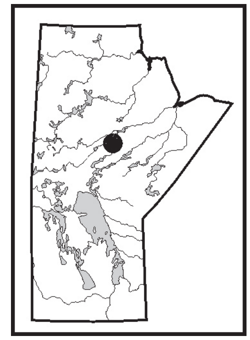
# GS-8 Structural geology of the Mystery-Apussigamasi lakes area, Manitoba (parts of NTS 63P13 and 14)

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



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## Summary

This report summarizes new structural data for the Mystery-Apussigamasi lakes area. A major shear zone, trending ~030°, was found along Mystery Lake. It shows east-southeast-side-up sinistral movement and it crosscuts folds in the hostrocks to the east and west. A minor northwest-side-up dextral shear/fault zone exists along the northeastern part of Apussigamasi Lake and the southwestern part of the Burntwood River. It ends in Kanutiministikwapisk Bay, where it branches into various splays. No shear zone was found along the north-east branch of Mystery Lake, but asymmetric folds may indicate northwest-side-up dextral movement. Older folds exist in domains that are not affected by shearing or faulting.

The regional movement along the various shear zones of the northern Superior Boundary Zone (Mystery-Apussigamasi lakes area, Assean Lake and Aiken River shear zones, and the Setting Lake structure along the Thompson Nickel Belt) is complex and may not be explained by a promontory model alone. Alternative explanations are that various shear zones may have formed at different times, or that the northern Superior Boundary Zone is a zone of brecciation, rather than a zone of rigidly moving domains. If the Superior Boundary Zone is a large-scale tectonic-breccia zone, mineralization (e.g., gold) may be complexly distributed along major and minor shear and fault zones, as well as in local areas of brecciation.

## Introduction

Detailed structural geological mapping was carried out in the Mystery-Apussigamasi lakes area (Figure GS-8-1). The results of the summer 2005 mapping in the Mystery-Apussigamasi lakes area are presented in this report and an accompanying preliminary map (Kuiper, 2005). The area has previously been mapped by Bleeker (1990a), Weber and Scoates (1976) and Patterson (1963), and was partly covered by the Thompson Nickel Belt Geology Working Group (2001) and Zwanzig (2000). New structural analysis and the kinematics of shear and fault zones in the Mystery-Apussigamasi lakes area, which has not previously been mapped in detail, are described in this report.

The 2005 field season concludes a three-year post-doctoral research project by the senior author. Previous research was concentrated along the Assean Lake and Aiken River shear zones (Kuiper et al., 2003; Kuiper and Lin, 2004a, b; Kuiper et al., 2004a–c; Figure GS-8-1). The main goal of mapping the Mystery-Apussigamasi lakes area was to gain a better understanding of the movement along the northern Superior Boundary Zone, and how this movement was accommodated by shear zones and, possibly, other mechanisms (e.g., folding or brecciation). Movement along the Assean Lake shear zone was dextral southeast-side-up, and movement along the Aiken River shear zone was dextral north-side-up (Kuiper et al., 2003; Kuiper and Lin, 2004a, b; Kuiper et al., 2004a–c). Movement along the Setting Lake structure of the Thompson Nickel Belt (Figure GS-8-1) was sinistral and later southeast-side-up (Bleeker, 1990a, b).

The Mystery-Apussigamasi lakes area straddles the highly sheared northern part of the Thompson Nickel Belt and includes an area northeast of the belt but southwest of the Assean Lake and Aiken River shear zones (Figure GS-8-1). The regional significance of the shear zones is discussed below. Previous work has shown that most of the area is underlain by Archean orthogneiss, which forms the basement to the Paleoproterozoic supracrustal rocks (Ospwagan Group), and that ultramafic to felsic intrusions occur in the Thompson Nickel Belt (Bleeker, 1990a; Zwanzig, 2000; Thompson Nickel Belt Geology Working Group, 2001). A compilation of extensive drillcore and detailed exploration mapping (Thompson Nickel Belt Geology Working Group, 2001) indicates that a structural keel of the Ospwagan Group underlies the main arm of Mystery Lake and that a second, parallel keel lies north-west of Southwest Bay. The intervening area is underlain by highly sheared Archean gneiss and local Ospwagan Group, intruded by a Paleoproterozoic pluton (Mystery Lake granodiorite in Bleeker, 1990a). The west end of Southwest Bay is underlain by garnet-biotite gneiss of uncertain origin.

