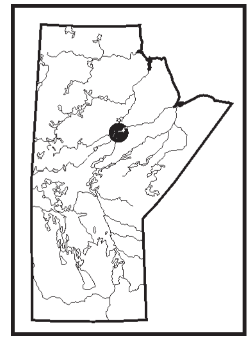
GS-18 Structural geology of the Aiken River deformation zone, Manitoba (NTS 64A1 and 2)

by Y.D. Kuiper[1], S. Lin[1], C.O. Böhm and M.T. Corkery



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Summary

The Aiken River deformation zone shows evidence for dextral, north-side-up movement. Some of this movement may be related to movement on the gold-hosting Assean Lake deformation zone to the north, suggesting that the Aiken River deformation zone may also have potential for mineralization.

This paper discusses the transition of structures from the Central Split Lake Block into the Aiken River deformation zone. The Split Lake Block shows moderately to steeply southeast-plunging folds. Toward the shear zone, the following modifications occur: 1) folds tighten; 2) shear fabrics develop on the fold limbs but not the fold hinges; 3) fold axes start rotating, which is the initiation of sheath-fold development; and 4) dextral, north-side-up shear fabrics are pervasive and sheath folds are present. This sequence of changes may indicate that the pure shear component of this transpressive shear zone is accommodated over a wider area than the simple shear component.

Introduction

The Aiken River deformation zone forms the boundary between the Split Lake Block to the north and the Pikwitonei Granulite Domain to the south (Figure GS-18-1). Three and a half weeks of structural mapping were carried out in the Split Lake–Aiken River area in 2003 (Kuiper et al., 2003). A total of two weeks were spent this summer on the western extent of the Aiken River deformation zone and surrounding areas, along the Burntwood River and western Split Lake. Additional mapping was conducted within the Split Lake Block, along northeastern Split Lake (*see* Hartlaub et al., GS-16, this volume). This report compiles all results and is accompanied by preliminary maps PMAP2004-1 (Hartlaub and Kuiper, 2004), -3 (Kuiper and Lin, 2004a) and -4 (Kuiper and Lin, 2004b).

Structural geology of the Aiken River deformation zone

The structural domains along the Aiken River deformation zone are 1) lit-par-lit gneiss, 2) lit-par-lit gneiss with close to open folds, 3) mylonite, 4) hornblende/biotite gneiss affected by the Aiken River deformation zone, 5) southern Split Lake Block, and 6) central Split Lake Block. Lithological boundaries close to the Aiken River deformation zone are partly based on deformation and therefore coincide with structural domain boundaries (Kuiper and Lin, 2004a, b; Figure GS-18-1).

Rock types along the Aiken River deformation zone were described by Haugh (1969) and Kuiper et al. (2003). Rocks of the Split Lake Block were described in detail by Haugh (1969), Corkery (1985) and Hartlaub et al. (GS-16, this volume). In general, rock types are dominated by hornblende/biotite gneiss, clotted tonalite, amphibolite gneiss and anorthosite. Locally (rafts of?) mafic granulite or metasediment are present. All rock types are intruded by fine- to medium-grained mafic dikes similar to 1883 Ma Molson dikes (Heaman et al., 1986), and by pegmatite and aplite dikes that may be related to the 1825 Ma Fox Lake granite (Heaman and Corkery, 1996). These mafic and felsic dikes are generally only deformed by late centimetre-scale shears, faults and joints. Locally, mafic dikes and aplite are folded.

In this paper, structures are described for domains 3–6, from north to south, because rocks are increasingly more affected by the Aiken River deformation zone toward the south (cf. Figure GS-18-2). The descriptions and interpretations for domains 1 and 2 are unchanged from Kuiper et al. (2003).

