink-like geometries. In the File Lake Formation at Snow Lake, S_2 at low angle to bedding is folded by F_3. Limbs of these F_3 microfolds are transposed into an S_3 foliation axial-planar to major F_3 structures. On west Wekusko Lake, F_3 folds in File Lake Formation are crosscut by the 1841-1834 Ma Wekusko Lake pluton. This relationship implies that deposition of the File Lake Formation, folding and metamorphic peak must have occurred within less than 20 Ma. Intrusion of the Wekusko granite is superseded by emplacement of east to eastsoutheast trending dykes. The northeast-trending Berry Creek shear zone truncates F_3 structures and the northern margin of the undeformed Tramping Lake Pluton. Microstructures and a steeply northeast/northnortheast plunging lineation in the mylonitic foliation suggest a sinistral southside-down movement. Two parallel structures, the Bartlett shear zone and Anderson Bay shear zone probably represent splays from the Berry Creek shear zone. The ductile shear zones are postdated by brittle-ductile to brittle conjugate fractures and minor faults, which are present throughout the area. Brittle fault gouge and, locally, S_3 are deformed by kink bands.

KINEMATIC ANALYSIS OF A COMPLEX SHEAR ZONE IN THE ELBOW LAKE AREA, FLIN FLON-SNOW LAKE GREENSTONE BELT, CENTRAL MANITOBA

J.J. Ryan and P.F. Williams
Centre for Deformation Studies in the Earth Sciences,
Department of Geology, University of New Brunswick,
P.O. Box 4400, Fredericton, New Brunswick, E3B 5A3

The Early Proterozoic Flin Flon-Snow Lake greenstone belt is a polydeformed domain within the Trans-Hudson Orogen. The Elbow Lake area, situated in the centre of the belt, hosts a variety of Amisk Group metavolcanic and related intrusive rocks (1900-1875 Ma), and large granitoid plutons (1869-1845 Ma). The Elbow Lake area is transected by the NNE-trending *Elbow Lake shear zone* (ELSZ) and the NNW-trending *Claw Bay shear zone* (CBSZ). The regional metamorphic grade increases from lower-middle greenschist facies on the west side of the ELSZ to upper greenschist-lower amphibolite on the east side. The ELSZ reaches a maximum width of about 2000 m in the centre of Elbow Lake, where it is intersected by the CBSZ. The foliation within both shear zones is generally vertical and locally anastomoses around low-strain domains which vary in scale from centimetres to hundreds of metres. Shear zone rocks are marked by flattened, stretched or obliterated primary features. The degree of flattening is highly variable throughout the shear zones but appears to increase inward. The shear zones contain an intense vertical stretching lineation. Structures within the shear zone define a vertical plane of symmetry indicative of transcurrent movement. In the central and eastern parts of the area, several generations of structures occur within and adjacent to the shear zones in which all foliations are vertical and all fold axes plunge vertically. Within a low strain area where the two shear zones coalesce, two cleavages (S_1 and S_2) and F_2 folds are refolded about F_3 folds. The axial planar foliation is parallel to the ELSZ fabric (S_3). S_3 near this locality is intensely F_4 folded with an axial planar crenulation cleavage parallel to the CBSZ (S_4). Shortening of S_3 can be explained by dextral shear along the CBSZ. S_4 is consistently sinistrally folded (F_5) with a locally well-developed axial planar crenulation cleavage (S_5) oriented parallel to the ELSZ. This shortening of S_4 can be explained by a reversal to sinistral movement along the ELSZ. Shear sense reversals are supported by overprinting relationships of kinematic indicators. Post F_5 structures include ductile to brittle shears, brittle faults and kink bands. The ELSZ narrows significantly in the southern Elbow Lake area where it coincides with the western margin of the Elbow Lake tonalite (1869 +20/-7 Ma). Deformed mafic xenoliths within the tonalite batholith and cross-cutting relationships of tonalite dykes indicate that the ELSZ had a pre-1869 Ma history. The dykes themselves are intensely deformed within the shear zone. It is not possible to correlate the post-F_3 structures in the southern portion of the area to structures in the central portions of the area.

Fold style and the intense flattening of primary features indicate a large component of shortening across the ELSZ. Shortening across the shear zone, its plane of symmetry and the vertical stretching lineations can be explained by a transpressional model. Alternatively, the shear zone may have initiated as an early thrust in which the stretching lineation developed parallel to the movement vector. The shear zone was then vertically reoriented and reactivated with transcurrent movement. This model is supported by a change in affinity of rock type across the shear zone, based on geochemical investigations. The first model is favoured because no kinematic information was observed in cross-section to support an early thrust event.

STRUCTURAL ANALYSIS OF THE BIRCH RAPIDS STRAIGHT BELT, TRANS-HUDSON OROGEN, SASKATCHEWAN

M.L. Coté
Department of Geology, University of Toronto
22 Russell Street, Toronto, Ontario, M5A 3B1

The Birch Rapids Straight Belt (BRSB) is a 250 km long, subvertical deformation zone in the western Trans-Hudson Orogen which coincides (?) with the boundary of the La Ronge and Rottenstone Domains. The belt trends N32°E at the shield's edge (Clam Lake) and is characterized by straight structures which contrast with complex fold structures in adjacent rocks. In the study area, about 25 km northwest of La Ronge, Saskatchewan, the BRSB is composed of paragneiss with related migmatites and a few late-plutonic bodies. Early subhorizontal fabrics (both foliations and lineations) as well as stromatic migmatitic layering are affected by two distinct episodes of folding which produced: 1) early small-scale recumbent folds; 2) kilometre- to metre-scale upright, noncylindrical folds. All linear elements (lineations and fold hinges) are subhorizontal, suggesting the BRSB records a large history of transcurrent shear. However, the early recumbent folds may be thrust related.

