Deformational History of the Silence Lake Lineament, Quetico-Wawa Structural Junction, Quetico Provincial Park, Ontario Canada

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INTRODUCTION: The Silence Lake Lineament is a previously unstudied N35E trending lineament southeast of the Quetico-Wawa subprovince junction. Due to evidence of motion along the lineament in the form of slickenlines and breccias, the lineament was determined to be a fault. The newly named Silence Lake Fault runs subparallel to the Reid Lake Lineament and is a dextral fault. The amount of offset is undetermined. The Silence Lake Fault shows evidence of multiple deformational events. Early ductile deformation along the fault was overprinted by brittle deformaiton Three tectonic models have been developed to explain the relationship between the amphibolite and tonalite units along the fault.

GEOLOGIC SETTING: The Superior Province of the Canadian Shield is comprised of various subprovinces which have been defined based on structural and lithologic characteristics (Card and Ciesielski, 1986). These subprovinces include metasedimentary, metavolcanic, plutonic, and high grade gneiss terranes (Figure 1). The Quetico subprovince consists of a 2694±1Ma tonalite unit and a 2678±6 Ma hornblende quartz monzonite (Woodard and others, this volume). In addition to igneous intrusions, the Quetico belt also contains metasediments and metavolcanics such as those comprising the Wawa subprovince. Percival and Williams (1989) suggest that the Quetico subprovince developed as a prism between accreting arcs now represented by the metavolcanic Wawa subprovince to the southeast and the metavolcanic Wabigoon subprovince to the northwest.

The area which includes the Wawa-Quetico belt boundary (Figure 1) has been affected by a minimum of two deformational events. At least one event was predominantly ductile; and at least one was mainly, if not exclusively, brittle. Intrusions within the Quetico subprovince both predate and postdate ductile deformation. A series of complex minor folds resulting from plastic deformation deform the boundary between the Quetico and Wawa subprovinces. Evidence of late stage brittle deformation is extensively preserved in the form of pervasive slickenlines, and at least two well- developed sets of fractures. A N60W-striking joint set is common throughout the entire study area. A N35E-striking fault zone runs subparallel to both the Reid Lake Lineament and Silence Lake Lineament. The fault zone displays hydrothermal alteration, brecciation, and slickenlines. The structures produced by brittle deformation truncate the pre-existing ductile features.

The Silence Lake Lineament (SLL) is located 1 km southeast of the Reid Lake Lineament (RLL) (Figure 1). The SLL is a geomorphological feature which roughly parallels the regional lithologic contacts. The SLL region consists of tonalite surrounding a central region of amphibolite (Figure 1).

GOALS:
- To construct a geologic map of the Silence Lake Fault and surrounding region based on surficial mapping.
- To determine the deformational history of the Silence Lake Fault.
- To construct a series of tectonic models constrained by surrounding structural and lithologic field relationships.

DEFORMATION: The studied area has been affected by multiple deformational events. Cross-cutting relations indicate that the ductile deformation pre-dates the brittle deformation. Brittle deformation cuts and sometimes offsets (on a mm to cm scale) earlier ductile deformation features. Fractures and associated epidote veins along the SLF within the jointed amphibolite cross-cut schistosity and display right-lateral micro-offset.

FIGURE 1. Lithologic Map of Reid Lake-Keewatin Lake Area Showing S_1 Foliation, Slickenside, and Slickenline Measurements Along the Reid Lake-Keewatin Lake Lineament.