Central Split Lake Block (domain 6)

The main structural pattern of rocks in the studied part of the central Split Lake Block (*see* Kuiper and Lin, 2004a, b; Hartlaub and Kuiper, 2004; Hartlaub et al., GS-16, this volume) is dominated by moderately to steeply southeast-plunging open to tight folds (Figure GS-18-3a). An axial-planar cleavage (S_3) is commonly visible, and the intersection

[1] Department of Earth Sciences, University of Waterloo, Waterloo, Ontario N2L 3G1

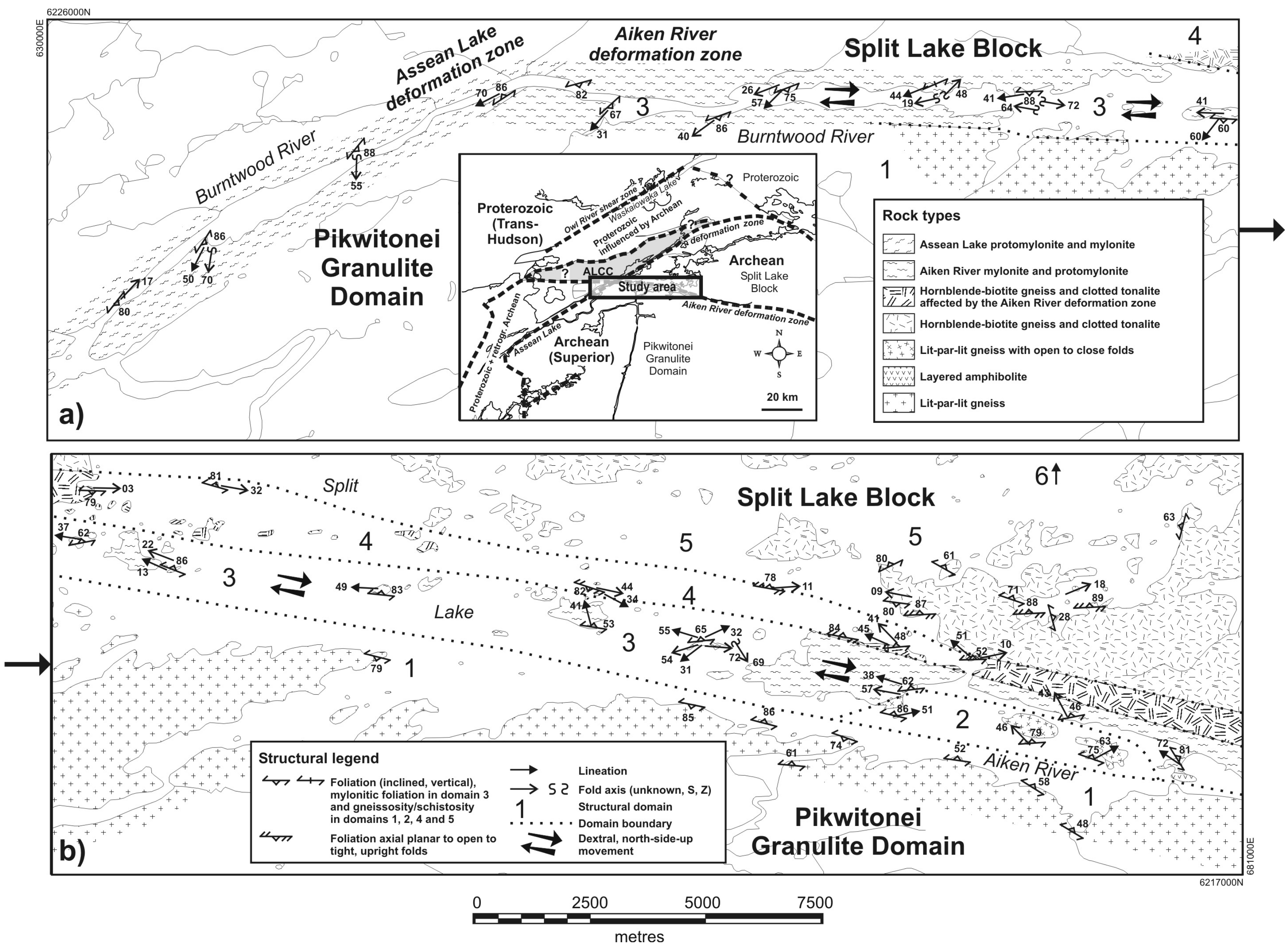

Figure GS-18-1: *Simplified geology of the Aiken River deformation zone:* ***a)*** *western part,* ***b)*** *eastern part. Insert shows location. Abbreviation: ALCC, Assean Lake Crustal Complex.*