The Ohaninyank pluton, a tabular granitoid body, provides evidence for at least a late increment of dextral shear. Strain-sensitive foliations strike N15°E in the moderately deformed center of the pluton, while in the higher-strained margins of the pluton, the foliation strikes N32°E parallel to the estimated shear plane of the BRSB. These fabric relationships suggest a rotation of the progressive-strain ellipsoid in response to a dextral internal vorticity in the Ohaninyank pluton during noncoaxial deformation. Accordingly, material lines oblique to the principal directions, undergo a shear strain. Given the orientation of the finite strain ellipsoid from C-S planes within the pluton, the igneous contact oriented at N18°E has been subjected to dextral shear strain. Good evidence of dextral shear in the Ohaninyank pluton contrasts to the lack of sense of shear indicators in the migmatites. However, hook folds in the migmatites point to an increment of sinistral shear. The relative age of these increments remains to be established.

MODEST MOVEMENTS, SPECTACULAR FABRICS IN A INTRACONTINENTAL DEEP-CRUSTAL STRIKE-SLIP FAULT: STRIDING-ATHABASCA MYLONITE ZONE, SASKATCHEWAN-NWT

Simon Hanmer
Continental Geoscience Division,
Geological Survey of Canada, 601 Booth St,
Ottawa, Ont. K1A 0E8, Canada.

Geometry and strain partitioning within lower-crustal intraplate strike- slip shear zones can be extremely complex, compared with analogous structural levels of interplate strike-slip shear zones sited at plate margins. The latter tend to be planar and kinematically simple, closely reflecting the generalised pattern of plate interaction, whereas the former may be significantly influenced by local, crustal-scale rheological variation. Striding-Athabasca mylonite zone, Canadian Shield, is a spectacular ca. 500 km long example of a granulite facies continental intraplate shear zone. Magnetic anomalies along the NE-SW trend of the mylonite zone define a chain of crustal-scale "lozenges" cored by relatively stiff rocks of mafic to intermediate composition. The shear zone is composed of Mid-Archean granulite facies annealed mylonites (ca. 3.13 Ga) and Late Archean (ca. 2.62-2.60 Ga) granulite facies ribbon mylonite belts, which thread a sinuous course along the chain of lozenges. I focus here on the Late Archean history of the mylonite zone.

Striding-Athabasca mylonite zone is not a transcontinental fault. It is an adjustment feature, formed within the continental crust at the margins of a crustal strength heterogeneity, far removed from the active compressional orogenic events occurring at the plate boundaries. To the NE, the mylonites form a northerly to easterly trending 5-10 km thick dextral strike-slip belt. The markedly non-linear trace of the mylonite zone is primary. To the SW, it bifurcates into a pair of conjugate strike-slip shear zones, overlain by a contemporaneous dip-slip shear zone. Striding-Athabasca mylonite zone was kinematically inefficient as a strike-slip fault and cannot have accommodated large wall-rock displacements. Nevertheless, spectacular granulite facies ribbon mylonites were formed throughout the shear zone reflecting the very high temperatures (ca. 850-1000xC), high recrystallisation rate/strain rate ratios and the transpressive nature of the deformation ($W_k<1$), possibly accommodated by significant volume loss by magma migration.

DEFORMATION MECHANISMS IN THE EAST ATHABASCA MYLONITE ZONE, NW SASKATCHEWAN

Dazhi Jiang
Center for Deformation Studies in the Earth Sciences
Department of Geology
The University of New Brunswick

The East Athabasca mylonite zone (Hanmer et al. 1992, 1993) is a segment of the Snowbird Tectonic Zone (3.2 Ga) dominated by granulite and transitional granulite facies mineral assamblages in a variety of lithologies. The extensive occurrences of anomalously fine-grained mylonites contradict the classical expectation of grain growth favoured at the apparent high temperatures of metamorphism/deformation. These rocks comprise globally-unique material for the direct observation of microstructures representative of the physiochemical processes in the lower crust.

Mylonites typically comprise ≤10μm diameter plagioclase, opx, cpx and garnet. Geothermometers give syndeformational temperatures ranging from 800°C to 900°C, with the most strongly deformed assemblage giving 950°C. Limited geobarometric calculations give 800 - 1000 MPa.

Heterogeneous distribution of flow on various scales is evidenced by the observed variable kinematics (Hanmer et al. 1992, 1993), the variation of strain, strain rate and deformation mechanisms between minerals. Opx deformation is dominated by a single glide system, (100)[001], with exsolution of cpx subparallel to the glide planes. Extreme elongation of opx (120:1) occurs in these rocks. Equally intense deformation of plagioclase has produced strong crystallographic preferred orientations. The plagioclase grains are in various stages of deformation, including dislocation-free recrystallized grains. Generally plagioclase grains are heavily dislocated on several dislocation systems suggesting strong intracrystalline deformation rather than grain-size-sensitive processes such as grain boundary sliding. In contrast to opx, the deformation of cpx, which comprises lower finite crystal strain, appears to be dominated by dislocation creep and grain-boundary-dislocation assisted grain boundary sliding. Good core-mantle structures are seen in cpx and dynamic recrystallization is better developed in cpx than in opx. The deformation of garnet occurs by ductile + brittle pull apart and rotation. Deformation evidently continued during hydration (retrogressive metamorphism) at amphibolite grade conditions, during which localized shear planes developed in conjunction with cpx→amphibole reactions.

HIGH-STRESS AND HIGH-STRAIN-RATE DEFORMATION OF CONTINENTAL LITHOSPHERE

Joseph Clancy White
Centre for Deformation Studies in the Earth Sciences
Department of Geology, The University of New Brunswick

Access to the dynamics of rheological behaviour largely rests on the interpretation of processes recognized in the geologic record, in concert with the application of experimental and theoretical constraints. To be successful, sufficient evidence of the operative processes and relevant deformation conditions must be preserved in the rock record. Granulite mylonites from the East Athabasca mylonite zone contain an array of delicately preserved microstructures consistent with high P/T deformation. In particular, evidence for shear-induced transformation of ortho- to clinoenstatite provides a strain rate dependent marker. Although not previously recognized at temperatures above 650°C, paleopiezometry, metamorphic temperature calculations and experimental flow laws are consistent with the transformation occurring at temperatures in excess of 800°C.