## Structural geology of the Mystery Lake area

The Mystery Lake area is subdivided into the following three domains, based on structures and exposed rock types: 1) northeastern Mystery Lake, 2) Southwest Bay, and 3) central Mystery Lake (Figure GS-8-1). The dominant rock type of domain 1 is Archean basement

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

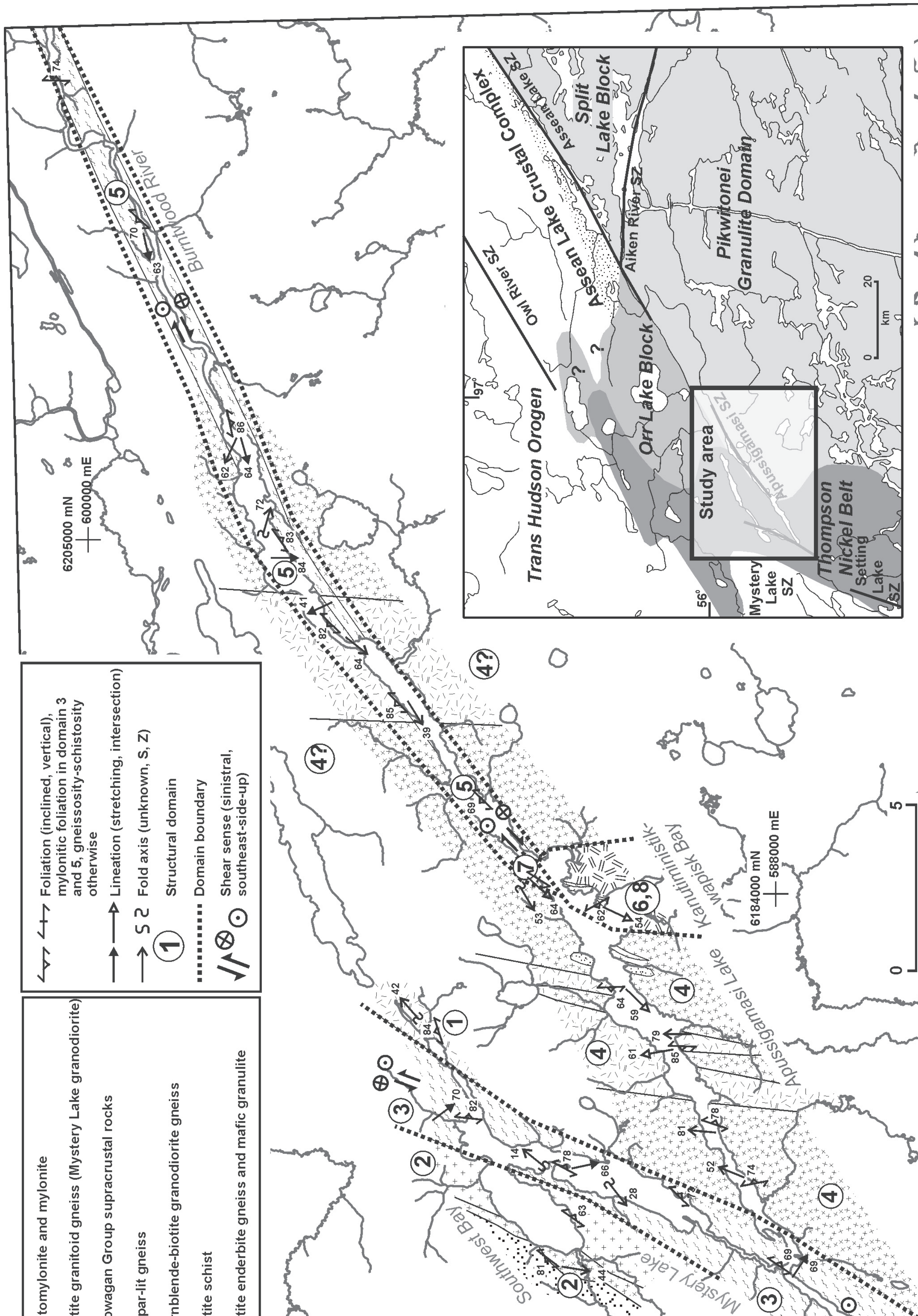


***Figure GS-8-1**: Simplified geology of the Mystery-Apussigamasi lakes area. Inset map shows study area within the regional geology. Abbreviation: SZ, Shear Zone.*

gneiss, composed primarily of hornblende-biotite granodiorite gneiss. Its foliation is crosscut by undeformed pink and white aplite. One white aplite dike is folded. Therefore, at least two generations of aplite dikes exist.