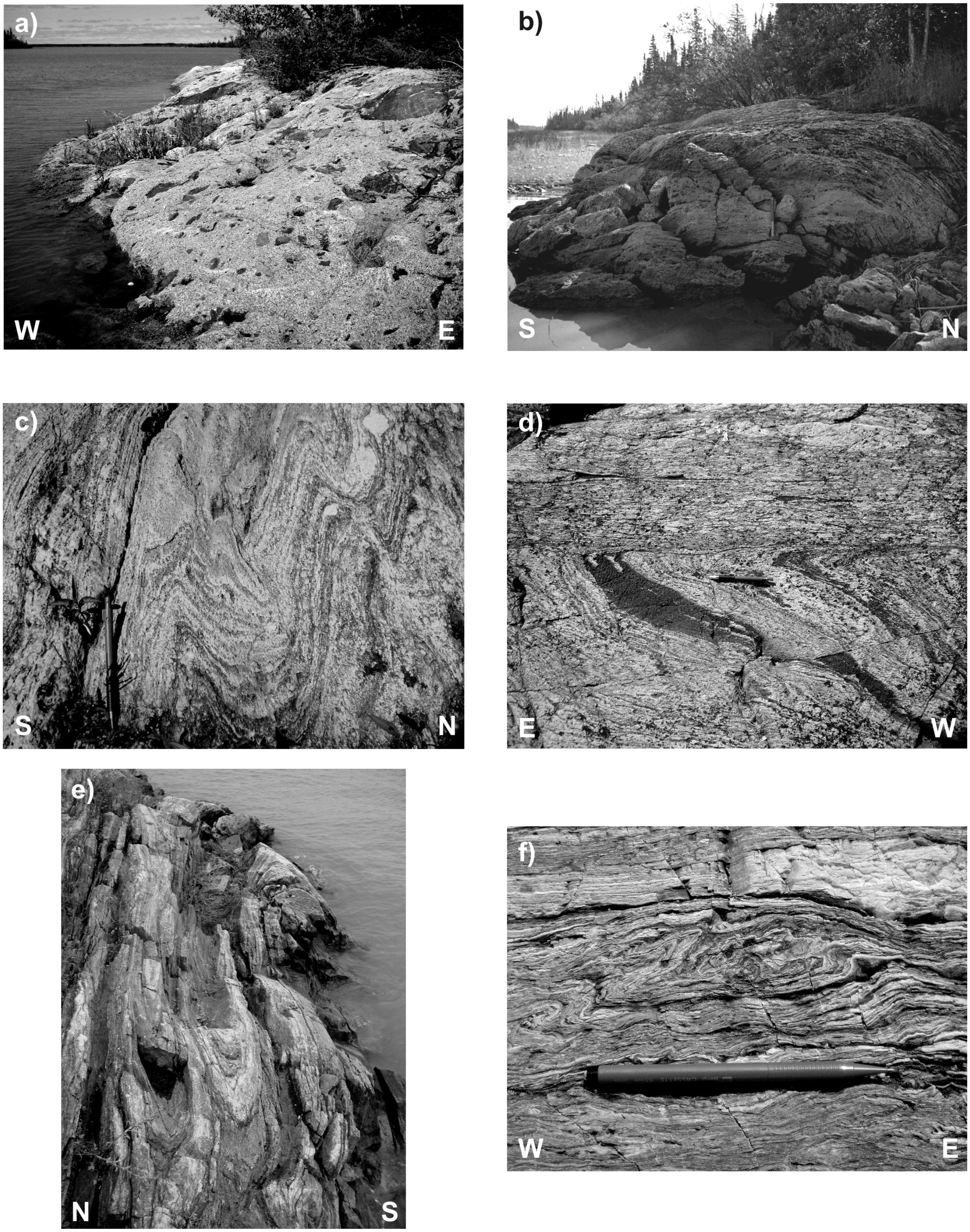

Figure GS-18-2: *Photographs of the rock types from the central Split Lake Block to the Aiken River deformation zone:* ***a)*** *nearly undeformed clotted tonalite (domains 5 and 6);* ***b)*** *open east-plunging fold in hornblende/biotite gneiss (domain 5);* ***c)*** *tight east-plunging folds in hornblende/biotite gneiss (axial-planar foliation is parallel to the pencil (domain 4);* ***d)*** *rotation of fold axes toward steeper orientations (steepening toward the front of the picture; domain 4);* ***e)*** *tightened fold hinge crosscut by dextral shear zone (domain 4); and* ***f)*** *dextral, north-side-up sheath fold in mylonite (domain 3).*