The OREN → CLEN transformation is associated with strain rates of 10^{-8} - 10^{-10} s^{-1}. Strain rates of this magnitude require extensive localization of displacements for any inferred plate-scale velocities. The need for localization coupled with the spatially-extensive occurrence of these rocks suggests that the typical crustal model of more distributed, slower-strain-rate deformation at depth may in fact be accumulated zones of much more intense deformation. This raises the problem of rheological reference frame whereby the nature of deformation inferred at the shear zone scale may not be that recorded by microstructures. Additionally, the occurrence of distinct low- and high-stress regimes may influence both the amplification of rheological perturbations and their subsequent preservation as geometrically-distinct structure.

HIGH_GRADE, HIGH_STRAIN ROCKS OF THE KRAMANITUAR COMPLEX, BAKER LAKE AREA, NORTHWEST TERRITORIES

M. Sanborn-Barrie,
Ottawa-Carleton Geoscience Centre,
Carleton University,
Ottawa, ONT,
K1S 5B6

Granulite-grade metaplutonic and metasedimentary rocks of the Kramanituar complex record strong to intense deformation, although moderate strain is preserved locally in coarse-grained gabbroic anorthosite. An outward increase in strain culminates in kilometre-wide zones of ultramylonite which appear to define boundaries to the complex.

Movement on the shear zones is consistent with uplift of granulite-grade material relative to amphibolite-grade rocks exposed north and south of the complex. It remains to be demonstrated whether finite strain recorded by the shear zones can account for the juxtaposition of disparate metamorphic terranes, or whether the shear zones dissect a previously assembled metamorphic terrane.

STRATIGRAPHY AND STRUCTURE ALONG THE WEST FLANK OF THE MONASHEE COMPLEX, SOUTHEASTERN CANADIAN CORDILLERA.

Johnston, Dennis H. and Williams, P.F.
Centre for Deformational Studies in the Earth Sciences, Department of Geology, University of New Brunswick, Fredericton, N.B., E3B 5A3.

The Monashee Complex is comprised of Early Proterozoic basement "core" gneiss unconformably overlain by Late Proterozoic to early Cambrian "cover" metasediments. The Frenchman Cap and Thor Odin culminations dominate the Monashee Complex to the north and south, respectively. Present dogma is that the Monashee Complex is a tectonic window exposed through the Selkirk Allochthon, separated from the allochthonous rocks by the Monashee de19collement. The location and nature of the de19collement in the depression or saddle between the culminations is yet to be established; to resolve this, an east-west corridor across the west flank of the Monashee Complex will be mapped in detail, from Davis Peak (Monashee Mountains) west to Joss Mountain (Mabel Range).

Westward from Davis Peak to Joss Pass, gneisses consistently dip south- southwest. At Davis Peak, basement core gneiss is overlain by a quartzite - calc- silicate gneiss - quartzite cover assemblage. A distinctive sillimanite (after kyanite)/biotite schist occurs in the middle of the calc-silicate unit. Above and west of this assemblage, psammitic gneiss grades into a thick unit of semi- pelitic schist which dominates the peak just west of Davis. Core gneiss reappears in the next saddle westward, possibly as a fault-bounded sliver. To the west, psammitic gneiss containing very large amphibolite boudins (up to 10m. thick) grades to a heterogeneous unit of garnetiferous amphibolitic semi-pelitic schist, marble and minor quartzite; exactly how these allochthonous rocks are separated from basement core and cover to the east will be the focus of future work.

Joss Mountain is dominated by a foliated leucogranite and an overlying thick marble; both dip consistently south-southeast. Along the west flank of Joss Mountain, a thick quartzite (≥7m.) overlies the marble. Above the quartzite a psammitic gneiss thickens southwestward. West of Joss Mountain, a very thick heterogeneous, predominantly calcareous, metasedimentary unit of marble, amphibolitic gneiss, calc-silicate gneiss, semipelitic schist and minor quartzite occurs below the foliated leucogranite.

Boudinage is ubiquitous and appears to be early, likely associated with F_1. F_1 intrafolial, isoclinal folds are refolded by asymmetric F_2 folds with shallow to moderate plunges. In the Davis Peak area F_2 folds verge to the northwest; west towards Joss Pass they verge southeast. At Joss Mountain, F_2 folds verge southwest. The style and general timing of these folds is very similar, suggesting the different vergences are related to a single folding event. F_3 folds are open upright folds trending approximately north-south. An east-west mineral lineation overprinting F_1-F_3 is strongest in the Monashees; cutoffs related to this lineation are common in the Monashees. Topography is strongly controlled by late north-south, east-west brittle deformation.

The heterogeneous metasedimentary unit east of Joss Pass can be correlated to a regional semipelitic-amphibolite unit ("SPA"); similar rocks that occur below the leucogranite west of Joss Mountain may define a large synform through Joss Pass. Correlation of the marble and overlying quartzite of Joss Mountain to the Hamill Formation (quartzite) and overlying Badshot Formation (limestone) of the Selkirk Allochthon suggest this is an overturned limb. The style and orientation of the southwest verging asymmetric folds at Joss Mountain are very similar to that of northeast verging asymmetric folds common throughout the Monashees. Are these asymmetric folds part of a northeast-directed thrust nappe?

THE INTRA-CRATONIC PALEOPROTEROZOIC FORWARD OROGENY, AND IMPLICATIONS FOR REGIONAL CORRELATIONS, NORTHWEST TERRITORIES, CANADA

Cook, D.G. and Maclean, B.C.
Geological Survey of Canada
3303 33 St. N.W.
Calgary
Alberta, T2L 2A7

The intra-cratonic Forward Orogeny is identified on reflection seismic data from the Colville Hills and Anderson Plain and on published geological maps of Coppermine Homocline. Large rotated fault blocks, with up to six km of uplift involve strata considered equivalent to the 1663 Ma Hornby Bay Group of Coppermine Homocline to the east. The strata are unconformably overlain by a younger sequence considered equivalent to the >1267 Ma Dismal Lakes Group, also exposed on the homocline. These correlations date the orogeny as older than superincumbent 1267 Ma Coppermine basalts (Copper Creek Formation). Variable structural orientations are consistent with a general northwest-southeast compression. The orogeny is probably co-genetic with the collisional Racklan Orogeny, reported in the northern cordillera, where deformed Wernecke Supergroup rocks are unconformably overlain by the >1270 Ma Fifteenmile Group. The widely accepted regional stratigraphic sequences A and B are modified . Wernecke Mountains Supergroup of the cordillera and Hornby Bay Group of Coppermine Homocline, both orogenically deformed, are retained in Sequence A. Sequence B is subdivided into B1 and B2. The Fifteenmile Group in the cordillera and the Dismal Lakes Group in the homocline, both >1270 Ma, and both post-orogenic, are assigned to Sequence B1, as are the 1267 Ma Coppermine basalts. The unconformably overlying Rae Group and the correlative Shaler Group and Mackenzie Mountains Supergroup are assigned to sequence B2. Sequence C is untouched.