Rock types of domain 2 are biotite granitoid gneiss (Mystery Lake granodiorite) in the southeast and biotite-garnet semipelitic schist in the northwest (including Ospwagan Group and paragneiss of unknown origin). Granite gneiss locally contains feldspar augen. Semipelitic schist contains centimetre-scale, isoclinally folded quartz-feldspar layers.

Mylonite and protomylonite exist along the shorelines of the middle and southern parts of Mystery Lake, which trend ~025º, and the Burntwood River toward Thompson. Most (proto)mylonite is derived from granitic and granodioritic rocks, but some is mafic in composition or derived from metasedimentary rocks. Close to Thompson, the composition is grey tonalite. The shear zone, which locally contains rocks that are not mylonitic, includes small areas of Ospwagan Group and its contained mafic-ultramafic intrusions (Thompson Nickel Belt Geology Working Group, 2001; Zwanzig, 2000). Lit-par-lit gneiss along the east shore has been included in the Archean basement, and white biotite granitoid gneiss along the west shore forms part of the Mystery Lake granodiorite or related dikes. These are interpreted as more competent lenses within the shear zone. In addition, lenses and dikes of undeformed or weakly foliated, fine-grained mafic rock are present in the (proto)mylonite.

### *Domain 1 (northeastern Mystery Lake)*

In domain 1, moderately northeast-plunging, tight to isoclinal Z-folds dominate (Figure GS-8-2a). Their axial planes dip steeply to the southeast and intersection lineations (Figure GS-8-3a) parallel their fold axes. The folds may indicate northwest-side-up dextral movement and be part of a larger scale, northwest-side-up dextral system or, alternatively, may be parasitic folds on the limb of a larger scale fold related to folds in the southwestern domain of Apussigamasi Lake (*see* below). Moderately northeast-plunging fold axes and lineations also exist along Moak Lake (Scoates and Macek, 1977; Scoates et al., 1977). Most folds have Z-asymmetry (Patterson, 1963).

### *Domain 2 (Southwest Bay, Mystery Lake)*

Poles to foliations in rocks of domain 2 form a partial great circle, indicating that the rocks may be deformed by an upright, shallowly south-southwest-plunging open antiform (Figure GS-8-2b). Steeply southeast-dipping foliations along the southeast shore of Southwest Bay and steeply west-northwest-dipping foliations along its south and northwest shore are interpreted as the two limbs of the antiform. The trend of the axial plane of the antiform is ~210º.

Very few northwest-side-up, and both dextral and sinistral, shear bands and folds were found in metasedimentary rocks along the northwest shore of the bay. These may indicate northwest-side-up movement.

### *Domain 3 (central Mystery Lake; Mystery Lake shear zone)*

Mylonite and protomylonite, which dominate the Mystery Lake shear zone (Burntwood shear zone of Bleeker, 1990a), are separated by less strained rocks, including a synformal keel of Ospwagan Group rocks occurring under, and locally on, islands in the lake (Figure 1 in Zwanzig, 2000). Highly strained basement gneiss within the Mystery Lake shear zone contains a steep, east-southeast-dipping mylonitic foliation (Figure

