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GS-14 Structural geology of the Assean Lake and Aiken River deformation zones, northern Manitoba (NTS 64A1, 2 and 8)

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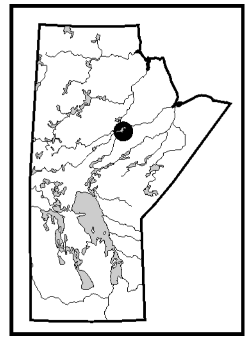

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Summary

The current level of understanding of geologically complex regions within the Superior Boundary Zone in Manitoba is not sufficiently developed to guide exploration companies. A thorough understanding of the nature of major terrane-bounding shear zones, and of deformation and timing thereof, is essential for producing modern geological maps of the Superior Boundary Zone in the study area. Regional geology suggests that the potential for a variety of mineral-deposit types is high in the area.

Preliminary maps and structural data are presented for areas around the Assean Lake and Aiken River deformation zones, along the western side of the Split Lake Block. The Assean Lake deformation zone records at least one generation of tight to isoclinal folding, including south-side-up sheath folding. Shear movement was south-side-up and dextral. The Aiken River deformation zone displays two generations of tight to isoclinal folding, followed by close to open east-trending folding and subsequent open north-trending folding. Shear movement was north-side-up and dextral.

Introduction

The Assean Lake and Aiken River deformation zones separate the Split Lake Block (SLB) from the Assean Lake Crustal Complex (ALCC) to the north and the Pikwitonei Granulite Domain (PGD) to the south, respectively (Fig. GS-14-1a). Three weeks of mapping were conducted in the Assean Lake area (Fig. GS-14-1b), and three and a half weeks were spent in the Split Lake–Aiken River area (Fig. GS-14-1c). Preliminary results are presented here. In addition, U-Pb and $^{40}Ar/^{39}Ar$ geochronology will be carried out in the future to constrain the timing of deformation and metamorphism, and to unravel the uplift histories of various geological domains. This project forms part of the Superior margin program described in Böhm et al. (GS-12, this volume).

The Assean Lake area was mapped previously by Haugh (1969) and Böhm (1997b), and the Split Lake–Aiken River area was mapped by Haugh (1969). Corkery (1985) compiled work by himself and others into a map of the lower Nelson River. The western extent of the area includes Little Assean Lake and the northeastern part of Split Lake. Little Assean Lake was visited during this study, and data are included in Figures GS-14-2a–c. This study complements earlier work and is the first detailed structural study on the Assean Lake and Aiken River deformation zones.

The Assean Lake deformation zone was initially interpreted as being the Paleoproterozoic contact between the Archean PGD or Superior Province to the southeast and the Paleoproterozoic Kisseynew Domain or Trans-Hudson Orogen to the northwest (Corkery, 1985, and references therein). Discovery of Mesoarchean (pre–3.0 Ga) crustal material in the ALCC, however, indicates that the contact lies farther to the northwest (Böhm et al., 2000). The Assean Lake deformation zone may be an older (Archean?) suture zone between the SLB and the ALCC. Late Archean (ca. 2695 Ma) zircon in samples of the SLB (Böhm et al., 1999), and ca. 2.68 and ca. 2.61 Ga zircon overgrowths and ca. 2.6 and ca. 2.45 Ga monazite (Böhm et al., 2003) in rocks of the ALCC may represent pre-Hudsonian deformation and metamorphism, part of which may be related to accretion between the ALCC and the SLB.

Metamorphism reached granulite facies in the SLB and amphibolite facies in the ALCC (Corkery, 1985). Metamorphism in the PGD reached granulite facies, except for the northern part where only amphibolite-facies conditions were recognized (cf. Haugh, 1969). All three domains, plus the Assean Lake and Aiken River deformation zones, experienced retrograde greenschist-facies conditions (cf. Haugh, 1969; Corkery, 1985).

The purpose of this project is to clarify the mechanisms and timing of juxtaposition of the SLB, ALCC and PGD, and of later movement between the domains. Furthermore, the uplift histories of the various domains and the relationship between uplift and movement on the Assean Lake and Aiken River deformation zones will be studied. A detailed microscopic and macroscopic structural study, combined with U-Pb and $^{40}Ar/^{39}Ar$ geochronology, will be conducted. Uranium-lead geochronology will be used to constrain the timing of deformation and $^{40}Ar/^{39}Ar$ geochronology will be used to unravel the uplift histories of the SLB, ALCC and PGD.