ANALYSE STRUCTURALE PRéLIMINAIRE DU SILLON VOLCANIQUE DE BELLETERRE.

Jean Goutier,

MER, Service géologique du Nord-Ouest, 19 Perreault O., suite 330,
Rouyn-Noranda, Québec, J9X 5N4.

Ghislain Tourigny,

MER, Service géologique du Nord-Ouest, 400 boul. Lamaque,
Val d'Or, Québec, J9P 3L4.

Le sillon de Belleterre représente à la terminaison d'un ensemble volcanique archéen dans la partie sud de la sous-province de Pontiac. Le centre de l'ensemble est caractérisé par des tonalites cisaillées qui sont bordées par les volcanites. Le pourtour du sillon est composé de métasédiments au Groupe de Pontiac et d'intrusions felsiques, syn à post-tectoniques.

Il a été possible de reconnaître cinq phases de déformation différentes qui ont créé des structures polyphasées. La phase D1 est associée à une tectonique horizontale et elle est marquée par une schistosité, une linéation minérale et des zones de cisaillements qui affectent à la fois les tonalites et les volcanites. L'attitude des strates et de la schistosité S1 permet de définir les structures de la deuxième et de la troisième phase. Les structures D2, principalement des plis isoclinaux et kilométriques dans les volcanites et les métasédiments, sont reprises par une grande structure antiforme D3, déjetée vers le sud, plus ou moins E-O et s'incurvant vers le SE. Les structures D4, mineures, sont des ondulations orthogonales. Des failles orientées NNE, à rejet senestre, correspondent à la phase D5 et sont associées à l'orogenèse grenvillienne puisqu'elles affectent à la fois les roches archéennes et protérozoïques.

L'agencement des structures serait le résultat d'un transport vers sud. Ceci aurait produit des cisaillements subhorizontaux repris par des plis plus ou moins coaxiaux, d'amplitude de plus en plus grande en fonction de l'évolution de la déformation. Le redressement des strates de la bordure sud a probablement été amplifié par l'orogenèse grenvillienne. La cartographie du sillon de Belleterre permet de faire ressortir des contrastes importants entre la structure de ces roches et celle de la sous-province de l'Abitibi située plus au nord.

No. de contribution: 93-5130-08

STRUCTURAL STYLES IN THE ABERDEEN AND MASSEY-WEBWOOD AREAS OF THE SOUTHERN PROVINCE

Steven L. Jackson
Ontario Geological Survey,
933 Ramsey Lake Road
Sudbury, Ontario, P3E 6B5

The Aberdeen area (western Southern Province) is characterized by low-grade, regional metamorphism and WNW-striking faults, folds and cleavage. Two structural domains, separated by the WNW-striking McCarrol Fault, are recognized. A northern structural domain displays generally SSW-dipping and younging strata; however, out-of-sequence units, SSW-dipping foliation and SSW-plunging stretch-lineation may reflect NNE-directed thrust imbrication. In the southern portion of this domain, a structural discordance is marked by a regional change in both magnitude of bedding dip and cleavage dip-direction. Coincident with the discordance is a sedimentary "mega-breccia" and change in regional sedimentary formations. The discordance may be a syn-sedimentary fault reactivated during compression. A southern structural domain in the Aberdeen area is disected by WNW-striking faults and gently plunging, upright, open folds. The angular relationship between folds and faults may indicate a component of sinistral displacement along the faults.

The Massey-Webwood area is situated at the western end of the "Espanola Wedge". The area is transected by the dextral (?) Murray Fault zone (MFZ) which separates low-grade, SSE-dipping and younging rocks to the north from high-grade, multiply-deformed rocks to the south. North of the MFZ, out-of-sequence units suggest the presence of NNW-verging reverse faults. South of the MFZ, penetrative mica foliation is locally axial-planar to recumbent to moderately inclined folds of bedding. Staurolite and garnet porphyroblasts grew approximately syn- to post-foliation development. Over large areas, the foliation is commonly oriented at a consistent, low-angle to bedding. Highly boundinaged meso- to map-scale elements within the foliation plane suggests high extensional strain. Collectively, these features may indicate that foliation development occured during pre- to syn-peak-metamorphic nappe development. ENE- and WNW-striking faults, folds and axial-planar crenulation cleavage are superimposed upon the early mica foliation and related folds. Preliminary work suggests that the WNW-striking faults are dextral and north-side-up and that they and other WNW-oriented structural elements post-date ENE-striking structures. The WNW- and ENE-striking folds are the folds commonly delineated on township maps.

Further work will test: i) validity of correlation of "orientation-based" structural sets; ii) the extent of early nappes/recumbent folds; and iii) whether WNW-striking high-level thrusts and folds in the Aberdeen area can be correlated with any of the structural sets of the Massey-Webwood area and regions to the east.

Background information on the Southern Province in east-central Ontario.

