DEFORMATION HISTORY OF THE CENTRAL CROSS LAKE SHEAR ZONE, NORTHWESTERN SUPERIOR PROVINCE (PART OF NTS 63I/12)

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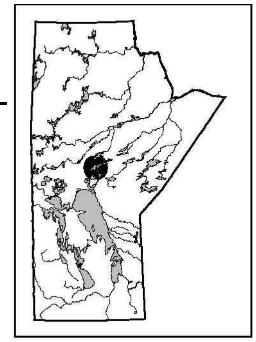

Dai, T., Jiang, D. and Corkery, M. T. 2001: Deformation history of the Central Cross Lake Shear Zone, northwestern Superior Province (part of NTS 63I/12); *in* Report of Activities 2001, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 111-114.

SUMMARY

On the basis of previous mapping and work on geochronology and metamorphism, we have conducted structural analysis of the central and southern parts of the Cross Lake greenstone belt, concentrating on the east-southeast-trending high-strain zone. Five generations of deformation have been identified. The D_1/D_2 deformation is defined by isoclinal folds, which are intrafolial to a dominant transposition foliation. Folds belonging to D_3 are generally open to tight asymmetrical and overprint the transposition foliation. Both D_1/D_2 and D_3 have a dextral sense of movement, and are interpreted as a continuous progressive deformation. The D_4 deformation is defined by en échelon veins observed in amphibolite or other more competent layers. The veins indicate a sinistral sense of movement. Folds associated with D_4 are difficult to recognize. The D_5 deformation produces open asymmetrical folds that indicate a dextral sense of movement. Dextral transpression associated with D_1/D_2 is responsible for the transposition and the formation of the shear zone.

INTRODUCTION

The Cross Lake greenstone belt is near the western edge of the Gods Lake Domain and extends westward into the Pikwitonei (granulite) Domain in the Superior Province of Manitoba. The belt has two sets of shear zones, one trending east-southeast and the other trending northeast. Previous work in this area on detailed stratigraphy, geochronology and metamorphic history includes Corkery (1983, 1985), Corkery et al. (1988), Corkery and Lenton (1989) and Corkery et al. (1992). A thermotectonic pilot study of the Cross Lake greenstone belt was conducted by Breedveld (1989).

Corkery et al. (1992) described three distinct unconformable groups of supracrustal rocks that make up the Cross Lake greenstone belt:

1) the Pipestone Lake Group (2760 Ma), a sequence of metavolcanic and subordinate metasedimentary rocks, weakly to strongly deformed pillowed basalt and minor massive basaltic flows;
2) the Gunpoint Group (2730 Ma), a fining-upward clastic sedimentary sequence with interbedded felsic volcanic rocks that unconformably overlies the older Pipestone Lake Group; and
3) the Cross Lake Group (<2710 Ma), a fining-upward sequence of fluvial-marine clastic sedimentary rocks with shoshonitic volcanic rocks near the top, unconformably overlying the Gunpoint Group.

The metamorphic grade of the Cross Lake greenstone belt increases from upper greenschist facies at Pipestone Lake to hypersthene granulite grade in the gneissic terrane northwest of Cross Lake (Breedveld, 1988).

The structural framework and kinematic evolution of the belt are unclear. Understanding the deformation history of the two sets of shear zones is critical and will elucidate the regional tectonics of the northwestern Superior Province. We carried out a structural analysis on a major east-southeast-trending shear-zone area, the central Cross Lake Shear Zone (CCLSZ), during the summer of 2001 with support from the University of Maryland and from Manitoba Industry, Trade and Mines. The study area starts at a point west of Pipestone Lake and extends about 15 km westward along central Cross Lake, between Cross Island in the north and Ross Island in the south (Fig. GS-16-1). Large-scale mapping was carried out within and adjacent to the CCLSZ and preliminary results of the fieldwork are reported below.

PRELIMINARY RESULTS OF STRUCTURAL ANALYSIS

Five generations of deformation are distinguished on the basis of style, overprinting relationships and sense of movement.