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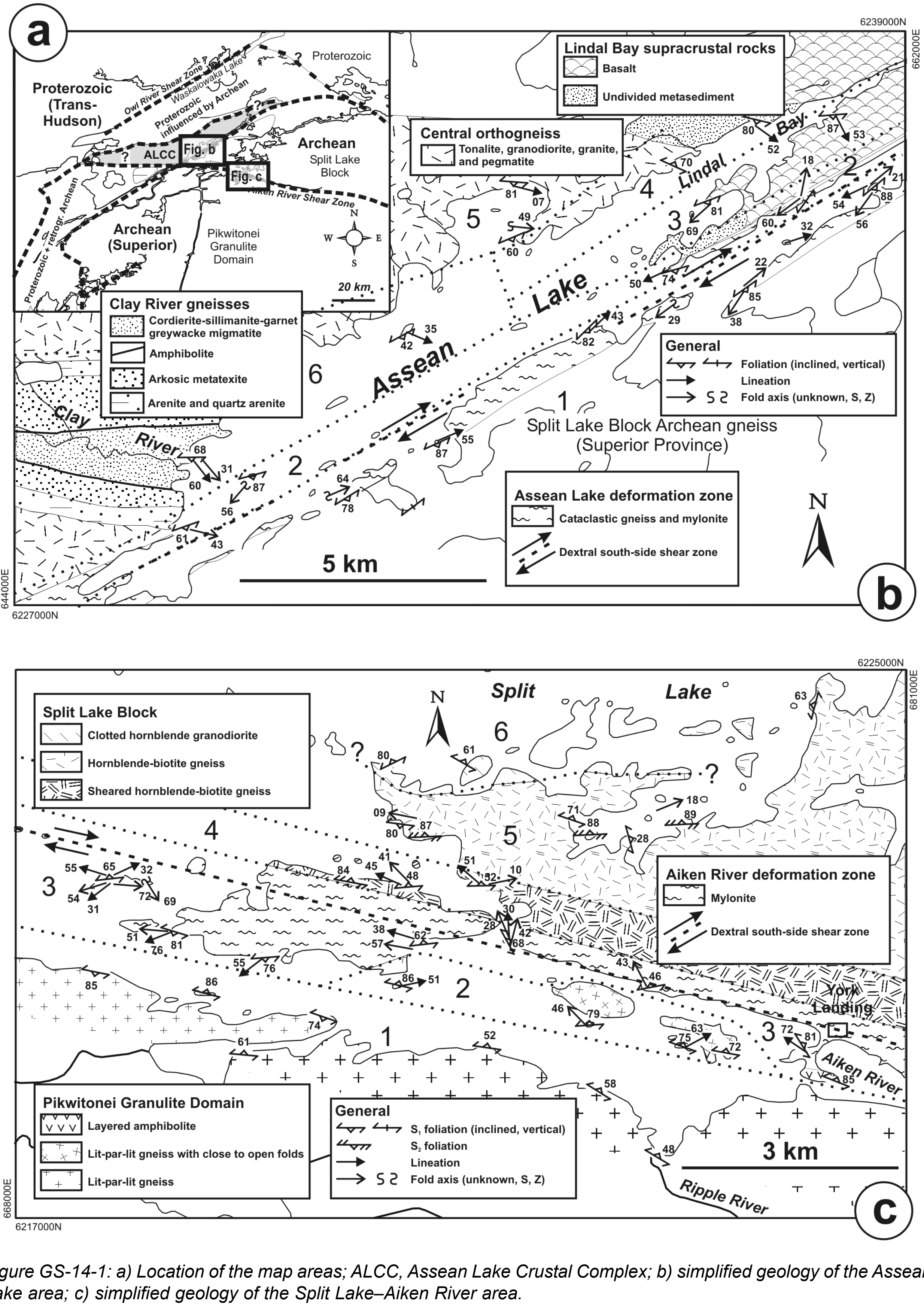

Figure GS-14-1: a) Location of the map areas; ALCC, Assean Lake Crustal Complex; b) simplified geology of the Assean Lake area; c) simplified geology of the Split Lake–Aiken River area.