Deposition of the Huronian Supergroup

The Huronian Supergroup in the SP (Figure 1) consists of an apparently cyclical association of conglomerates, siltstones and sandstones which may be as much as 12 km thick south of the Murray Fault. Conglomeratic parts of the sequence (Ramsay Lake, Bruce and Gowganda Formations) appear to have been deposited in a glacial to paraglacial environment (Young 1988), while most of the associated sandstones (Matinenda, Mississagi, Serpent and Lorrain Formations) are predominantly fluvial, with clear evidence of marine influence only in the upper part of the Lorrain and Bar River Formations. Mudrocks in the lower part of the Supergroup (McKim and Pecors Formations) appear to be of deep-water lacustrine origin, while those in the upper part of the sequence (Espanola, Gowganda and Gordon Lake Formations) contain evidence of deposition in restricted and open marine settings.

Deposition of the lower part of the Huronian Supergroup took place in a narrow east-west oriented trough associated with rifting (Young 1988; Young and Nesbitt 1985), possibly localized along preexisting zones of weakness in the Archean basement (Sims and Peterman, 1983). Most of the Huronian formations thicken significantly to the south of the Murray Fault, indicating that it may have acted as a growth fault during deposition of the sequence.

The presence of minor low-Ti tholeiitic basalts and crustally derived calk-alkaline rhyolite near the base of the sequence supports the idea that the basin developed as an intracratonic rift or aulacogen (Young 1988; Jolly 1987). Alternatively the basin may have had an initial left lateral strike-slip component (Long and Lloyd 1983), reflecting initiation on a transform segment of a passive margin. Deposition of the Gowganda Formation appears to have coincided with a change in character of the basin from a simple rift or transtensional basin to a passive margin, with the break-up unconformity at the base of the Gowganda Formation (Young and Nesbitt 1985; Young 1988). A passive margin origin for the upper part of the supergroup is supported by paleocurrents in both the Lorrain and Bar River Formations.

Deformation of the Huronian Supergroup

The Huronian Supergroup was folded during a pre-Nipissing diabase event, the timing and nature of which remains uncertain (Bennet et al. 1991). It is generally assumed that the bulk of the deformation and metamorphism in the SP is the result of a compressional event referred to as the Penokean orogeny. According to the tectonic model by Zolnai et al. (1984) the southern part of the Huronian Supergroup was overridden from the south by a block of Archean crust, burying Huronian rocks in the southern part of the SP to midcrustal levels, while the thinner sequence in the northern part of the SP was buried less than 5 km (P = 4-5 kb. approx.). Zolnai et al. (1984) suggest that a remnant of the Archean block is located south of the SP on Manitoulin Island. On the basis of recent isotopic data Barovich et al. (1989) interpret this block as a Proterozoic island arc which may have similarities to the Killarney Complex.

A significant part of the sedimentation patterns in the Huronian Supergroup appears to have been controlled by a number of faults which originated as listric normal faults, with south-side-down displacement. These faults were subsequently reactivated as reverse faults during the compressional orogenic event. Three faults which have been identified as having this history are the Flack Lake Fault, the Agnew Lake Fault and the MFZ (Zolnai et al. 1984). The Flack Lake Fault is thought to represent the northern limit of reverse faulting in this part of the SP (Zolnai et al. 1984). The MFZ is arguably one of the most important features in the SP as marked changes in both stratigraphy and structure occur across it.