Deformations D_1 and D_2

The earliest deformation structures recognized in the CCLSZ are F_1 and F_2 isoclinal and commonly asymmetrical folds, which are intrafolial to a dominant east-southeast-trending transposition layering (S_T) that occurs throughout the zone. The two generations are indistinguishable, unless observed where a rare overprinting relationship occurs. Axes of the F_1/F_2 folds plunge moderately to steeply northeast (Fig. GS-16-2). Some F_1/F_2 folds have sheath fold geometry. An east-northeast-trending foliation (S_1/S_2) is defined by the preferred orientation of minerals and a local compositional layering. This S_1/S_2 foliation generally overprints the isoclinal folds intrafolial to S_T, but is axial planar to some. The geometrical relationship

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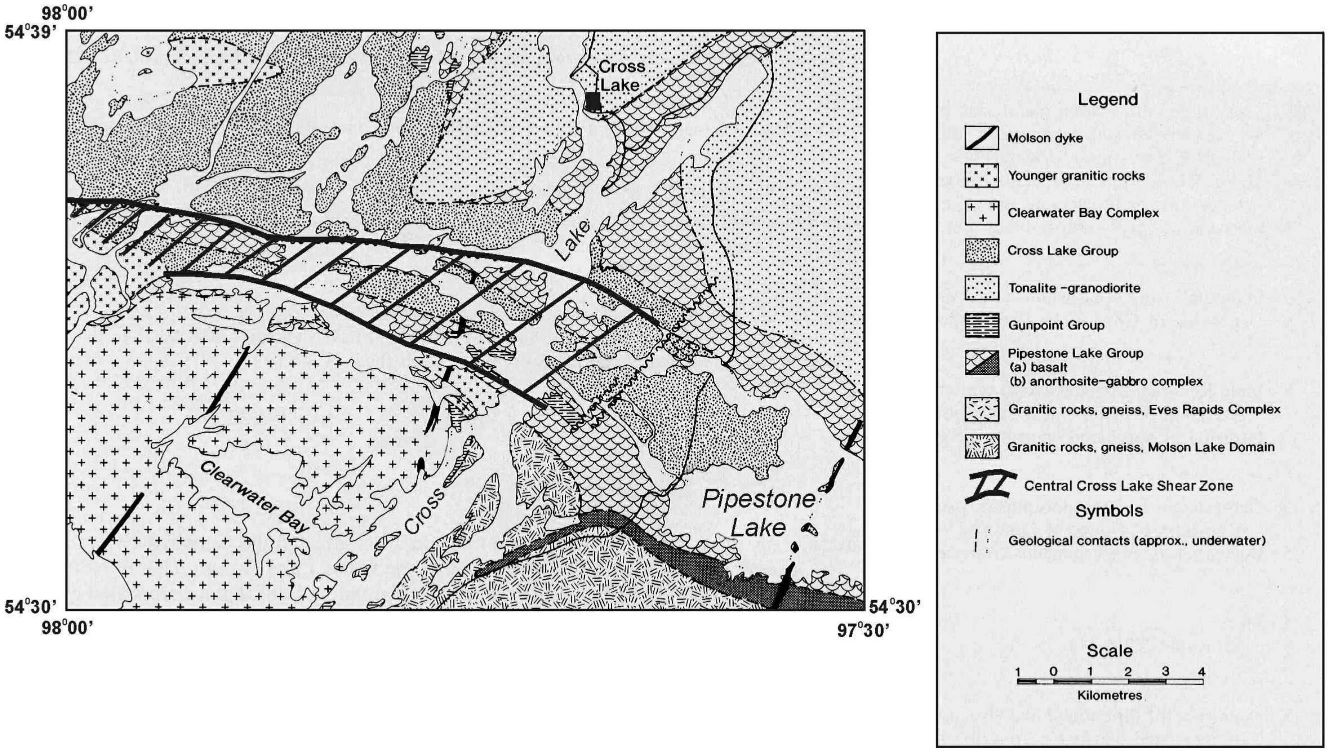

Figure GS-16-1: Simplified geology of the central Cross Lake greenstone belt (modified from Corkery et al., 1992).

between S_1/S_2 and S_T is constant, where not obscured by later deformation. The S_T transposition layering is inclined to S_1/S_2 by about 10 to 20° (Fig. GS-16-2). Treating it as an S/C fabric (S_T//C and S_1/S_2//S fabric), a dextral sense of shear of D_1/D_2 deformation is indicated. The L_1/L_2 lineations, which are defined by F_1/F_2 axes, aligned hornblende and the intersection between S_1/S_2 and S_T, plunge moderately to steeply northeast.

Boudinage is a common feature of the S_T fabric at scales varying from millimetres to metres. In some layers (e.g., pegmatite, amphibolite), the separation of boudins can be greater than their long dimension as seen on outcrop. Other layers may show considerable continuity. Boudins are generally on the limbs of F_1/F_2 folds, which indicates that they may be contemporary with folding. Boudin neck folds occur commonly, and are usually asymmetrical. The consistent Z style also indicates a dextral sense of shear that is consistent with the D_1/D_2 deformation. However, this asymmetry could also be due to D_3 modification (*see* below).