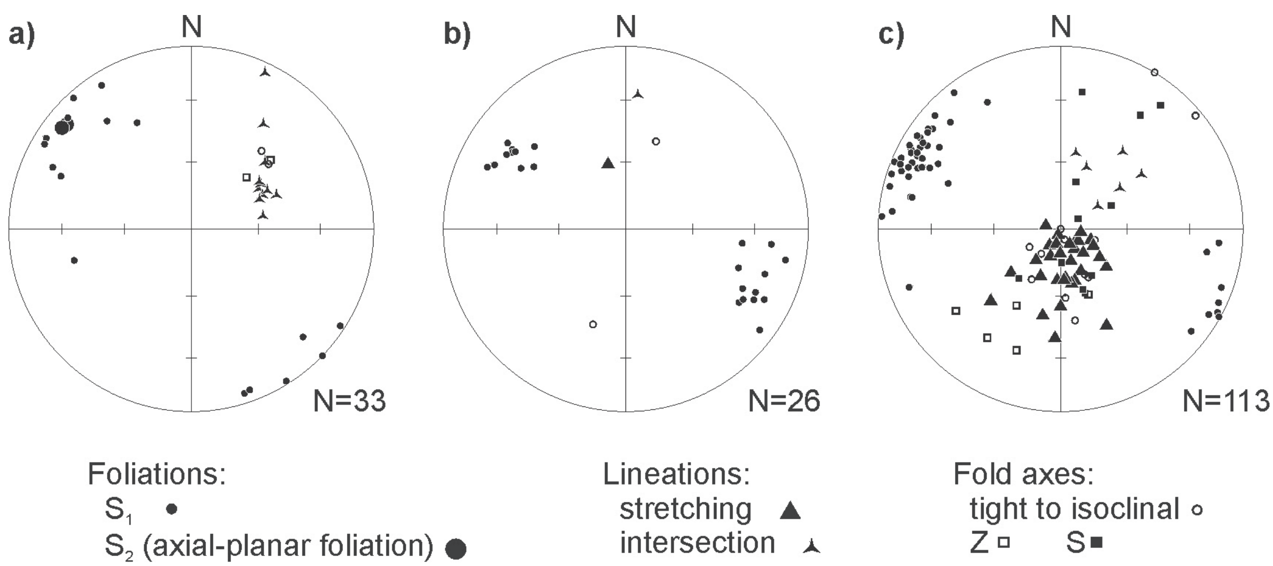


***Figure GS-8-2**: Equal-area lower-hemisphere projections of structural data from Mystery Lake: **a)** domain 1 (northeastern Mystery Lake); **b)** domain 2 (Southwest Bay); and **c)** domain 3 (central Mystery Lake; Mystery Lake shear zone).*