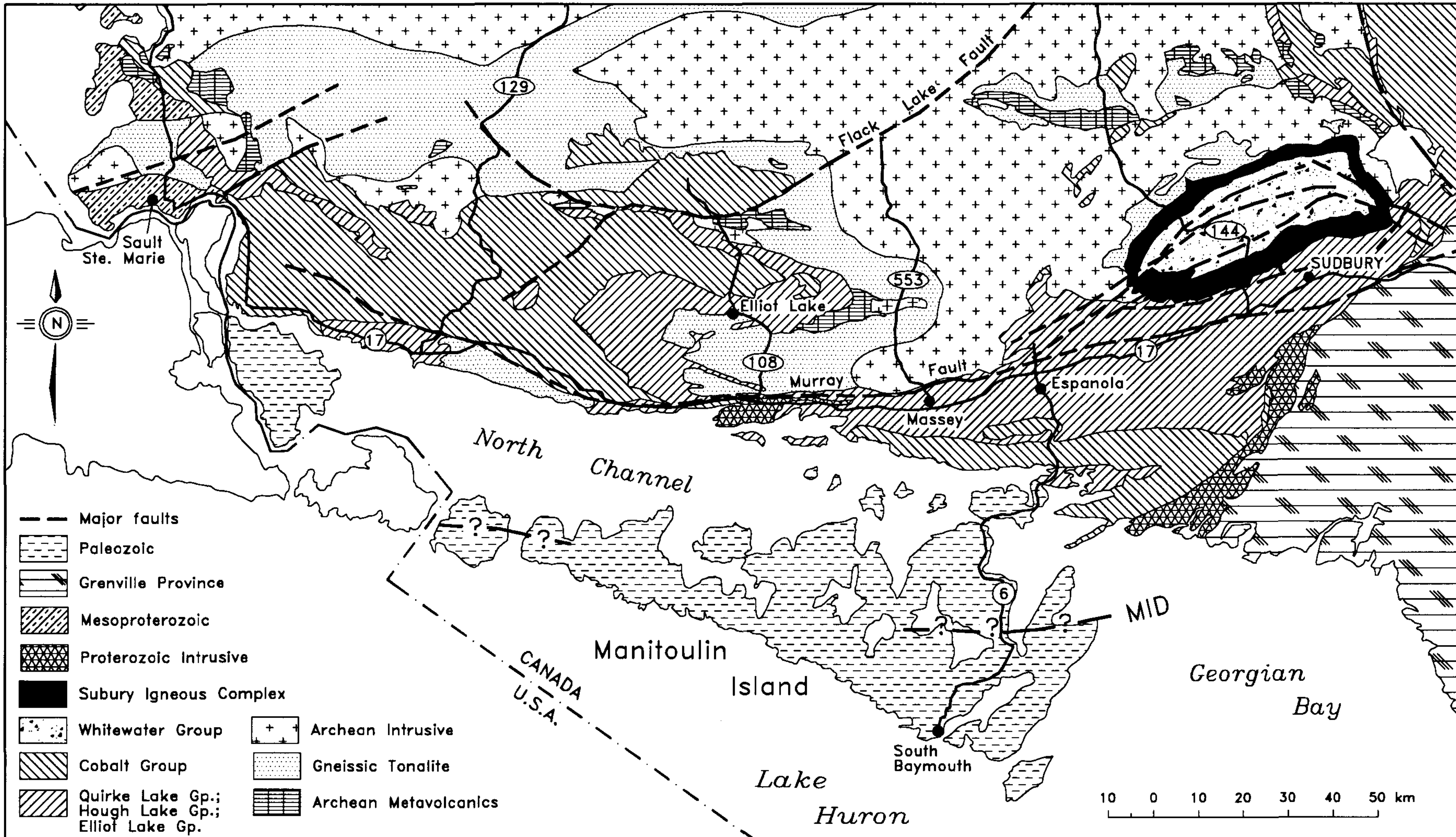


Figure 1: Simplified geology map of the Southern Province modified after Ontario Northern Development and Mines Map 2544. Location of Manitoulin Island discontinuity (MID) after Van Schmus et al. (1975).

Murray Fault

The Murray Fault is one of the most prominent structural features within the Southern Province. Card and Hutchinson (1972) found evidence that the MFZ system originated prior to Huronian sedimentation and was initially part of a graben fault system forming depositional basins for Huronian sediments. During Penokean deformation the MFZ has been interpreted as becoming a south dipping thrust fault (Cooke 1946, Zolnai et al. 1984) with considerable right lateral displacement (Cooke 1946, Yates 1948, Card 1968, Zolnai et al. 1984). Reverse faults between the MFZ and the Flack Lake Fault involve the basement suggesting a 'thick-skinned' thrust style for the SP. Zolnai et al. (1984) suggest that a sole thrust is located at 5 km depth within the basement. Rocks north of the MFZ are largely restricted to subgreenschist to lower greenschist metamorphism and were only buried to depths of less than 5 km; however mafic intrusions in this area indicate grades as high as lower amphibolite facies (James, R. pers. com. 1991). The elliptical shape of the isograds and the gaps in the isograd sequences, particularly adjacent to the MFZ (Card 1978), suggest that thrust faulting has been operative south of the MFZ as well.

South of the MFZ rocks are more highly strained and have undergone greenschist to amphibolite facies metamorphism (Bennett et al. 1991), corresponding to burial depths of 15-20 km (Zolnai et al. 1984). Folds south of the MFZ have long southern and short northern limbs and may be rootless. The thrusts are now near vertical, likely due to continued crustal shortening. The basement of the Huronian Supergroup does not outcrop south of the MFZ. Zolnai et al. (1984) proposed that the top of the basement presently lies at a depth of 5 km. If this interpretation is valid, then as Zolnai et al. (1984) suggested this requires a total of 10-15 km relief across the MFZ. Fueten and Redmond (1992) however find no evidence for displacements on that order of magnitude in the area south of Sudbury. The question still remains: at what depth is the basement south of the MFZ and how much displacement has there been on the MFZ since the deposition of the Huronian Supergroup.

Shanks and Schwerdtner (1991) believe that a major ductile reverse shear zone, the South Range Shear Zone (SRSZ), which cuts the SS, may be a splay of the MFZ. They estimate that the SRSZ has a vertical displacement exceeding 8 km which would correspond to a horizontal shortening of 6 km. Depending on the placement of the boundary of the SRSZ, the total displacement along it may be nearly 19 km.

Zolnai et al. (1984) attribute late brittle right-lateral movement on the Murray Fault to be due to northwest-southeast compression during the Grenvillian Orogeny.

Southern boundary of the Southern Province

In this area the southern boundary of the Huronian Supergroup, which has been termed the Manitoulin Discontinuity (Van Schmus et al. 1975) lies beneath Paleozoic sediments on Manitoulin island. The Manitoulin terrane which occurs to the south of this Discontinuity is nowhere found in outcrop. Its character has been defined by samples obtained from drill-core and by geophysical interpretation. Van Schmus et al. (1975) report that positive aeromagnetic anomalies within this zone correlate with quartz-monzonitic composite plutons which date at 1,500 +/- 20 Ma. The plutons are surrounded by metasedimentary, gneissic and granitic rocks which have a minimum age of 1,700 Ma. They found no evidence for the existence of an Archean basement. The Manitoulin terrane may be similar to the Killarney complex (Davidson 1986) and may represent part of a post-Penokean orogenic event. On the basis of the seismic data obtained with the GLIMPCE profile, Green et al. (1988) state that the Manitoulin terrane is characterised by numerous east dipping reflectors and interpret a set of reflectors as a major decollement of the Penokean orogeny. They propose a tectonic model in which the Penokean orogeny is followed by subsequent northwest directed stacking of microterranes. It should be noted that the main GLIMPCE profile was nearly perpendicular to the Grenville Front and therefore could be expected to image features associated with that structure. Unfortunately this profile was nearly parallel to the trend of the Manitoulin discontinuity and did not cross the Manitoulin terrane - SP boundary and therefore provided no information on these structures.

Geophysical Signature of the Huronian

As noted by many authors the SS is associated with a regional gravity anomaly which appears to extend from Elliot Lake to Englehart (Card et al. 1984). Interpretation of this anomaly remains controversial. Current interpretations of seismic and potential field data from the Sudbury LITHOPROBE traverse attribute this anomaly to the Levack gneisses, the North Range Norite and Huronian metavolcanics. This interpretation cannot provide a general solution. Gupta et al. (1984) for example postulate that the anomaly is associated with a regionally extensive mafic zone at depth. It might also be noticed that this anomaly appears to be closely associated with the known distribution of the basal Huronian volcanics (Bennett et al. 1991).

The boundary between the Manitoulin terrane and the SP is marked by an E-W zone of gravity and magnetic lows. The North Channel Magnetic Low, which is a very intense feature, extends along the whole length of the north shore of Lake Huron (Gupta 1991a). And as noted by Card et al. (1984) the explanation of this anomaly is as yet unresolved. Possibilities include: a) a very thick accumulation of Proterozoic rocks; b) intense fracturing leading to magnetic mineral oxidation and; c) contrast effect produced by the intense magnetic highs associated with the Manitoulin Intrusions to the south.