Pegmatite dykes subparallel to S_T are another common feature of D_1/D_2. Pegmatite layers are locally cut and dragged (Lister and Williams, 1983) by S_T, and the sense of shear is dextral. These pegmatites are isoclinally folded (Fig. GS-16-3) and commonly boudinaged. Some pegmatites related to D_1/D_2 are overprinted by later stages of deformation (e.g., D_3).

Deformation D_3

The F_3 folds are generally open to tight drag folds, and commonly have a Z geometry. They fold the transposition foliation S_T and S_1/S_2. There is a weak axial-plane foliation (S_3) defined by shape fabrics. Axes of F_3 folds plunge steeply. Shear-sense indicators (e.g., asymmetrical boudinage) indicate dextral sense of movement. The D_3 deformation overprints D_1/D_2 transposed pegmatite dykes with open to tight drag folds (Fig. GS-16-4a, b). There is a gradation in the tightness of F_3 folds. Some very tight F_3 folds with an axial-plane foliation are distinguishable from F_1/F_2 folds only by virtue of their association with more open F_3 folds. The kinematics from D_1/D_2 to D_3 are consistently dextral. We interpret this as progressive deformation.

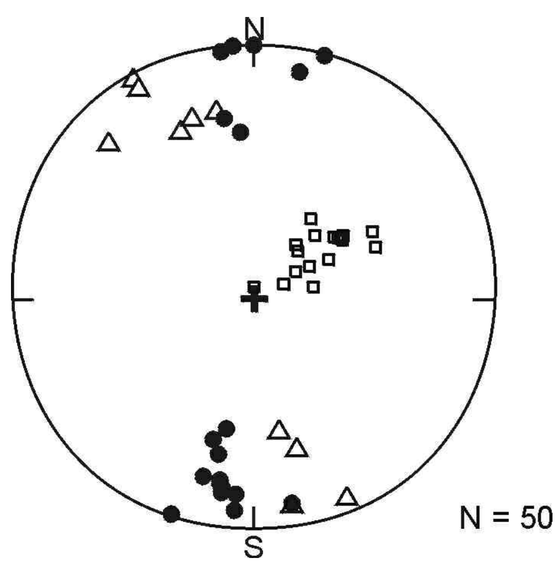

Figure GS-16-2: Lower hemisphere equal-area plot of F_1-F_2 fold axes (square), S_T (dot) and S_1-S_2 foliation (triangle).

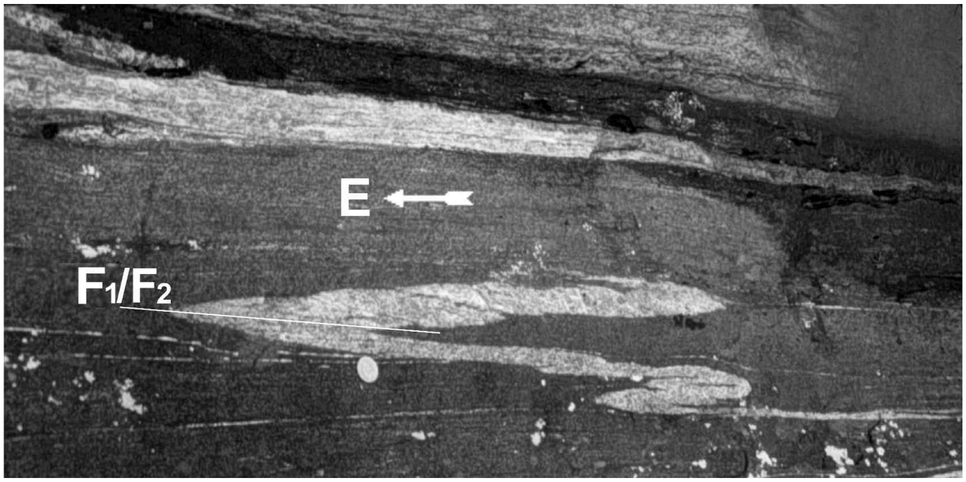

Figure GS-16-3: Isoclinal F_1/F_2 fold in pegmatite dykes in Cross Lake Group sandstone, northern Ross Island.