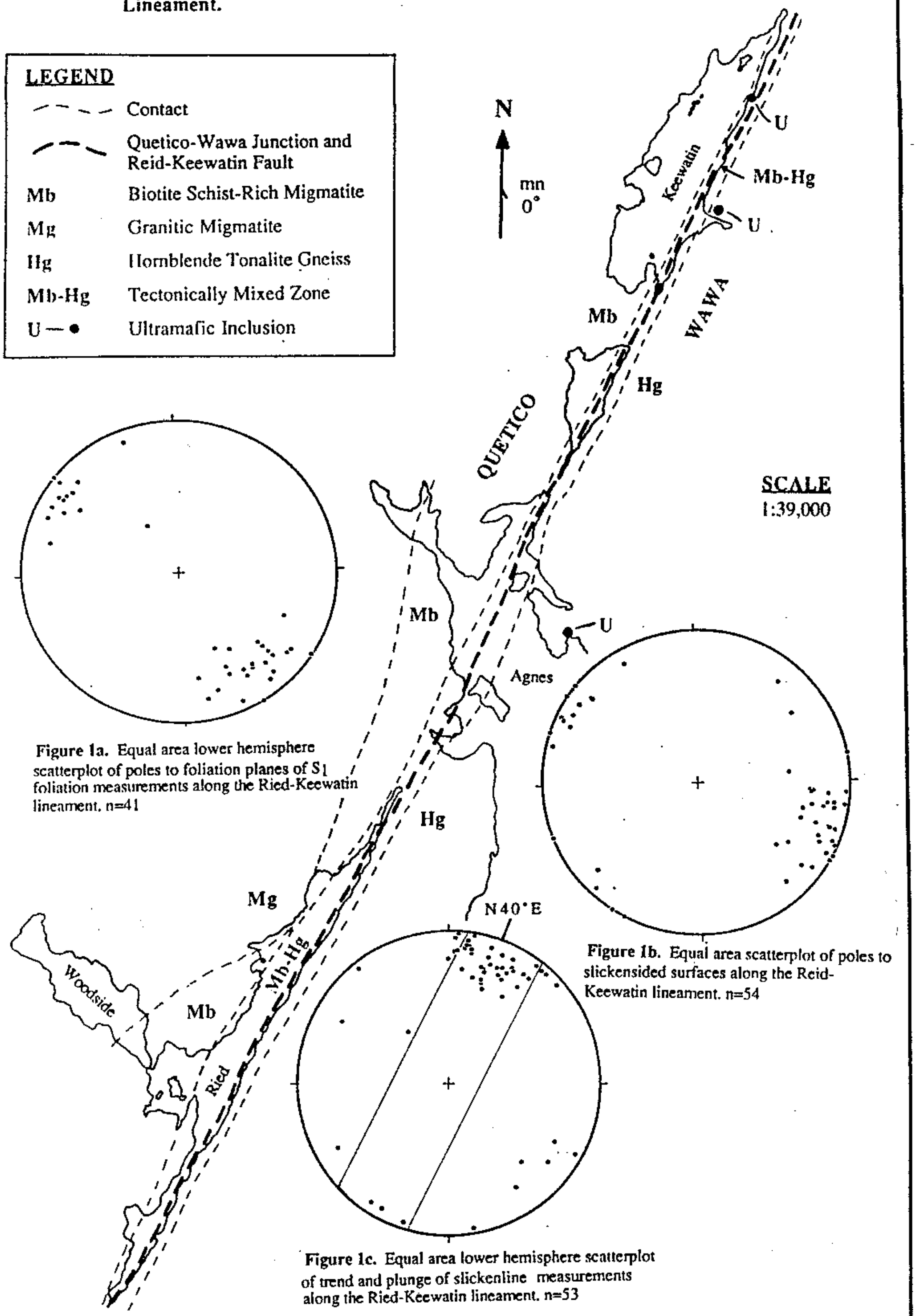

Figure 1a. Equal area lower hemisphere scatterplot of poles to foliation planes of S_1 foliation measurements along the Ried-Keewatin lineament. n=41

Figure 1b. Equal area scatterplot of poles to slickensided surfaces along the Reid-Keewatin lineament. n=54

Figure 1c. Equal area lower hemisphere scatterplot of trend and plunge of slickenline measurements along the Ried-Keewatin lineament. n=53