Closer examination of the regional gravity map (Gupta 1991b) shows that the form of the gravity anomalies for both of these areas is very poorly constrained. In the region of the proposed corridor the average spacing between stations is around 10 km. Prior to developing geologically meaningful gravity models it will be necessary to obtain a new suite of gravity and rock density measurements for this region.

References

Barovich, K.M., Patchett, J.P., Peterman, Z.E. and P.K. Sims 1989. Nd isotopes and the origin of 1.9-1.7 Ga Penokean continental crust of the Lake Superior region. Geological Society of American Bulletin, v. 101, p. 333-338.

Bennett, G., Dressler, B.O. and Robertson, J.A. 1991. The Huronian Supergroup and associated intrusive rocks; in Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 1, p. 549-593.

Card, K.D. 1968. Geology of Denison-Waters area. Ontario Deptartment of Mines, Geological Report 60, 63 p.

Card, K.D. and Hutchinson, R.W. 1972. The Sudbury Structure: its regional geologic setting; in New Developments in Sudbury Geology, ed. J.V. Guy-bray, Geological Association of Canada, Special Paper 10 p. 67-78.

Card, K.D. 1978. Metamorphism of the middle Precambrian (Aphebian) rocks of the eastern southern province; in Metamorphism in the Canadian Shield, Geol. Survey Can. Paper 78-10, p. 269-282.

Card, K.D., Gupta, V.K., McGrath, P.H. and Grant, F.S. 1984. The Sudbury Structure: Its regional geological and geophysical setting; in The geology and ore deposits of the Sudbury Structure, edited by E. G. Pye, A.J. Naldrett and P.E. Giblin, Ontario Geological Survey, Special Volume 1, p. 255-45.

Cooke, H.C. 1946. Problems of Sudbury Geology, Ontario. Geological Survey of Canada Bulletin 3, 77 p.

Davidson, A. 1986. Grenville Front relationships near Killarney, Ontario. The Grenville Province, Edited by J.M.Moore, A. Davidson and A.J. Baer. Geological Association of Canada Special Paper 31. p. 107-117.

Fueten, F. and Redmond, D. 1992. Structural studies in the Southern Province south of Sudbury, Ontario. Current Research, Part C, Geological Survey of Canda, Paper 92-IC pp. 179-187.

Green, A. G., Miklereit, B., Davidson, A. and C. Spencer. 1988. Crustal structure of the Grenville front and adjacent terranes. Geology v. 16, p. 788-792.

Gupta, V.K., Grant, F.S. and Card, K.D., 1984. Gravity and magnetic characteristics of the Sudbury Structure; in The geology and ore deposits of the Sudbury Structure, edited by E.G. Pye, A.J. Naldrett, and P.E. Giblin, Ontario Geological Survey, Special Volume 1, p. 381-411.

Gupta, V.K. 1991a. Shaded image of total magnetic field of Ontario, southern sheet. Ontario Geological Survey, Map 2587, scale 1:1 000 000.

Gupta, V.K. 1991b. Bouger gravity of Ontario, southern sheet. Ontario Geological Survey, Map 2595, scale 1:1,000,000.

Jolly, W.T. 1987. Geology and geochemistry of Huronian rhyolites and low-Ti continental tholeiites from the Thessalon region, central Ontario. Canadian Journal of Earth Sciences v. 24, p. 1360-1385.

Long, D.G.F. and Lloyd, T.R. 1983. Placer gold potential of basal Huronian strata of the Elliot Lake Group in the Sudbury area, Ontario; in J. Wood, O. L. White, R. B. Barlow and A.C. Colvine (editors) Summary of Field Work, 1983, by the Ontario Geological Survey. Ontario Geological Survey, Miscellaneous Paper 116, p. 2566-258.

Milkereit, B. Green, A. and the Sudbury Working Group 1992. Deep geometry of the Sudbury structure from seismic profiling. Geology v. 20, p.807-811.

Shanks, W.S., and Schwerdtner, W.M. 1989. Deformation of the Sudbury Structure and its Footwall; in Geoscience Research Grant Program, Summary of Research 1988-1989, ed. V.G. Milne, Ontario Geological Survey, Miscellaneous Paper, 144, p.4-17.

Sims, P.K. and Peterman, Z.E. 1983. Evolution of the Penokean foldbelt, Lake Superior region, and its tectonic environment; in L. G. Medaris, Jr., (editor) Early Proterozoic Geology of the Great Lakes Region. Geological Society of America, Memoir 160, p. 3-14.

Schmus, W.R., Card, K.D., and K. L. Harrower, 1975. Geology and Ages of Buried Precambrian Basement Rocks, Manitoulin Island, Ontario. Can. J. Earth Sci., v. 12, p. 1175-1189.

Yates, A.B. 1948. Properties of the International Nickel Company of Canada; in Structural Geology of Canadian Ore deposits, Canadian Institute of Mining and Metallurgy, Jubile Volume, pt. 7, p. 596-617.

Young, G.M. 1988. Proterozoic plate tectonics, glaciation and iron-formations. Sedimentary Geology v. 58, p. 127-144.

Young, G.M. and Nesbitt, H.W. 1985. The Gowganda Formation in the southern part of the Huronian outcrop belt, Ontario, Canada: stratigraphy, depositional enrivonments and regional tectonic significance. Precambrian Research v. 29, p. 265-301.

Zolnai, A.I., Price, R.A. and Helmstaedt, H. 1984. Regional cross section of the Southern Province adjacent to Lake Huron, Ontario: implications for the tectonic significance of the Murray Fault Zone. Canadian Journal of Earth Sciences, v. 21, p. 447-456.

Field trip - pseudo guide

The number of stops on our field trip will depend somewhat on the weather and on the extent of discussions that take place on the outcrop (or, negatively stated, on our ability to MOVE ALONG). At the least we will try to visit the 10 locations shown in Figure 2. Those stops illustrate some of the interesting aspects of the Southern Province. They represent outcrops which are routinely visited by Ontario Universities (in fact, the map and parts of the descriptions were lifted from the U. of Toronto field camp guide; courtesy of Sandy Cruden). In addition we will do the standard "Huronian Walk-About", conducted by all Universities.