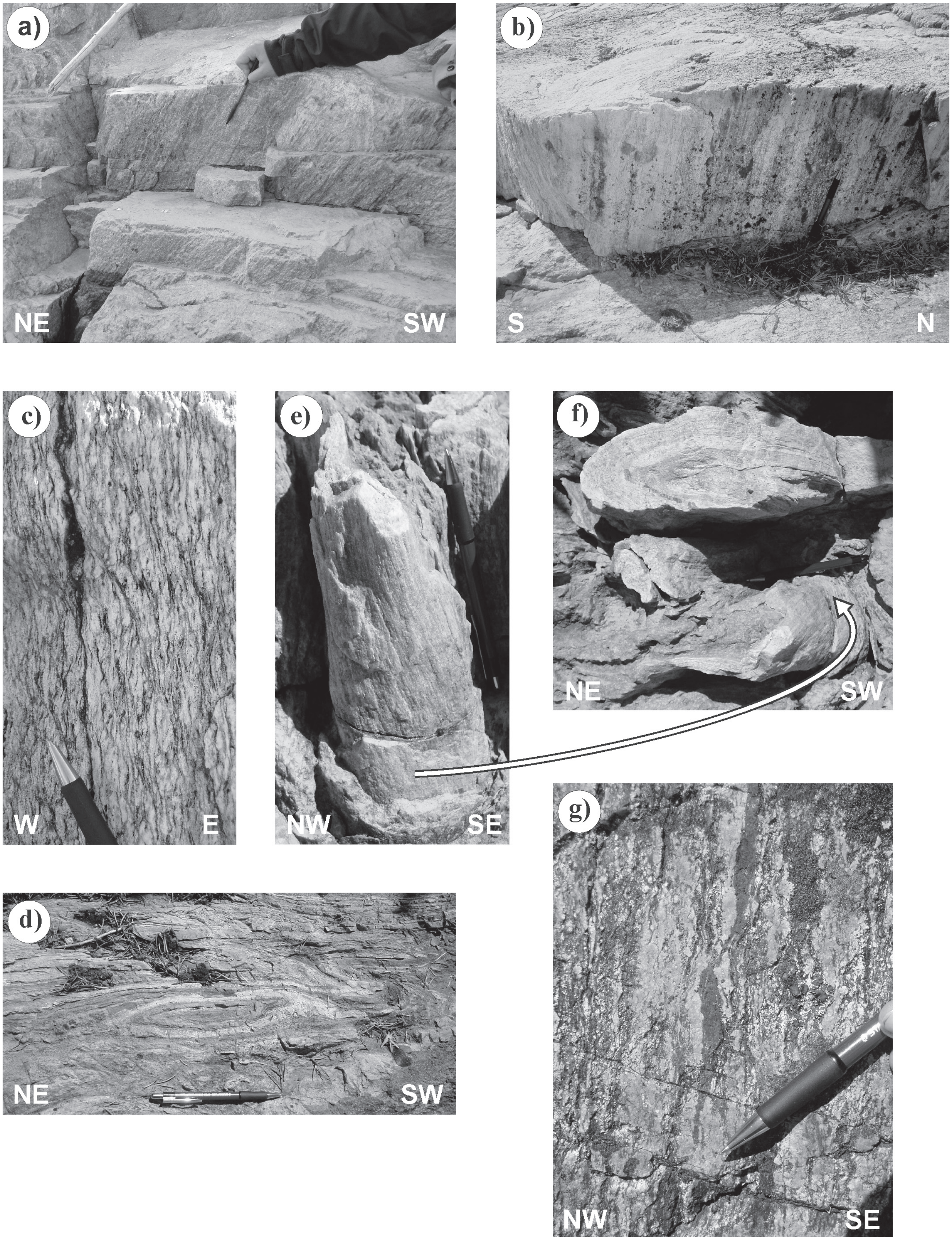


***Figure GS-8-3**: Outcrop photographs of the Mystery and Apussigamasi lakes area: **a)** moderately northeast-plunging intersection lineations (parallel to pen) in domain 1; **b)** steeply south-plunging lineations in domain 3 (Mystery Lake shear zone); **c)** south-southeast-side-up shear bands in domain 3 (Mystery Lake shear zone); **d)** sheath fold in domain 3 (Mystery Lake shear zone); **e), f)** folded lineation in domain 3 (Mystery Lake shear zone); and **g)** northwest-side-up shear bands in domain 5.*

GS-8-2c) that is interpreted as being parallel to the shear-zone boundaries. Steeply south-plunging lineations (Figure GS-8-3b), shear bands (Figure GS-8-3c), S-C fabric and sheath folds (Figure GS-8-3d) indicate east-southeast-side-up sinistral movement with a large vertical component on the shear zone. The distribution of S- and Z-folds on either side of the lineations (Figure GS-8-2c) indicates that fold axes rotated toward parallelism with the lineations to form sheath folds. In one location, lineations were folded (Figure GS-8-3e, f). Although this indicates that the lineations formed earlier than the folds, both structures are interpreted as having formed as a result of the east-southeast-up sinistral shear.

The Mystery Lake shear zone crosscuts the northeastern and southwestern domains of Mystery Lake, and the southwestern domain of Apussigamasi Lake. The shear zone boundaries are gradual, being several hundreds of metres wide. For example, the boundary between the northeastern domain and the Mystery Lake shear zone is a zone where the intersection lineations of the northeastern domain have disappeared and where local east-southeast-side-up sinistral shear bands (but no protomylonite) exist.

Intersection lineations (Figure GS-8-2c) exist in outcrops along the east side of the Mystery Lake shear zone. These are probably a result of earlier folding that is visible in the southwestern domain of Apussigamasi Lake.

Lenses and dikes of undeformed or weakly foliated, fine-grained mafic rock are present in the (proto)mylonite. These lenses are locally lineated along their margins, which suggests that at least part of the deformation along the shear zone postdates mafic-dike emplacement.

## Structural geology of the Apussigamasi Lake area

Based on structural analysis and main rock types, the Apussigamasi Lake area is divided into five structural domains (numbered as on Figure GS-8-1). Three major structural domains are: 4) southwestern Apussigamasi Lake, 5) northeastern Apussigamasi Lake, and 6) Kanutiministikwapisk Bay. The two other, minor structural domains are: 7) a transitional domain between domains 4, 5 and 6; and 8) a shear zone domain at Kanutiministikwapisk Bay.

Rocks within the southwestern (4) and transitional (7) domains consist mainly of lit-par-lit gneiss and hornblende-biotite granodiorite gneiss, both of which were mapped as Archean orthogneiss by the Thompson Nickel Belt Geology Working Group (2001). The lit-par-lit gneiss has pink and grey layers due to variations in K-feldspar and mafic mineral content. The mafic minerals are hornblende and/or biotite. Pink and white aplite dikes intruding domains 4 and 7 are undeformed or isoclinally folded. Pink pegmatite dikes are weakly foliated or undeformed. Locally, the lit-par-lit gneiss contains amphibolite xenoliths. Hornblende-biotite granodiorite gneiss is locally migmatitic and contains some amphibolite rafts that could be the same as the hornblende-biotite granodiorite gneiss exposed in domain 1 (northeastern Mystery Lake). Minor rock types are granite gneiss and biotite schist with centimetre-scale, isoclinally folded, quartz-feldspar layers.

Domain 5 comprises a variety of rock types. In the southwest, hornblende-biotite granodiorite gneiss and lit-par-lit gneiss dominate. Less abundant rock types are biotite tonalite gneiss, mafic hornblende tonalite gneiss, hornblende diorite gneiss, opdalite gneiss, retrogressed mafic granulite, foliated granite, and fine-grained mafic schist. In the northeastern part of domain 5, zones of brecciated rocks of variable composition are prominent. Protomylonite and mylonite exist throughout domain 5 within a zone that trends 050º. They are mostly derived from granitic and granodioritic rocks, which locally contain recognizable amphibolite rafts. Mafic dikes are weakly foliated and, in some places, form a series of lenses.