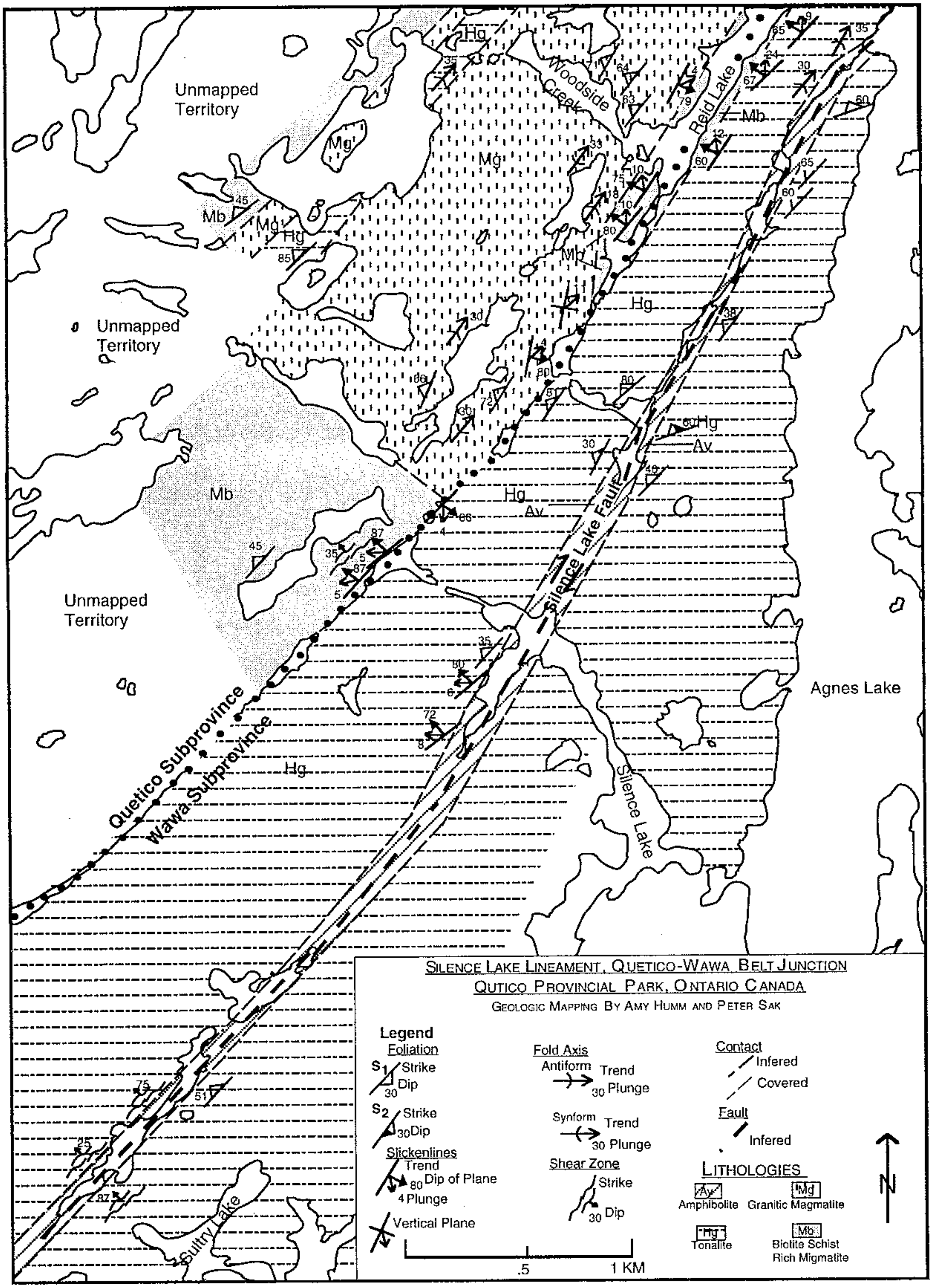

Figure One: A 1:24 000 scale geologic map of the Silence Lake Fault and surrounding region.

The ductile deformation is characterized by minor folds and S_1, S_2, and possibly S_3 foliations. The folds, D_1 and D_2, are disharmonic on an outcrop scale. The fold axes trend roughly N35E along both lineaments These isoclinal folds plunge to the northeast at approximately 30°. Amplitudes of folds range in size from 3 cm to outcrop size. The amphibolite is isoclinally folded. The biotite schist rich migmatite and granitic migmatite units often display minor folding which is highlighted by the leucosome-melanosome relationships. Folds were more difficult to observe within the tonalite. The fold axes trend subparallel to both the lineaments.

The S_1 foliation strikes N30E-N50E. This foliation is the dominant foliation throughout the study area. The strike of the foliation is relatively consistent for such a large area. The northwest dips however, demonstrate a much broader range; from 30° to near vertical.

STRUCTURAL INTERPRETATIONS: The sheared rocks and slickenlines along the SLF indicate right-lateral strike-slip motion. It is not possible to gauge the offset because the contacts of the faulted units strike sub-parallel to the fault and are thus not truncated by the structure. The neighboring RLL has evidence of left-lateral offset.