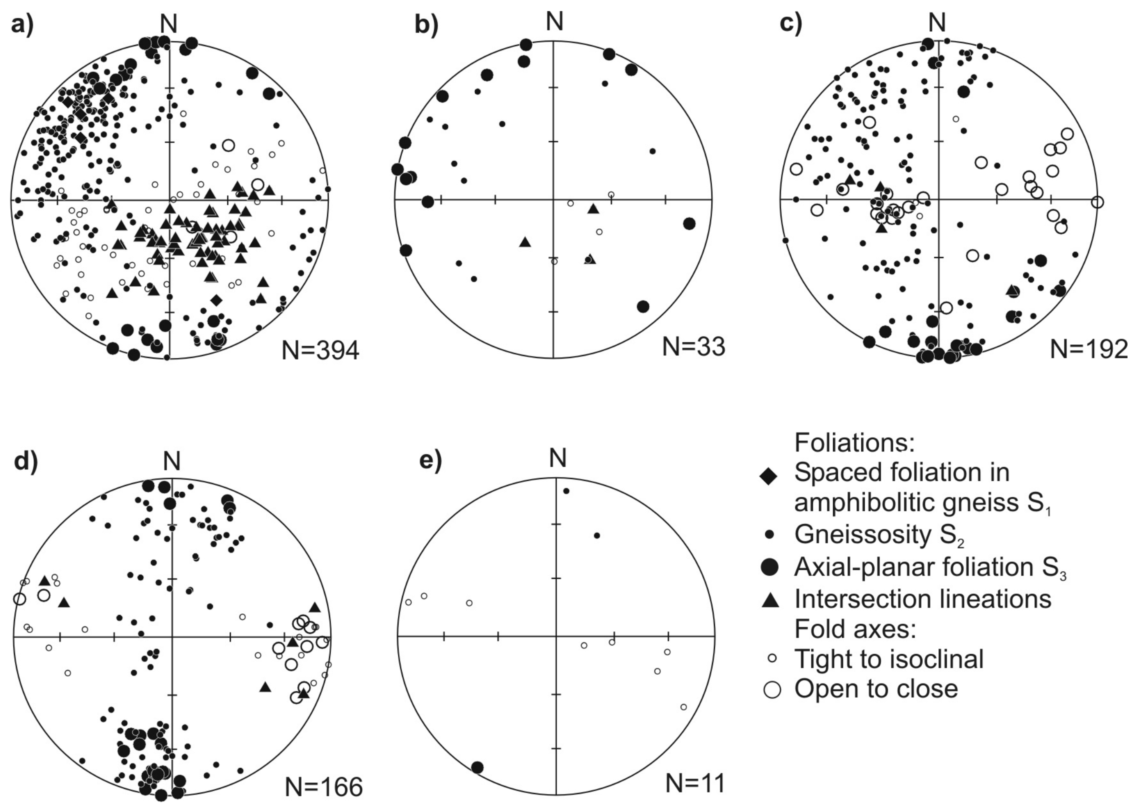

***Figure GS-18-3:** Equal-area lower-hemisphere projections of structural data from the Split Lake Block: **a)** central Split Lake Block, excluding stations 593, 598 and 618, where folds have rotated (domain 6); **b)** stations 593, 598 and 618 (domain 6); **c)** southern Split Lake Block (domain 5); **d)** Aiken River flattening zone (domain 4), excluding station 609, where fold axes steepen; and **e)** Aiken River flattening zone (domain 4), station 609.*