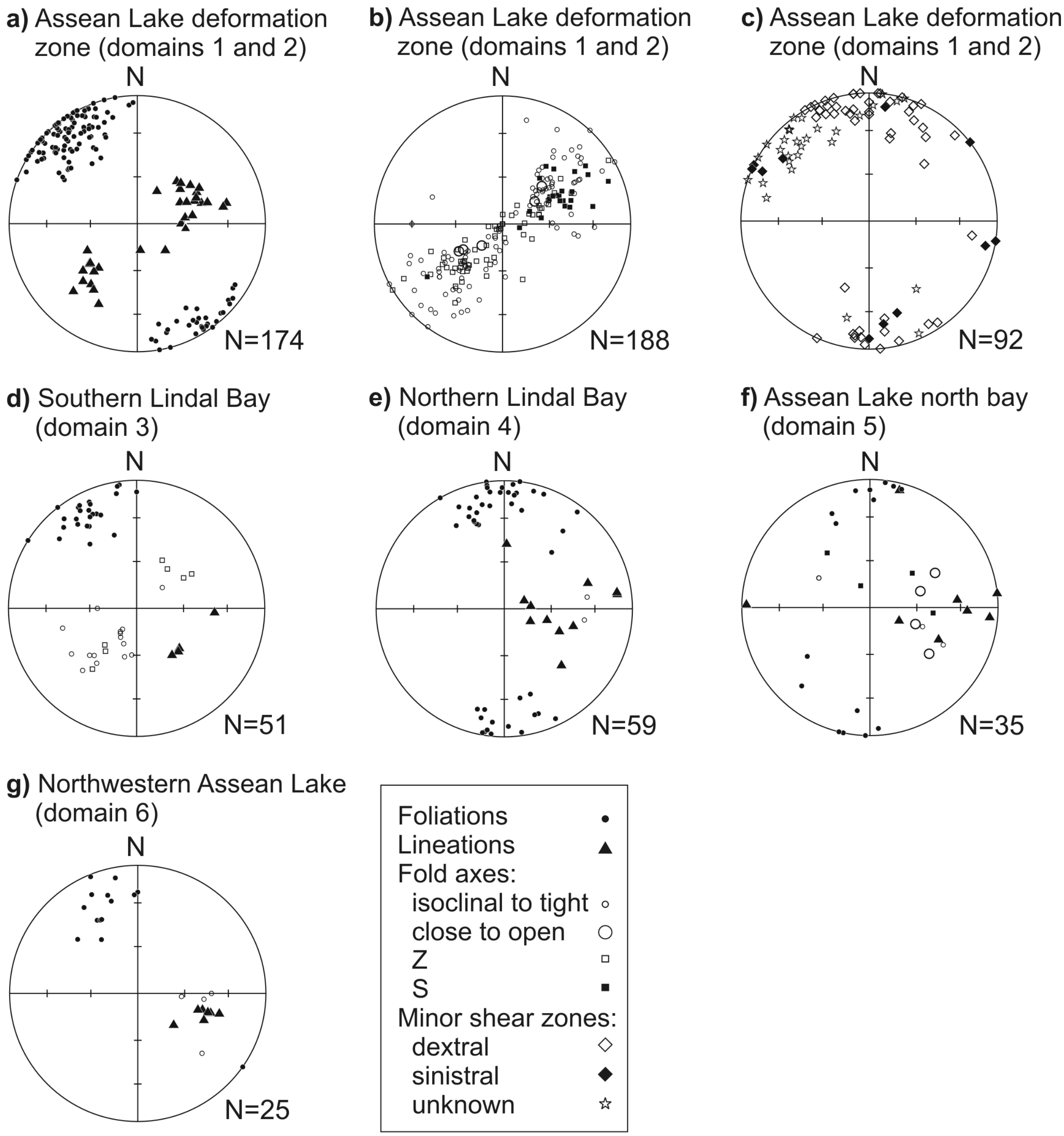

Figure GS-14-2: Equal-area lower-hemisphere projections of structural data from the Assean Lake area.

Assean Lake Area

The Assean Lake area can be divided into two domains based on rock type. Rocks south of the Assean Lake deformation zone, in the SLB, consist of granitic gneiss, hornblende-bearing granodioritic gneiss, lenses and dikes of deformed amphibolite, and aplite dikes. The area north of it (part of the ALCC) consists of granitic and tonalitic gneiss, metasediment, layered amphibolite and pegmatite. All rocks are deformed. Rocks of the ALCC have been previously described by Corkery et al. (2000) and Böhm et al. (2003), and all rock types are described by Böhm (1997a).

The Assean Lake area is divided into six structural domains: 1) the southern Assean Lake deformation zone, 2) the northern Assean Lake deformation zone, 3) the southern Lindal Bay area, 4) the northern Lindal Bay area, 5) the north bay area and 6) northwestern Assean Lake (Fig. GS-14-1b).

Domains 1 and 2

Structures in domains 1 and 2 are the same, except that lineations in domain 1 plunge predominantly to the northeast and in domain 2 to the southwest. Figure GS-14-2a shows foliations and lineations, and Figure GS-14-2b the fold axes, for both domains. Only one generation of foliations was recognized. The foliations trend 050° and are subvertical. Lineations form two clusters that are moderately northeast and southwest plunging.

Lineations in all rock types, except for amphibolite, are formed by quartz and feldspar, and locally by biotite. Quartz and feldspar lineations are commonly rods and, in some locations, they are parallel to fold axes. Hornblende and plagioclase lineations are present in amphibolite and have the same orientations as the quartz/feldspar and biotite lineations in the other rock types.