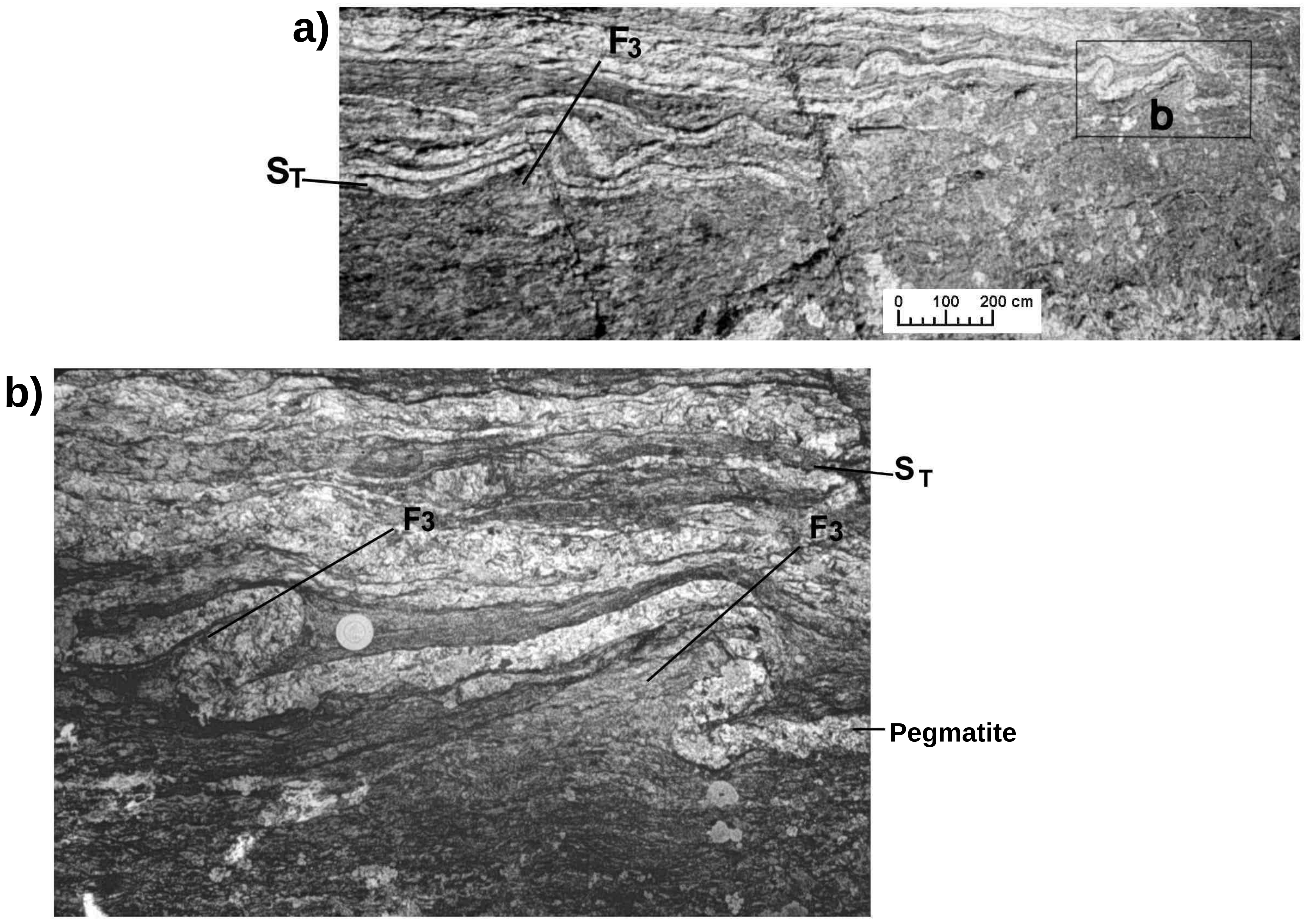

Figure GS-16-4: a) Open to tight F_3 drag folds of pegmatite dykes in Cross Lake Group sandstone; b) late and medium stage of F_3 folding, southwestern Cross Island; note coin for scale.

Deformation D_4

Normal to sigmoid, en échelon pegmatite and quartz veins occur commonly in amphibolite layers parallel to S_T. They consistently indicate a sinistral sense of movement. The development of en échelon structure is also an indication that the deformation condition is near the brittle-ductile transition. This and the sense of shear are in contrast to the sense of shear from D_1/D_2 to D_3.

It is difficult to distinguish F_4 folds from F_3 folds. Open to tight S-folds in the CCLSZ overprint S_T, with axes plunging shallowly to steeply. In some outcrops, S-folds are clearly smaller scale parasitic F_3 folds whose larger scale geometry is Z shaped. We interpret continuous chains of S-folds as F_4 folds, but realize that some of them may belong to F_3. Where isolated S-folds are observed, it is impossible to tell whether they are F_3 or F_4. Metamorphism associated with some of these folds is being investigated in the hope that it may help identify these folds.