between S_3 and the gneissosity (S_2) defines an intersection lineation (Figure GS-18-3a) that is parallel to the fold axis. The larger spread in orientations of fold axes than of lineations is attributed to the larger measurement error on (especially open) fold axes compared to lineations. Locally, the orientations of the folds vary (Figure GS-18-3b). Because mafic and aplitic dikes are folded at these locations, the variation in F_3 fold axes is attributed to late folding. This folding may be related to late movement on the Aiken River and/or Assean Lake deformation zones, but the relationship is unclear. The variable orientation of F_3 folds is apparent in the orientation of S_3 in Figure GS-18-3b. This may also be part of the cause for the spread of fold axes and lineations in Figure GS-18-3a. The poles to S_2 form a weak girdle, the pole of which coincides with the concentration in the plunges of lineations and fold axes to the southeast (Figure GS-18-3a). The maximum of S_2 poles plunges shallowly northwest, or the majority of S_2 surfaces dip steeply southeast, close to the fold-hinge orientation. This is consistent with a generally open (cylindrical) geometry of the folds. The folds may be related to moderately east-plunging folds in the Assean Lake Crustal Complex (Kuiper et al., GS-17, this volume).

Two pre-S_3 foliations are present in the amphibolite gneiss. The S_1 is a spaced foliation that has aligned within it strongly flattened rafts and felsic melt layers up to several millimetres wide. This foliation is folded tightly to isoclinally by deformation that formed a penetrative foliation (S_2). These folds, which are mainly S-asymmetric, may either reflect a regional structural phenomenon or simply result from the map area being limited to one limb of a large-scale fold. The S_1 foliation was not recognized in the hornblende/biotite gneiss and anorthosite; however, few isoclinal folds are present in these rock types, which may be pre-S_3.

Based on its orientation, a weak foliation in the clotted tonalite is thought to be the same generation as S_2 and is therefore plotted as S_2 in Figure GS-18-3a. The hornblende/biotite gneiss and clotted tonalite are interpreted as the same rock type, their differences being related to differing degree of deformation. Both are compositionally identical and contain amphibolite rafts. At their contacts, the clotted tonalite (Figure GS-18-2a) gradually becomes more gneissic with increasing deformation until it grades into the hornblende/biotite gneiss (Figure GS-18-2b). The authors hypothesize that the clotted hornblende may occur in large-scale fold hinges, where (shear) strain is lower, and the hornblende/biotite gneiss on fold limbs, where shear strain is greater and a gneissosity was preferentially developed. If true, then S_2 (gneissosity) and S_3 (the axial-planar cleavage) developed at the same time. This interpretation could not be tested in the field, however, due to the large scale of the folds and the lack of continuous outcrop. Alternatively, the gneissosity may have developed at the same time as the isoclinal folds (*see* above).

Southern Split Lake Block (domain 5)

This domain is a combination of domains 5 and 6, the hornblende/biotite gneiss and clotted tonalite, respectively, of Kuiper et al. (2003). The two domains were previously separated because the relationship between the two rock types was unclear. As explained above, however, these rock types are probably the same, the only difference being their level of deformation.

The open to tight folds in domain 5 generally plunge shallowly east but can vary (Figures GS-18-2b, -3c). The nature of the lineations was not always clear from field observations, but they are thought to be parallel to the fold axes. The poles to the gneissosity (S_2) spread evenly along a girdle (Figure GS-18-3c), suggesting cylindrical folding. The S_3 foliation is axial planar to the east-plunging folds (Figure GS-18-3c).

Aiken River flattening zone (domain 4)

Compared to folds in domain 5, those in domain 4 are tighter (commonly isoclinal) and the fold axes plunge shallowly east and west (Figure GS-18-3d). An example is shown in Figure GS-18-2c. The lineations are intersections between the gneissosity (S_2) and the axial-planar foliation (S_3) to the folds. Poles to S_2 form a girdle perpendicular to the fold axes. Most S_2 planes are subvertical and east trending, which is the orientation of the fold limbs and the axial-planar foliation (Figure GS-18-3d). This confirms that the folds are isoclinal. Dextral, north-side-up shear fabrics are visible on both fold limbs, but not on the hinges. At one location (Figure GS-18-2d), a dextral shear zone cuts off half of a fold hinge. At locations very close to the mylonite zone (domain 3), fold axes rotate toward steeper plunges (Figures GS-18-2e, -3e).