The SLF zone displays extensive brecciation resulting from shearing along the fault to a greater degree than the nearby RLL. The dip of the brecciated horizon in the southern end (south of Silence Lake) of the SLF ranges from 25-35°NW. This dip may be associated with the relative motion between the Wawa and Quetico belts. However, to the north along the SLF the fault surface brecciation is steeply dipping. The shallowly dipping brecciation suggests a thrust model, while the steeply dipping brecciation at the north end of the SLF does not.

In an attempt to accurately account for the contacts between tonalite and amphibolite, three possible models are proposed. All three of these models are based upon the assumption that the tonalite is a intrusive sill which runs sub-parallel to SLF. This assumption is supported by the evidence of amphibolite xenoliths within the tonalite and by the cross cutting relationships between the tonalite and amphibolite.

MODELS:

Single Layer: Amphibolite inclusions are observed within the tonalite on both sides of the SLF. This relationship, coupled with the parallel orientations of the tonalite to the east and west of the amphibolite, suggests that the tonalite could have been injected as one sill. After injection, the sill may have been isoclinally folded. One fundamental drawback with the single layer model is that a hinge zone has not been discovered in the study area. However, a hinge zone may exist outside of the study area, either to the north or to the south. The very nature of an isoclinal fold, makes finding it difficult. The strike of foliation only changes in the immediate vicinity of the nose, assuming that it is even preserved. If a new foliation overprints and obliterates the previous foliation a nose in tonalite for example, would be difficult to determine. The lack of layering makes evidence of folding in tonalite much more subtle than in amphibolite. These factors combine to make the one layer model a viable option. More extensive mapping of the tonalite would be required to confirm this interpretation.

Double Layer: An alternative means for explaining the "sandwiching" of amphibolite between two tonalite units is that they were injected as two sub-parallel sheets and have remained in that configuration. Due to their proximity, it is highly probable that these two sills are genetically related. Based on the assumption that they are contemporaneous, it is possible that they intruded along planes of pre-existing weakness associated with the suturing of the Wawa and Quetico belts. The two units of tonalite on either side of the amphibolite may, in fact, be viewed as one large sill with a mappable xenolith of amphibolite in the center. In that case, further mapping of the tonalite would also be useful. If the tonalite appears as a single unit north of the study area, it could suggest a single intrusive body. The lack of extended (>2m) exposures of contacts between the amphibolite and tonalite results in speculative mapping. As depicted in figure one, the contact appears very regular, but this is inferred and may not actually be the case. A highly irregular contact would be more suggestive of the double layer model. However, the narrow elongate shape of the amphibolite unit coupled with the relatively enormous size of the tonalite unit makes modeling the amphibolite as a xenolith or remnant piece of wall rock fairly unlikely.

Duplex Structure: The position of the thin amphibolite unit between the genetically related tonalite unit(s) could alternatively be explained by invoking a thrust fault model. In such a model, the thrusting would propagate from the southwest and the resulting duplex structure, once eroded, would account for the tonalite-amphibolite-tonalite sequence. In the SLF type section, brecciation dips more gently (25-35°NW) than the local S_1 foliation. This brecciated, shallowly dipping plane is suggestive of a thrust fault. However, applying present-day plate tectonics to Archean docking events may be problematic. The Archean continental crust was almost certainly substantially thinner, hotter, and therefore less dense than modern-day continental crust. Accretion and even obduction may not have taken place in the same manner as in the more recent geologic past. Convergence at subduction boundaries may not have been necessary. However, having found neither an isoclinal fold nose, nor evidence of an irregular tonalite-amphibolite contact, thrusting must be viewed as an acceptable hypothesis.

CONCLUSIONS: Despite the problems intrinsic in each of the three models, the repetition of tonalite at the south end of the SLF could be explained by any of them. The double layer model seems the most problematic. The thinness of the amphibolite and the conjectured regular contact do not accommodate the double layer model. The single layer model is more probable because of the isoclinal folding present within the amphibolite. These could be parasitic to larger regional isoclinal folds. No major fold noses were discovered within the study area, but this does not eliminate the possibility of the existence of one. Preliminary observations most strongly support a model based on thrust faulting. The shallowly-dipping brecciated zone could result from thrust faulting produced by compressional stresses. Regardless of which model is selected, field observations suggest that the SLL has undergone multiple deformational events; both ductile followed by brittle including the faulting along the Silence Lake Lineament.