Folds are mostly isoclinal or tight. The few close folds that are present have orientations similar to the tight to isoclinal folds. Overprinting relationships were not found. Therefore, the two types of folds may be the same generation. Sheath folds were found along Little Assean Lake and in the southwestern part of the Assean Lake deformation zone. Their asymmetries consistently indicate south-side-up (Fig. GS-14-3a). Predominantly northeast-plunging S-folds and southwest-plunging Z-folds within domains 1 and 2 may well be part of the same sheath fold system, as is shown in the example in Figure GS-14-3a. Alternatively, the S- and Z-folds may have formed during separate events. This interpretation is not preferred, however, because no overprinting relationships were recognized.

Localized centimetre- to decimetre-scale greenschist-facies shear zones are present within the Assean Lake deformation zone. Most shears are dextral (occasionally with a south-side-up component), subvertical and east trending, but some subvertical sinistral shears trend 020° (Fig. GS-14-2c). Dextral movement is also indicated by shear bands (Fig. GS-14-3b) and sigmoidal (σ) clasts. Some dextral shear zones exist as chloritic schist layers, which may have been derived from mafic dikes. Mylonite units are locally present in domains 1 and 2. These may have formed during the greenschist-facies dextral (and sinistral?) shearing described above. Alternatively, they may have formed earlier, perhaps during the south-side-up sheath folding.