Aiken River deformation zone mylonite (domain 3)

A 1–1.5 km wide zone of well-developed mylonite is exposed along the Aiken and Burntwood rivers (Figure GS-18-1; Kuiper and Lin, 2004a, b). The fine-grained mylonite is, in places, ultramylonitic or cataclastic. In the western part of the zone (domain 3C), protomylonite is present. Dextral, north-side-up movement is indicated by shear bands, S-C fabric, oblique foliation, asymmetric clasts and Z-folds (Kuiper et al., 2003). Locally, dextral fabric and lineations are folded by Z-folds, which indicates that new Z-folds continued to develop during late shearing. A few north-side-up (and dextral?) sheath folds exist in domains 3B and 3C (Figure GS-18-2f). In the eastern part of the mylonite zone (domain 3A), they are not recognized, perhaps due to the complicated folding patterns (*see* Kuiper et al., 2003). The presence of shear bands and absence of kink structures indicate that the shear zone is thinning or transpressional (Williams and Price, 1990). The fact that sheath-fold axes and related fold axes lie within the plane of the shear zone (*see* below) is also consistent with transpression (in a transtensional zone they would be at an angle; Jiang and Williams, 1999).

The Aiken River deformation zone has been divided into three domains (Figures GS-18-1, -4; Kuiper and Lin, 2004a, b). In the east (domain 3A), the orientations of the mylonitic foliations indicate a west-northwest trend and a steep northerly dip for the mylonite zone (Figure GS-18-4a). Fold axes lie in the plane of the foliations (Figure GS-18-4c). In domain 3A, at least two isoclinal fold generations are recognized. They are thought to be related to the sheath folds in domains 3B and 3C to the west. Lineations plunge moderately to the west-northwest (Figure GS-18-4b). Z-fold axes spread along the plane of the foliation. S-folds are rare. Their fold axes plunge moderately to the west-southwest.

Farther to the west, in domain 3B (Figure GS-18-4d), structures are essentially the same as in domain 3A, except that the entire shear zone, including foliations, lineations and fold axes, trends west. This is also apparent in the westerly trend of Split Lake toward the Burntwood River, as opposed to the west-northwest trend of the Aiken River (Kuiper and Lin, 2004a, b, Figure GS-18-1). Lineations plunge moderately to the west. Sheath folds in this domain indicate north-side-up (dextral?) movement. The S-fold in Figure GS-18-4 is part of a north-side-up sheath fold.

In domain 3C, the Burntwood River trends west, whereas the mylonitic foliation trends west-southwest (Kuiper and Lin, 2004a, b; Figures GS-18-1, 4e). Fold axes and lineations lie within the plane of the foliations (Figure GS-18-4). Rare sheath folds indicate north-side-up, dextral movement. Lineations plunge moderately to the west-southwest.