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SMALL SCALE FOLD AND FOLIATION ORIENTATIONS RELATED TO MULTIPLE STAGES OF DUCTILE DEFORMATION, QUETICO-WAWA BELT JUNCTION, NEAR REID LAKE, QUETICO PROVINCIAL PARK, ONTARIO, CANADA.

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INTRODUCTION

The 1993 Quetico Keck project focused on understanding metamorphic terranes of the Canadian Shield, as they appear just north of the Minnesota-Ontario border within Quetico Provincial Park. The study area was located around Reid Lake. Sections of two subprovinces of the Superior Province of the Canadian Shield, the Quetico and the Wawa, and the junction between them, lie within the area. The Quetico subprovince has been interpreted as an accretionary wedge, consisting primarily of metagreywackes (Percival and Williams, 1989). It has undergone Amphibolite facies metamorphism which was overprinted by later Greenschist facies metamorphism (Oxboel, 1990; Percival, 1989). Related to this metamorphism, the Quetico subprovince has an axial zone of extreme anatexic migmatization and S-type plutonism (Card, 1990; Percival and Williams, 1989). The Wawa subprovince is a Granite-Greenstone belt, interpreted as a metamorphosed volcano-plutonic arc (Percival and Williams, 1989; Sylvester et al, 1987). Oceanic crust, north of the passive margin of the Wawa subprovince, was subducted beneath the Wabigoon volcano-plutonic arc. The Quetico subprovince was the fore-arc wedge of this system. When subduction ended, the Quetico collided with and sutured to the Wawa. This shifted the Quetico to a back-arc setting related to subduction on the southern margin of the Wawa (Williams, 1990; Card, 1990; Percival and Williams, 1989).

The rocks of the study area represent the suture boundary. Since these rocks were ductile and partially melted during the collision, the rocks of the two subprovinces are highly mixed together in the area. Thus no distinct boundary between the subprovinces exists. But in the zone of mixing, the suturing event created folds and foliations. This specific project was conducted to investigate the generations of these folds and foliations. Heavy anatexis of some units caused the study to be limited to the schist-dominated units of the area. In those units, thin leucosomes highlighted folding and schistosity was clear. The small size of the study area allows for the assumption that orientations, of axial surfaces and foliations, remained constant from outcrop to outcrop. Thus, orientations could be used to help distinguish between fabrics.

FOLDS

The orientations of 85 axial surfaces and hinge lines were measured in the field. Variations in strike, dip, and plunge are not isolated to individual localities, but are widely distributed. Axial surface orientations differ within the same outcrop. This was due to the presence of three generations of folds in the Reid Lake area. Although these have different orientations, all were observed to have disharmonic, noncylindrical properties.

When the axial surfaces were plotted as poles on stereonets, the three distinct orientations appeared. The fold hinge lines, which correspond with these axial surface categories, were then plotted on the stereonets. A great circle was fit to the hinge lines to represent the local orientation of the axial surface. The poles to these great circles always fell within the tight cluster of measured axial surface poles. The orientation of the F_1 axial surface was N30E;60W. The F_2 great circle showed an axial surface orientation of N75E;75W. The F_3 axial surface orientation was N05W;55W.

Each of the three generations of folds has distinctive characteristics. F_1 was usually isoclinal folding of an S_0 compositional banding. The limbs of these folds are parallel with the F_1 axial surface, which runs subparallel to the Quetico-Wawa boundary. F_1 folds usually showed S-symmetry, although some Z and M folds were seen. F_2 was ptygmatic and limited isoclinal folding of the F_1 axial surface and S_0 around the F_2 axial surface. These F_2 folds showed only S-symmetry. F_3 appeared as ptygmatic and isoclinal folding of the limbs of F_1 and F_2 isoclinal folds around the F_3 axial surface. These folds also have S-symmetry. Often, though, F_3 folding appeared only as ductile elongation of the older foliations, such as the S_0 leucosomes. In horizontal outcrop surfaces, this appeared as normal separation of leucosome boundaries. The paradox of these folds is that F_2 ptygmatic folding appears on the limbs of F_3 folds. Some F_4 ptygmatic folds were also observed.

FOLIATIONS

Up to six foliations have been observed in the outcrops of the Reid Lake area. Characteristics such as cross-cutting relationships and amount of post-formation deformation were used to assign numbers S_0 to S_4. S_0, as stated