Stop 1 - McKim Formation

Well bedded metagreywackes and metapelites of the McKim Formation. This outcrop features: sedimentary structures, folds, cleavage, a good bedding cleavage intersection lineation and chloritoid porphyroblasts pseudomorphing staurolite (at the north end). On the east side of the road breccia can be seen. This breccia is commonly considered to be "Sudbury Breccia".

Stop 2 - Espanola Formation - Sedimentary Structures

Sedimentary structures in metamorphosed calcareous sandstones.

Stop 3 - Espanola Formation - World famous clastic dyke.

Clastic dyke, containing pebbles of the underlying Bruce Formation have intruded into the overlying Espanola.

Stop 4 - More sedimentary structures in the Espanola

Stop 5 - Serpent Formation - Fault Breccia

Pink quartzites of the Serpent Formation are brecciated by a milky white quartz vein stockwork. Likely protoliths of the brecciated fault rocks can be found to the south of the breccia. (Ample room for discussion)

Stop 6 - Gowganda Formation, first look

Stop 7 - Gowganda Formation - Kinked

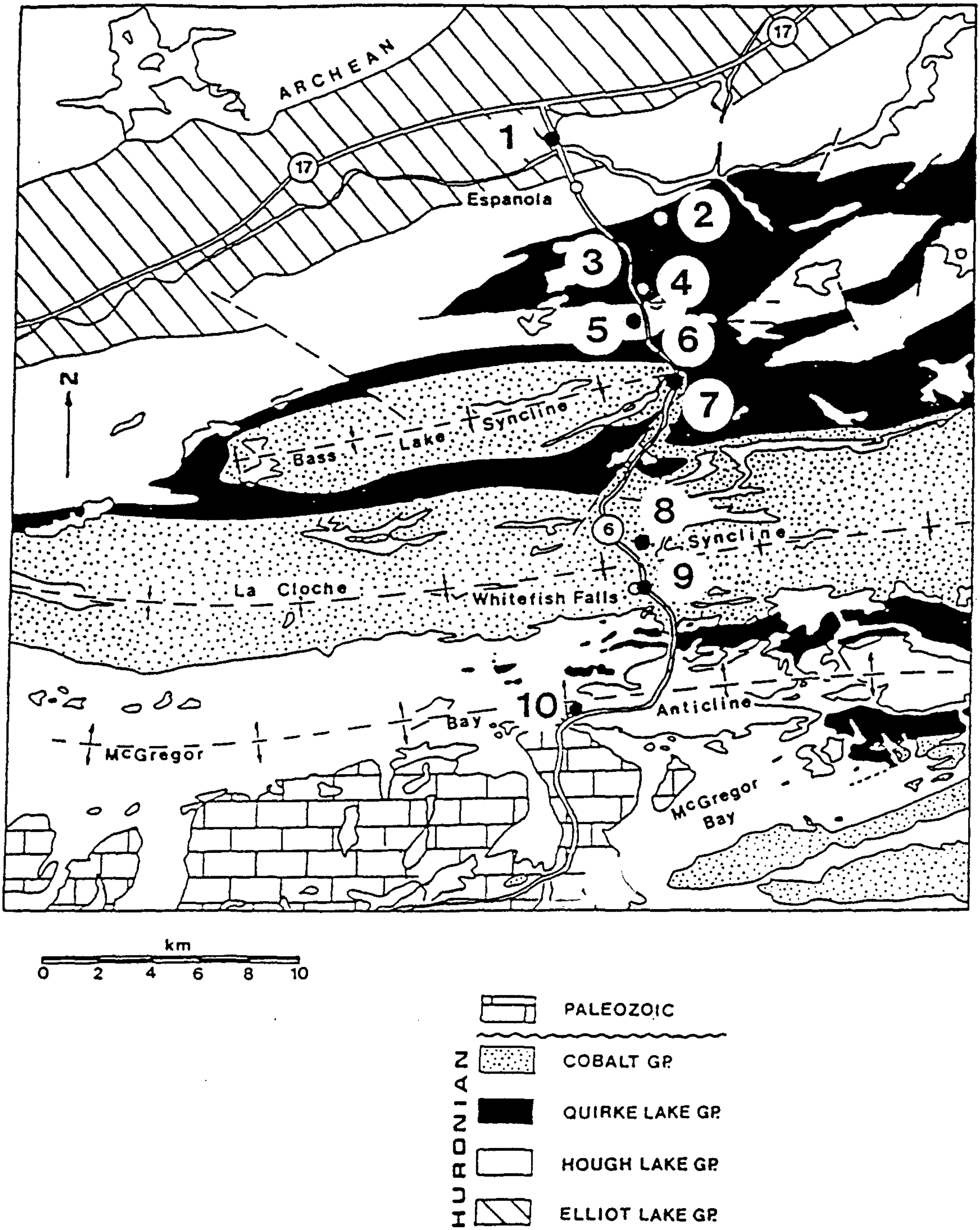
Stop 8 - Willisville Lookout - Lorrain Formation

Lorrain Formation in the core of the La Cloche Syncline. We'll walk north from the parking spot; from the core of the syncline across the Lorrain in the north limb. Note how this competent quartzite responds to the tight folding.

Stop 9 - Whitefish Falls - Diabase Dyke cutting the Lorrain.

Stop 10 - Unconformity

Unconformity between the underlying Huronian sediments and the overlying Paleozoic sediments. Not really a structure outcrop, but it's not often you can span a few billion years with your arms.


ARCHEAN
17
1
Espanola
2
3
4
5
6
7
N
Bass Lake Syncline
8
6
Syncline
9
La Cloche
Whitefish Falls
10
Anticline
Bay
McGregor
McGregor Bay
km
0 2 4 6 8 10
PALEOZOIC
HURONIAN
COBALT GP.
QUIRKE LAKE GP.
HOUGH LAKE GP.
ELLIOT LAKE GP.