Alternating layers of mafic granulite and biotite enderbite gneiss are present in Kanutiministikwapisk Bay (domain 6). Enderbite gneiss contains flattened mafic rafts. Local shear zones at Kanutiministikwapisk Bay are grouped separately and constitute structural domain 8.

### *Domain 4 (southwestern Apussigamasi Lake)*

Lit-par-lit gneiss and hornblende-biotite granodiorite gneiss in this domain are deformed by moderately to steeply plunging north-northeast-trending folds (Figures GS-8-1, -4a). The axial plane of the folds, which is derived from the folded gneissosity (Figure GS-8-4a), dips steeply to the east-southeast. Lineations are intersections between gneissosity and fold-axial planes. There are S- and Z-folds that are parasitic folds on the limbs of larger scale folds. The reason for the spread of fold axes and lineations within the axial plane is unclear.

### *Domain 5 (northeastern Apussigamasi Lake)*

Domain 5 is dominated by northwest-side-up dextral shear. This is indicated by steeply west-southwest-plunging lineations (Figure GS-8-4b), shear bands (Figure GS-8-3g) and S-C fabric in mylonite and protomylonite. Well-cemented brecciated zones exist throughout the domain, indicating that deformation continued into the brittle field. Brecciation and shearing also explain the large variation of rock types within this domain. The shear/fault zone dips steeply to the northwest. Mafic dikes are deformed, indicating that deformation occurred at least partly after mafic dike emplacement.