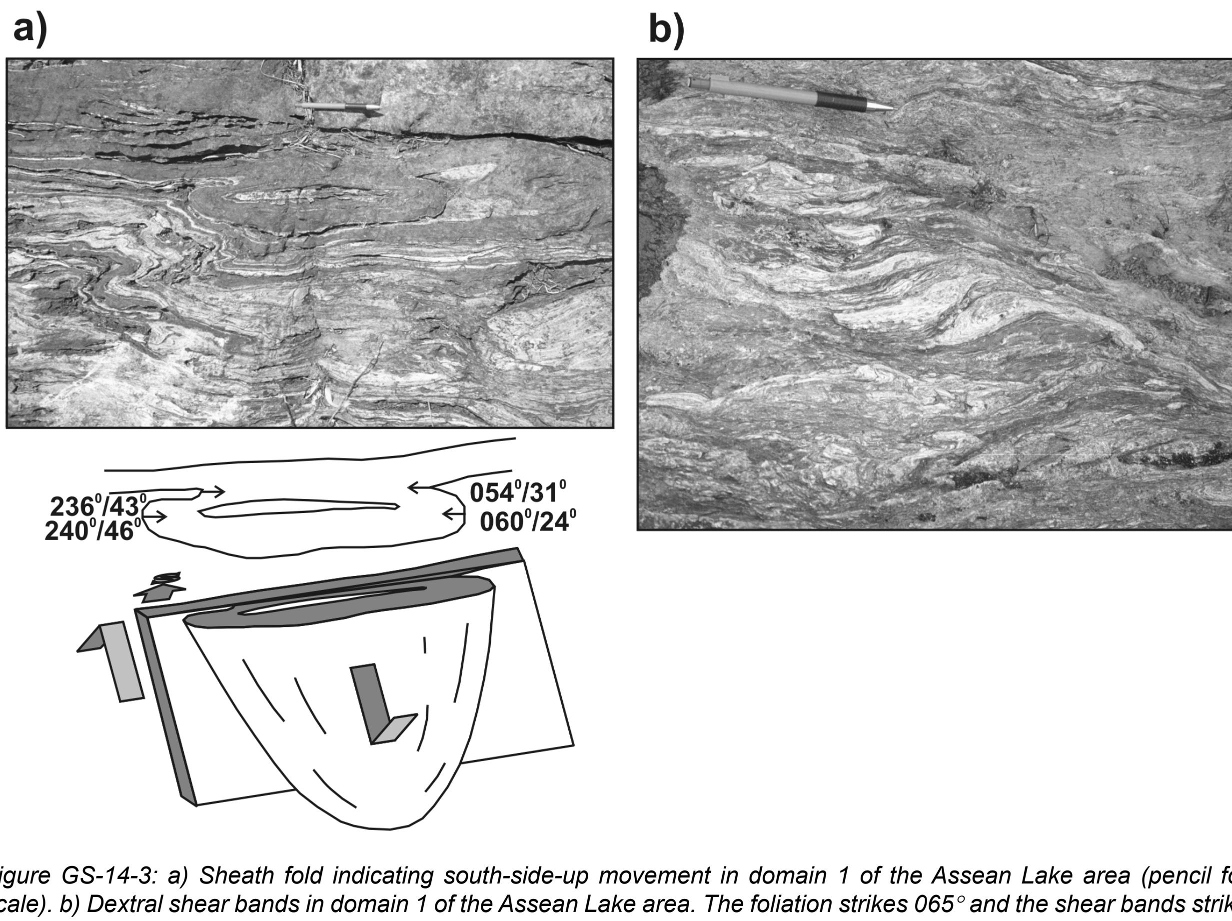

Figure GS-14-3: a) Sheath fold indicating south-side-up movement in domain 1 of the Assean Lake area (pencil for scale). b) Dextral shear bands in domain 1 of the Assean Lake area. The foliation strikes 065° and the shear bands strike 095°. The viewing direction is to the northwest (pencil for scale).

Domains 3 to 6

The northern part of the Assean Lake area (domains 3–6) is structurally complex. Structural data are shown in Figures GS-14-2d–g. Foliations in domains 3 and 6 trend 050° to 060°, as in the Assean Lake deformation zone (domains 1 and 2). Farther north, in domains 4 and 5, foliations trend east. Lineations in most rock types are defined by quartz, feldspar and locally biotite, and in the amphibolite by hornblende and plagioclase. Lineations in domain 3 are moderately southeast plunging. Strikingly, the lineations here are not parallel to fold axes, in contrast to those in domains 1 and 2. In domains 4 to 6, the lineations have approximately the same plunges as the fold axes. Folds in domain 3 show Z-asymmetry and those in domain 5 show S-asymmetry. In domains 4 and 6, few folds were found and asymmetries could not be determined. Most folds are isoclinal to tight. In domain 5, few close to open folds were found.

Lindal Bay was previously interpreted as a sinistral fault zone (Böhm, 1997a, b). In this study, evidence for dextral as well as sinistral shear has been recognized not only at Lindal Bay (domains 3 and 4) but also further west (domains 5 and 6), and relationships between these structures are not clear. Dextral structures are localized centimetre-scale shears, s-c fabric, shear bands, kinks and (in domain 3 only) Z-folds. Sinistral structures are localized centimetre-scale shears, s-c fabric, shear bands and (in domain 5 only) S-folds. The rocks could have been subjected to sinistral shear before dextral shear occurred, either throughout the entire sequence or localized along Lindal Bay. The scarcity of evidence for sinistral shear in domains 1 and 2 may then be a result of the strong overprint of dextral shear. Alternatively, the rocks of domains 3 to 6 were extended and boudinaged (rather than sheared), causing sinistral and dextral shears along the extensional lenses or boudins. A lens-type structure was recognized in domain 4.

Split Lake–Aiken River area

The rocks of the Split Lake–Aiken River area can be divided into domains north of the Aiken River deformation zone (SLB) and domains south of it (PGD). Rock types are described in Haugh (1969). In this study, rocks have been subdivided further, largely based on structures (Fig. GS-14-1c). A clotted hornblende granodiorite occurs in the northern part of the study area, within the SLB. Hornblende is partly retrogressed to biotite. The hornblende-biotite gneiss to the south is compositionally similar but exhibits a strong gneissosity, and the sheared hornblende-biotite gneiss is weakly deformed by the dextral, north-side-up shear of the Aiken River deformation zone (*see* below). The southernmost rock type of the study area, within the PGD, is a lit-par-lit gneiss. To the north, this gneiss exhibits close to open folds, which are also present in all rock types to the north of the lit-par-lit gneiss. The Aiken River deformation zone consists of mylonite that is derived from rocks of both the SLB and the PGD. All rock types are intruded by pegmatite, aplite and fine- to medium-grained mafic dikes, which are generally only deformed by late, centimetre-scale shears, faults and joints.

The structural domains in the Split Lake–Aiken River area coincide with lithological boundaries, because the lithological boundaries are partly based on deformation. The domains are 1) lit-par-lit gneiss, 2) lit-par-lit gneiss with close to open folds, 3) mylonite, 4) sheared hornblende-biotite gneiss, 5) hornblende-biotite gneiss, and 6) clotted hornblende gneiss. Layered amphibolite occurs within domains 2 and 3.

Structural data for the Split Lake–Aiken River area are plotted in Figures GS-14-4a–j. In general, four generations of folding, and late ductile-brittle to brittle shearing and faulting, are recognized.

Foliations

The first foliation (S_1) is a gneissosity in domains 4 and 5 and a mylonitic foliation in domain 3. A subvertical east-trending foliation (S_3) is axial planar to F_3 (*see* below). It is developed especially well in domains 4 and 5, and to a lesser extent in domain 3, where fine- to medium-grained rocks occur within the mylonite zone. The axial-planar foliation is formed by quartz and feldspar and, where it is present, by hornblende.