Deformation D_5

The F_5 folds are mostly asymmetrical and commonly open, and the fold axes plunge steeply. The sense of movement of this generation is dextral. The F_5 folds overprint D_4 structures; for example, D_4 sinistral en échelon veins containing layers are overprinted by F_5 Z-folds (Fig. GS-16-5). The F_5 Z-folds can only be distinguished from F_3 Z-folds where the overprinting relationship between F_5 and D_4 is observed. The Z-shape asymmetry of D_1/D_2 boudin neck folds may have been further enhanced by D_5 dextral shear.

DISCUSSION

Based on the observations outlined above, we conclude that the CCLSZ is primarily a D_1/D_2 structure. The F_3, F_4 and F_5 folds can be interpreted as drag folds (Jiang and Williams, 1999), developed largely due to transposition-foliation-parallel shear. The D_1/D_2 deformation is transpression shear, which makes it difficult to interpret the origin of F_1/F_2 folds. From our structural analysis of folds outside the shear zone, we think that F_1/F_2 folds originated before shearing (i.e., they were inherited from pre-D_1/D_2 deformation). The D_1/D_2 transpression shear strongly modified their geometries and led to complete transposition of bedding. The D_3 deformation is likely the progression of D_1/D_2. The reversal in sense of shear during D_4 is responsible for producing the conflicting sense of structures observed in the CCLSZ. The deformation became dextral again during D_5. The CCLSZ thus has a complicated kinematic history. Preliminary mapping in the northeast-trending high-strain zones to the north of the CCLSZ also suggests similar polyphase deformation. We suggest that the two sets of shear zones may have a conjugate kinematic relationship.

ACKNOWLEDGMENTS

The project is supported by University of Maryland and Manitoba Industry, Trade and Mines. We would like to express our gratitude to Paul F. Williams, Shoufa Lin, Chris Beaumont-Smith and Andy Parmenter for discussion, Neill Brandson for his support, and Jerine Thatcher for her tireless field assistance.

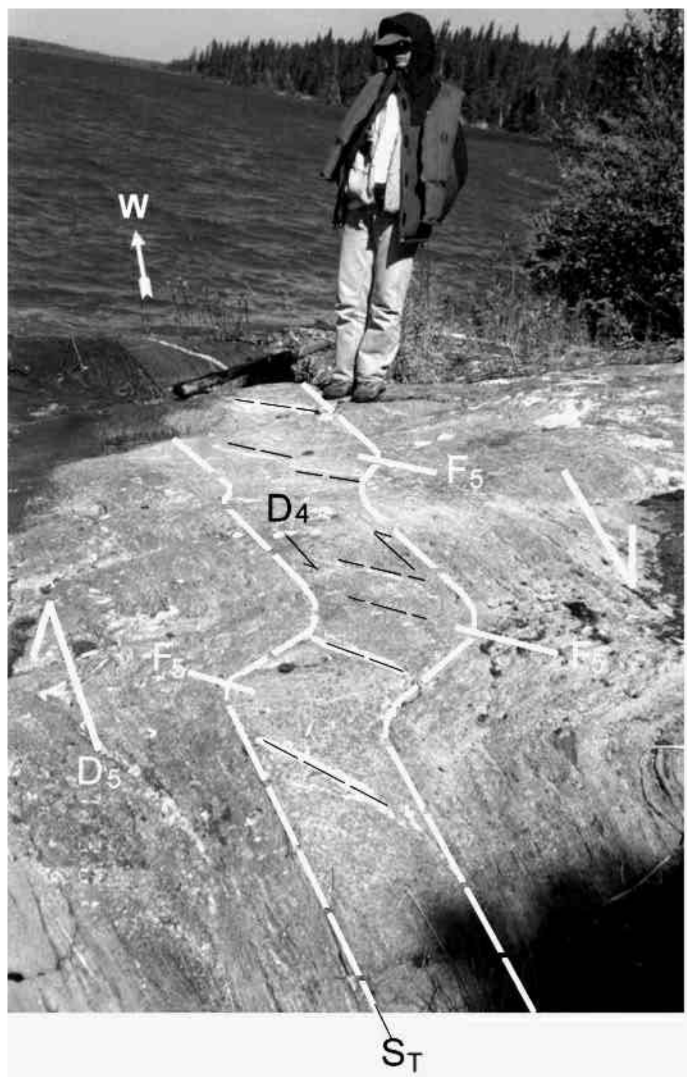

Figure GS-16-5: Sinistral en échelon D_4 structure overprinted by F_5 fold in Cross Lake Group sandstone, southern Metis Island.

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