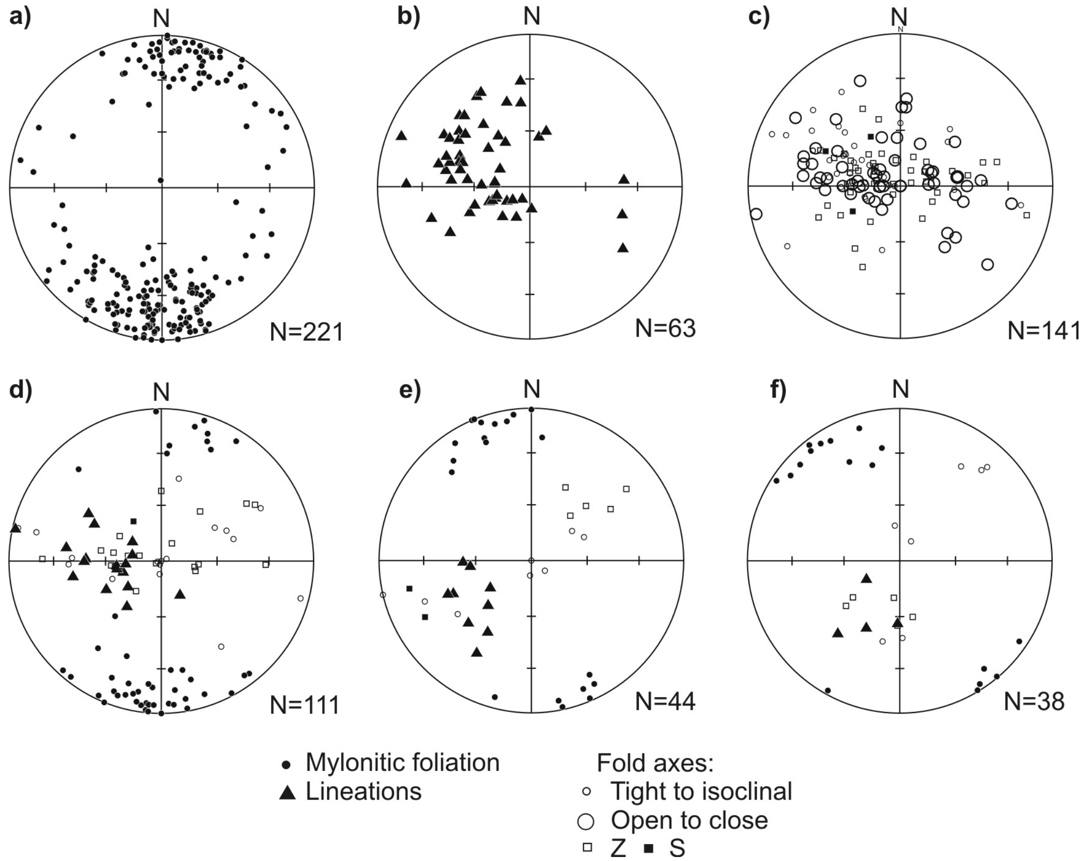

***Figure GS-18-4:** Equal-area lower-hemisphere projections of structural data from mylonite of the Aiken River deformation zone (domain 3), southeastern Split Lake: **a)** foliations; **b)** lineations; **c)** fold axes; **d)** mylonite of western Split Lake; **e)** Aiken River deformation zone mylonite, Burntwood River; and **f)** Assean Lake deformation zone mylonite, Burntwood River.*

The westernmost extent of the mapped area is along strike from the Assean Lake deformation zone (cf. Figure GS-18-1). Oblique foliations and S-C fabric, combined with a southwest-plunging intersection lineation, indicate dextral, southeast-side-up movement, consistent with movement on the Assean Lake deformation zone (Kuiper et al., 2003; Kuiper et al., GS-17, this volume). However, undeformed mafic dikes are present in the Aiken River deformation zone but absent in the Assean Lake deformation zone.

Transition from Archean (?) folds in the Split Lake Block to mylonite of the Aiken River deformation zone

Southeast-plunging folds of domain 6 consistently become tighter, and fold axes display shallow east and west plunges, toward the Aiken River deformation zone (domains 5 and 4). The fact that tightening of folds in proximity to the shear zone occurs before shear structures develop (*see* below) suggests that the pure shear component of the shear zone is accommodated in a wider zone than the simple shear component. This is consistent with an interpretation of the Roper Lake shear zone on Cape Breton Island, Canadian Appalachians by Lin et al. (1998), who discussed the phenomenon in more detail. It is unclear why the plunge of the fold axes becomes shallower toward the shear zone.

In approaching the shear zone, dextral, north-side-up shear fabrics develop on the limbs of the folds (domain 4). The shear sense is the same on both limbs and cannot therefore be attributed to shear on fold limbs during folding. The fold hinges are not affected by shear, probably because shear deformation in a vertical plane can more easily be accommodated in the subvertical fold limbs than on the subhorizontal fold hinges.

Closer to the mylonite zone, fold axes start to rotate, perhaps as a result of shear in the shear zone. This rotation may indicate sheath-fold development. Sheath folds are recognized within the mylonite zone to the west (*see* above). This suggests that sheath folds do not only evolve from shear zone–related Z-folds (*see* Kuiper et al., 2003), but also from preexisting folds.

Within the mylonite zone, dextral, north-side-up shear fabrics are well developed and penetrative (Kuiper et al., 2003), and sheath folds are present (*see* above). Shallowly east- and west-plunging folds are absent, as they have evolved into sheath folds and/or complex folds.