Folds

Tight to isoclinal folds are present in all domains except domain 6. Two generations of isoclinal folds (F_1 and F_2) were recognized within domain 3. One north-side-up sheath fold was recognized along the Aiken River deformation zone west of the study area, during a field trip. East-trending, close to open folds (F_3) developed in domains 3 to 5. They plunge mostly at shallow angles to the east (e.g. Fig. GS-14-4g). Plunges vary, probably as a result of subsequent F_4 folding (*see* below).

North-trending open folds (F_4) are present in domains 3 to 5. In one location in domain 4, the axial-planar

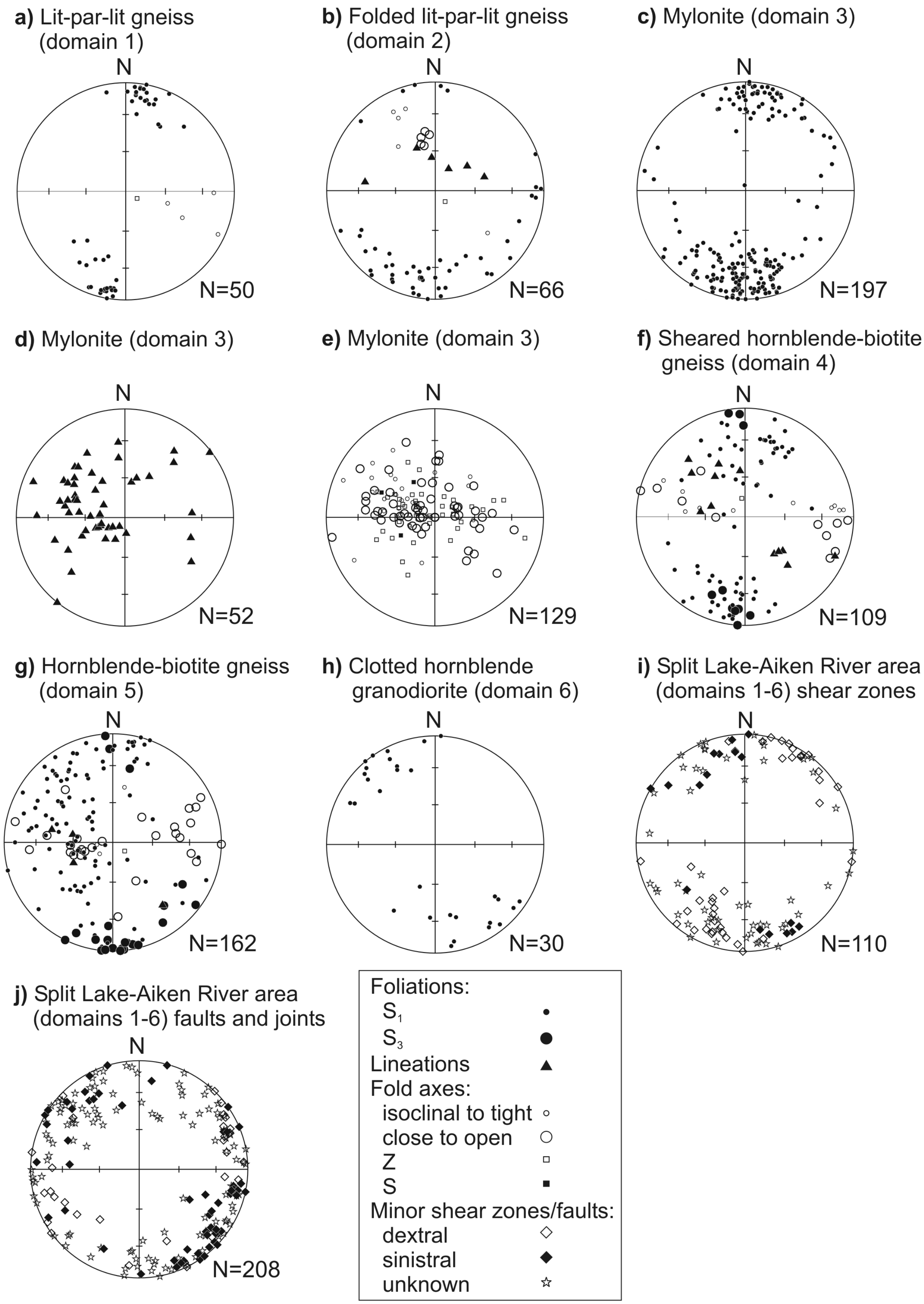

Figure GS-14-4: Equal-area lower-hemisphere projections of structural data from the Split Lake–Aiken River area.

foliation of the shallowly east-plunging folds is folded around a north-trending fold hinge. The spread of S_3 data in domain 5 may be a result of F_4 folding. The spread of S_1 data in domains 3 to 5 may have been caused by F_3 and F_4 folding. Multiple generations of folding resulted in complex fold-interference patterns in the mylonite, such as the mushroom pattern in Figure GS-14-5a.