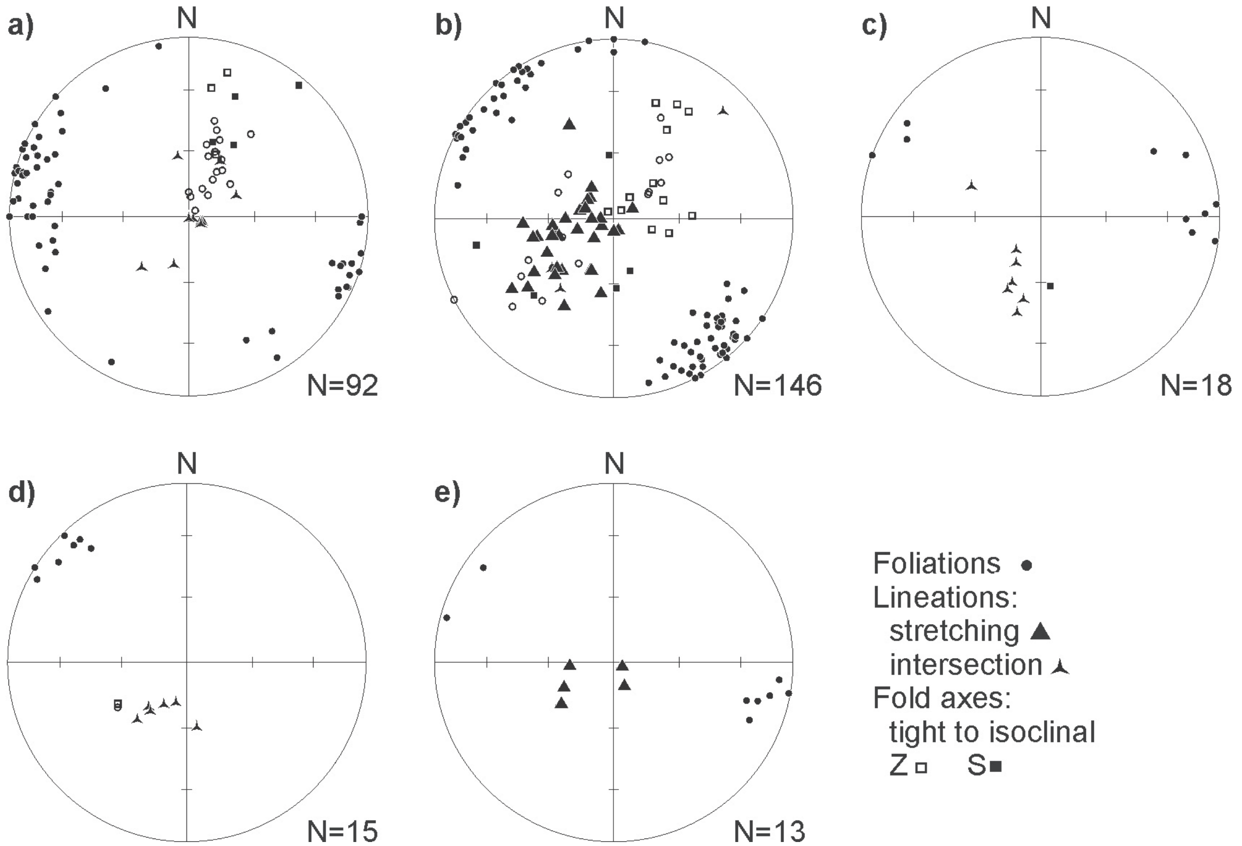


***Figure GS-8-4**: Equal-area lower-hemisphere projections of structural data from Apussigamasi Lake: **a)** domain 4 (southwestern Apussigamasi Lake); **b)** domain 5 (northeastern Apussigamasi Lake and Burntwood River); **c)** domain 6 (Kanutiministikwapisk Bay), **d)** domain 7 (central Apussigamasi Lake); and **e)** domain 8 (Kanutiministikwapisk Bay).*

### *Domain 6 (Kanutiministikwapisk Bay)*

Domain 6 consists of granulite-grade rocks. Outcrops are scarce, but structural data shown in Figure GS-8-4c suggest that the rocks are folded by moderately to steeply south-southwest-plunging upright folds.

### *Domain 7 (transition between domains 4, 5 and 6)*

This domain includes rock types, folds and intersection lineations of domain 4, but the orientation of the foliations, lineations and fold axes are similar to those in domains 5 and 6 (Figure GS-8-4d). It is therefore interpreted as a transitional domain.

### *Domain 8 (Kanutiministikwapisk Bay shear zone)*

Domain 8 consists of local shear zones (Figure GS-8-1). Shear bands, S-C fabric and Z-folds within these (proto)mylonite zones indicate northwest-side-up dextral shear. The steeply southwest-plunging lineations indicate a strong vertical component (Figure GS-8-4e). These shears are interpreted as splays of the shear/fault zone of domain 5. No discontinuity or (proto)mylonite or brecciated zones are present within domain 4. The splays are therefore interpreted as the end of the domain 5 shear/fault zone, indicating that it is likely a minor shear/fault structure.

## Shear zones of the northern Superior Boundary Zone: a synopsis

This section summarizes and discusses movement along shear zones of the northern Superior Boundary Zone (Figure GS-8-5). Structural mapping along the Thompson Nickel Belt by Bleeker (1990a, b) revealed sinistral and later southeast-side-up movement. The Mystery Lake shear zone is on strike with the Setting Lake structure of the Thompson Nickel Belt, and southeast-side-up sinistral movement along the Mystery Lake shear zone is consistent with movement along the Setting Lake structure. Movement along the Assean Lake shear zone is dextral southeast-side-up (Kuiper et al., 2003, 2004b). Previously, movement along the Setting Lake structure and the Assean Lake shear zone has been interpreted in terms of a promontory model (White et al., 2002). In this model, the Superior Province is interpreted as having moved to the northwest to collide with rocks of the Trans-Hudson Orogen. The promontory in the northwest