In summary, the transition from the moderately to steeply southeast-plunging folds of the Split Lake Block to shear zone–related structures displays the following phenomena as the shear zone is approached: 1) folds become tighter; 2) shear fabrics develop on the fold limbs but not the fold hinges; 3) fold axes start rotating, which is the initiation of sheath-fold development; and 4) shear fabrics are penetrative and sheath folds are fully developed.

Approaching the Assean Lake deformation zone

As one approaches the Assean Lake deformation zone (domain 3C), mylonitic structures of the Aiken River deformation zone rotate toward a west-southwesterly orientation, whereas the Burntwood River continues to trend west until it meets the southwestern extension of the Assean Lake deformation zone. Similar to the flattening or tightening of folds close to the Aiken River deformation zone, described above, this rotation may be a result of flattening of structures close to the Assean Lake deformation zone. Again, the pure shear component on the Assean Lake deformation zone would be accommodated over a wider area than the simple shear component. If true, the Assean Lake deformation zone was active at a later time than the Aiken River deformation zone. This is consistent with the observation that undeformed mafic dikes exist within the Aiken River deformation zone but not in the Assean Lake deformation zone (cf. Kuiper et al. GS-17, this volume). An alternative explanation for rotation of foliations of Aiken River mylonite is that it may be the result of simple shear on the Assean Lake deformation zone. This would, however, suggest sinistral movement on the Assean Lake deformation zone, which has not been recognized.

The westernmost part of the mapped area is along strike from the southwestern extension of the Assean Lake deformation zone. Oblique foliation and S-C fabric suggest dextral, southeast-side-up movement, consistent with movement on the Assean Lake deformation zone. The existence of undeformed mafic dikes, however, suggests that this part of the Assean Lake deformation zone was not active as late as the part to the northeast. The western extent of the Aiken River deformation zone (if present), west of the Assean Lake deformation zone, could not be traced due to a lack of outcrop. However, if the Aiken River deformation zone is deformed by the Assean Lake deformation zone, it is expected to continue farther to the north than is currently shown on maps (cf. Figure GS-18-1, insert). This is consistent with west-trending mylonite, similar to that of the Aiken River deformation zone, exposed on the central peninsula of Pukatawakan Lake, which is located about 5 km northwest of the presumed intersection of the Assean Lake and Aiken River deformation zones.

Economic considerations

The results presented in this report form part of a larger project, which includes studies of kinematics and timing of deformation of the Assean Lake deformation zone (Kuiper et al., GS-17, this volume). Exploration by Rare Earth Metals Corp. and their joint venture partner and operator, Canadian Gold Hunter Corp., has confirmed the occurrence of gold in and north of the Assean Lake deformation zone. Gold within the shear zone could be related to Paleoproterozoic reactivation and/or possible Neoarchean movement (Kuiper et al., GS-17, this volume). Movement on the Aiken River deformation zone seems, at least in part, older than movement on the Assean Lake deformation zone, although early (Neoarchean?) movement on both zones may have occurred simultaneously. If true, the Aiken River deformation zone may have the same potential for shear zone–hosted gold as the Assean Lake deformation zone. In order to establish the age or ages of movement on these shear zones and the potential for the Aiken River deformation zone to host gold mineralization, samples have been taken for U-Pb geochronology. Furthermore, $^{40}Ar/^{39}Ar$ geochronology will be used in future to elucidate the uplift history of the Assean Lake Crustal Complex, the Split Lake Block and the Pikwitonei Granulite Domain, in relationship to movement on the deformation zones (*see also* Kuiper et al., GS-17, this volume). If gold mineralization was controlled by deformation that occurred on both deformation zones, then prospects for gold exploration on the Aiken River deformation zone could be very promising.

Positive results from kimberlite indicator studies in the northern Superior Province to the southwest imply a potential for diamondiferous kimberlites in the region. Furthermore, the tectonic configuration of the study area along the Superior craton margin, where thick Archean lithosphere is bounded by major sutures against the Paleoproterozoic Trans-Hudson Orogen, is favourable for primary diamond sources. In addition, kimberlites may be emplaced along lithospheric discontinuities, such as the Aiken River deformation zone, or be associated with mafic dike swarms.

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