Close to open folds in domain 2 may or may not be the same as F_4 folds in domains 3 to 5. The close to open fold-axis data in Figure GS-14-4b were collected in one outcrop. Foliation data, however, which were collected throughout the entire domain, plot on a great circle, the pole of which coincides with the close to open fold axes. Therefore, close to open folds in domain 2 were probably a result of moderately north-plunging close to open folding.

Lineations

Lineations are best developed in the mylonite of domain 3. Few lineations were found in domains 2, 4 and 5. Most lineations are quartz/feldspar rods. In few locations, they are parallel to tight to isoclinal fold axes. Biotite is occasionally lineated. The scatter of the lineation data (Fig. GS-14-4b, d, f and g) is probably caused by F_3 and F_4 folding. In one location in domain 3, a biotite lineation and quartz/feldspar rods were folded around close (F_3 or F_4?) fold hinges.

Structures in the clotted hornblende granodiorite

No folds were observed in the clotted hornblende granodiorite or in domain 6. The scatter of foliation data (Fig. GS-14-4h), however, suggests that the foliations are folded. The weak foliation in the granodiorite may be S_1 or S_3. The fact that the clotted hornblende granodiorite did not develop a gneissosity can be explained several ways:

1) The granodiorite intruded after the gneissosity developed in the other domains.
2) The granodiorite escaped the deformation that caused the gneissosity. Perhaps it formed lenses or boudins of competent material within the deforming hornblende-biotite gneiss. Alternatively the granodiorite was in a lower strain zone.