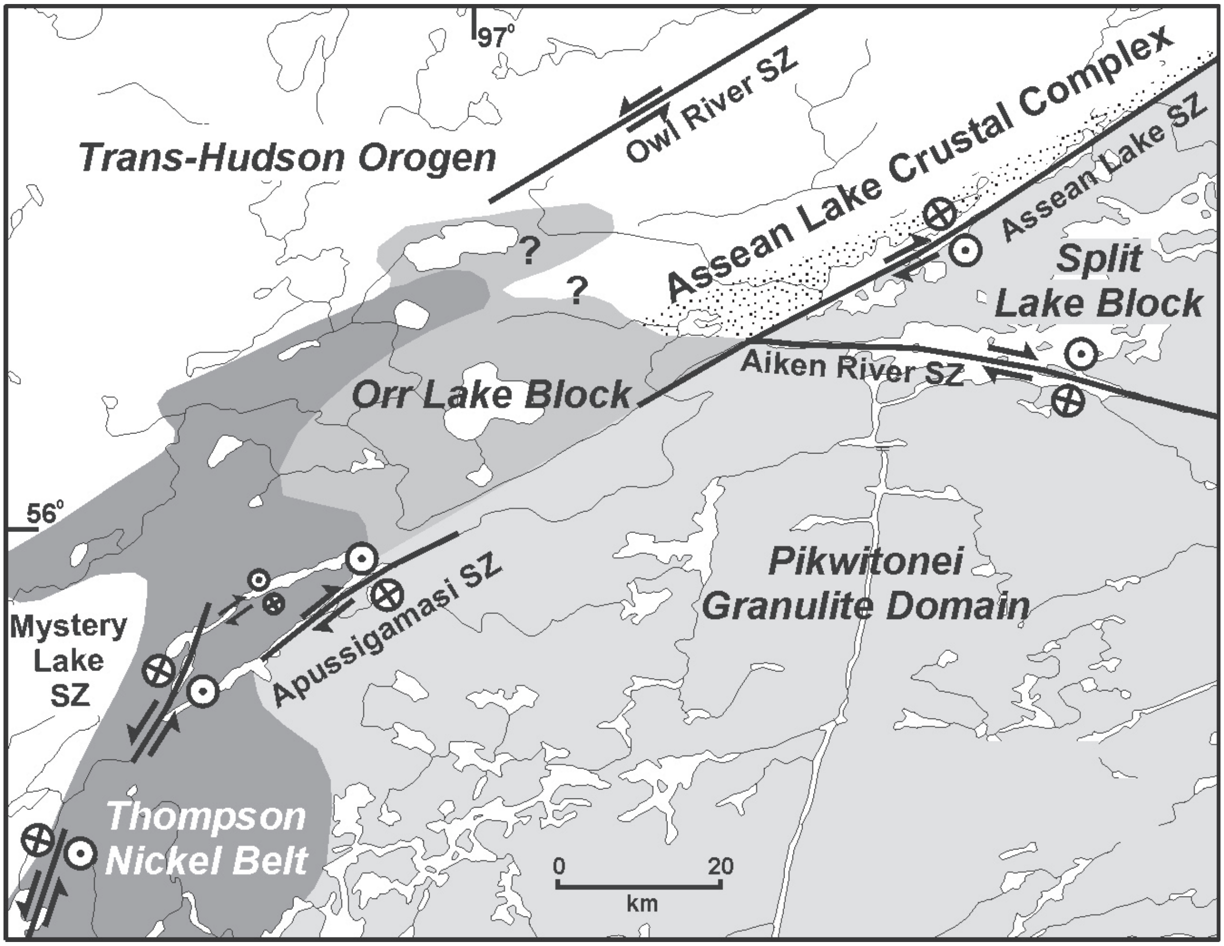


***Figure GS-8-5**: Overview of various shear zones of the northern Superior Boundary Zone and their senses of movement. Abbreviation: SZ, Shear Zone.*

caused sinistral (and southeast-side-up) movement along the Thompson Nickel Belt, and dextral (and southeast-side-up) movement along the Assean Lake shear zone.

The promontory model implies southeast-side-up movement along the Apussigamasi Lake–Burntwood River system and the northeast branch of Mystery Lake (domains 5 and 1, respectively). Movement along Apussigamasi Lake and the southwestern part of the Burntwood River, and possibly along the northeast branch of Mystery Lake, however, is northwest-side-up dextral. Furthermore, dextral north-side-up movement along the Aiken River shear zone (Kuiper et al., 2003, 2004c) remains unexplained. A simple promontory model may therefore not explain all shear zones of the northern Superior Boundary Zone. This may mean that shear zones formed at different times with, for example, movement on the Assean Lake shear zone outlasting movement on the Aiken River shear zone (Kuiper et al., 2004c).

Alternatively, the northern Superior Boundary Zone can be viewed as a zone of brecciation, rather than a zone of rigidly moving domains. This would explain the inconsistent movement along the various shear zones and the zones of brecciation found along Apussigamasi Lake and the Burntwood River.

## Economic considerations

The Mystery Lake shear zone has the same trend and a similar movement sense as the Setting Lake structure along the Thompson Nickel Belt. Better knowledge of the complex movement pattern in the Thompson Nickel Belt may help to find extensions to presently known nickel deposits into the Mystery Lake area, where the Ospwagan Group is intruded by large ultramafic bodies. The shear/fault zone along Apussigamasi Lake and the Burntwood River is along strike from the gold-hosting Assean Lake shear zone. Although shear senses on the shear zones are different, gold may have accumulated along the Apussigamasi Lake–Burntwood River shear/fault zone. If shear zones along the northern Superior Boundary Zone are truly part of a large-scale brecciated zone, then mineralization may be complex and distributed along several major and minor shear and fault zones, and in brecciated areas.

Positive results from kimberlite indicator studies in the northern Superior Province to the south imply a potential for diamondiferous kimberlites in the region. Furthermore, the location 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.

## Acknowledgments

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