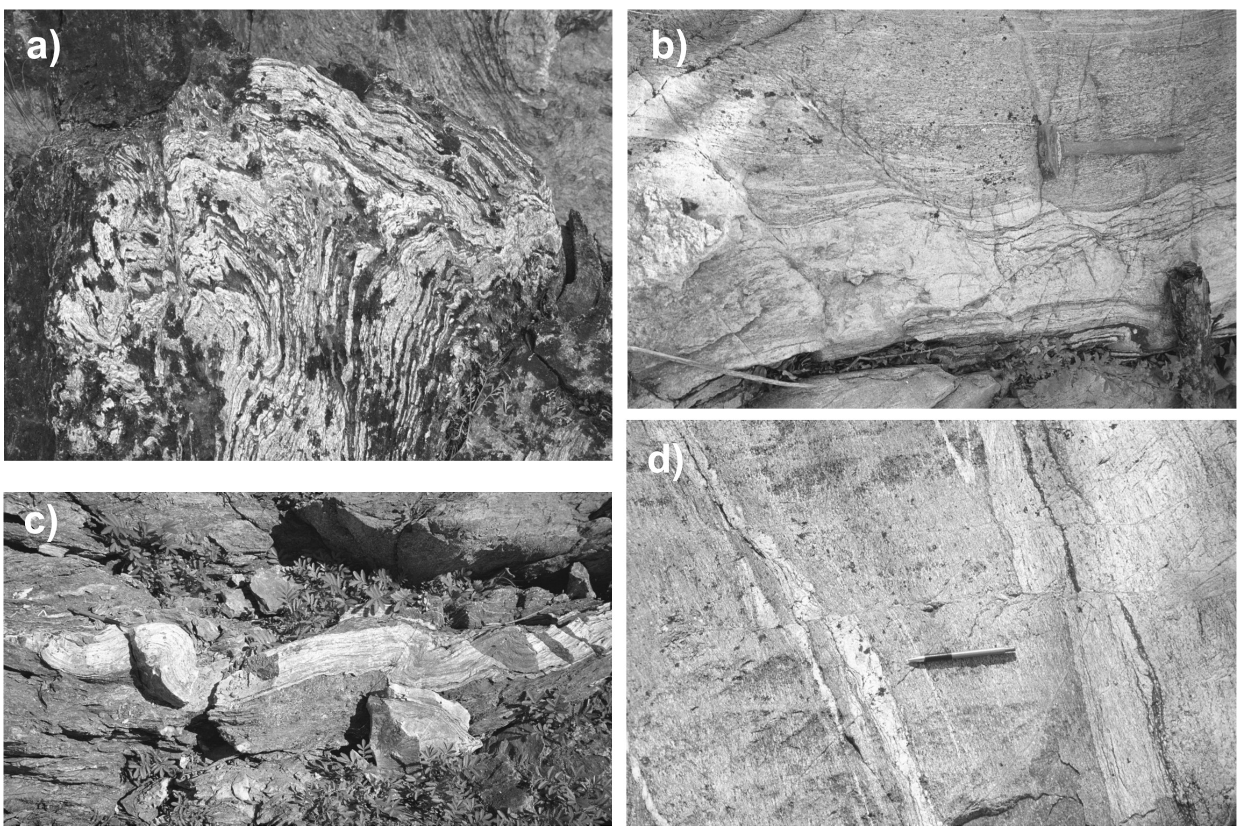

Figure GS-14-5: a) Mushroom folding pattern in mylonite of the Aiken River deformation zone, looking east; base of photo is 30 cm wide. b) Dextral shear bands in gneiss of domain 2, looking north (hammer for scale). c) Z-folds in mylonite in the Aiken River deformation zone, looking north (pencil for scale). d) Sinistral faults trending 030°, looking southeast (pencil for scale).

3) The granodiorite did have a previous gneissosity but recrystallized after deformation, during a subsequent metamorphic event.

Shearing and faulting

Dextral north-side-up shear bands occur throughout domain 3 and occasionally in domains 2 and 4. Figure GS-14-5b shows an example of dextral shear bands in domain 2. The predominance of Z-folds (Fig. GS-14-5c) over S-folds in domain 3 also indicates dextral shear. The relationship between the shear bands and the Z-folds, however, is not always clear and there may have been more than one dextral shearing event. Dextral σ clasts are present in domains 3 and 4. Shear zones commonly follow layers of chloritic schist, which may have been mafic dikes.

Late dextral and sinistral shears and faults, and joints, are present in all domains (Fig. GS-14-4i, j). Dextral shears and faults trend mostly northwest and sinistral shears and faults trend northeast, which may indicate north-south shortening. An example of sinistral faults is shown in Figure GS-14-5d. Late mafic and felsic dikes are parallel to the late shears, faults and joints. They are either undeformed or deformed by the late shears, faults and joints.

Economic considerations

Regional geology suggests that the potential for a variety of mineral-deposit types is high in the study area. The current level of mapping and knowledge of structural events affecting the rocks, however, is insufficient to guide exploration activities in this geologically complex region.

The northeast structural trend of the Thompson Nickel Belt suggests that Paleoproterozoic nickel-bearing assemblages could extend into the study area. Similarly, the Fox River Belt, with high potential for nickel and platinum group elements, strikes into the study area from the east. The extension of these belts into the Split and Assean lakes area is not sufficiently constrained, and an understanding of major bounding structures, such as the Aiken River and Assean Lake deformation zones, will be critical in developing the needed geological framework.

Gold occurrences in and near the Assean Lake deformation zone have been known since the 1930s. Recent and continuing exploration by International Curator has outlined seven new gold occurrences in favourable host rocks along the Assean Lake deformation zone (Christofferson, 2002). Small occurrences of pyrite exist in rocks of the Assean Lake deformation zone. The presence of pre–3.0 Ga crustal material in the ALCC (Böhm et al., 2000, 2003) implies that remnants of an ancient stable craton exist along the northwestern margin of the Superior Province. This, and the positive results from kimberlite indicator studies in the northern Superior Province to the south, imply a potential for diamondiferous kimberlites in the region.

Discussion

Both the Assean Lake area and the Split Lake–Aiken River area record a complex history of folding, shearing and faulting, but the folding histories are different. Sheath folds are present in the Assean Lake deformation zone but they are very rare in the Aiken River deformation zone. Late, shallowly east-plunging and subsequent north-trending folds are only present in the Split Lake–Aiken River area. Isoclinal to tight folding in the Aiken River deformation zone could be coeval with isoclinal to tight folding in the Assean Lake deformation zone, but a relationship is not clear.

The greenschist-facies, dextral, south-side-up shear on the Assean Lake deformation zone and greenschist-facies, dextral, north-side-up movement on the Aiken River deformation zone may have occurred simultaneously. If true, the vertical components on the shear zones indicate that the SLB may have been uplifted during dextral shear. Uplift of the SLB would result in exposure of deeper structural levels, and therefore exposure of rocks with higher metamorphic grades, in the SLB rather than in the ALCC and northern PGD. This is consistent with exposure of rocks that underwent granulite-facies metamorphism in the SLB and of amphibolite-facies rocks in the ALCC and PGD (cf. Haugh, 1969; Corkery, 1985). If movement on the Assean Lake and Aiken River deformation zones did not occur simultaneously, then the SLB is still uplifted relative to the surrounding areas. South-side-up sheath folding in the Assean Lake deformation zone may have caused part of the uplift, either during or before greenschist-facies shearing.

Acknowledgments

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