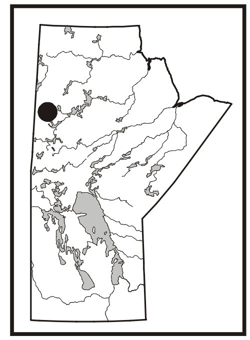
GS-12 STRUCTURAL ANALYSIS OF THE JOHNSON SHEAR ZONE IN THE GEMMELL LAKE-DUNPHY LAKES AREA, LYNN LAKE GREENSTONE BELT (PARTS OF NTS 64C/11, /12)

by C.J. Beaumont-Smith



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SUMMARY

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Gold mineralization west of Gemmell Lake occurs in several widely spaced localities, hosted either by sheared and altered felsic volcanic rocks or by sheared and altered mafic volcanic rocks. The felsic-hosted mineralization is characterized by the presence of very fine grained acicular arsenopyrite, locally accompanied by finely disseminated pyrite, within zones of syn-shear quartz veins, silicification and weak sericitization of the host dacitic pyroclastic rocks. This is a different and previously unrecognized style of mineralization, compared with the syn-shear, pyrite-associated, mafic volcanic–hosted mineralization associated with the Johnson Shear Zone. The abundance of thin, laterally continuous, felsic volcanic units within the mafic-dominated stratigraphy affected by the shear zone west of Gemmell Lake indicates significant areas of excellent gold-exploration potential. The second style of mineralization, informally termed 'BT-style' (after the Burnt Timber gold deposit), is associated with finely disseminated pyrite in highly silicified and carbonatized, sheared mafic volcanic rocks. The silicification is accompanied by moderate biotitization, reflecting syn-shear potassic metasomatism.

INTRODUCTION

A program of structural analysis of the Johnson Shear Zone (JSZ) was initiated in 1999 with the goal of understanding better the deformational history of the shear zone and associated gold mineralization. Initial efforts focused on the central portion of the JSZ, an area known to host numerous gold deposits and showings. Structural analysis of the JSZ during the 2000 field season focused on delineating the shear zone beyond the western extent identified in 1999. These efforts included detailed analysis of newly discovered, shear-hosted gold mineralization west of Gemmell Lake.

The JSZ has been a focus of gold exploration since the 1940s and hosts a number of gold deposits and showings (Fig. GS-12-1), including the past-producing Burnt Timber (BT) deposit (Bateman, 1945; Milligan, 1960; Gilbert et al., 1980; Kenaley, 1982; Peck, 1986; Fedikow et al., 1991; Sherman, 1992; Richardson and Ostry, 1996; Peck and Eastwood, 1997; Peck et al., 1998). Confirmation of the westward continuation of the JSZ west of Gemmell Lake significantly increases the amount of prospective auriferous stratigraphy and, as the results of the first two field seasons demonstrate, there is excellent potential for the discovery of additional shear-hosted gold mineralization.

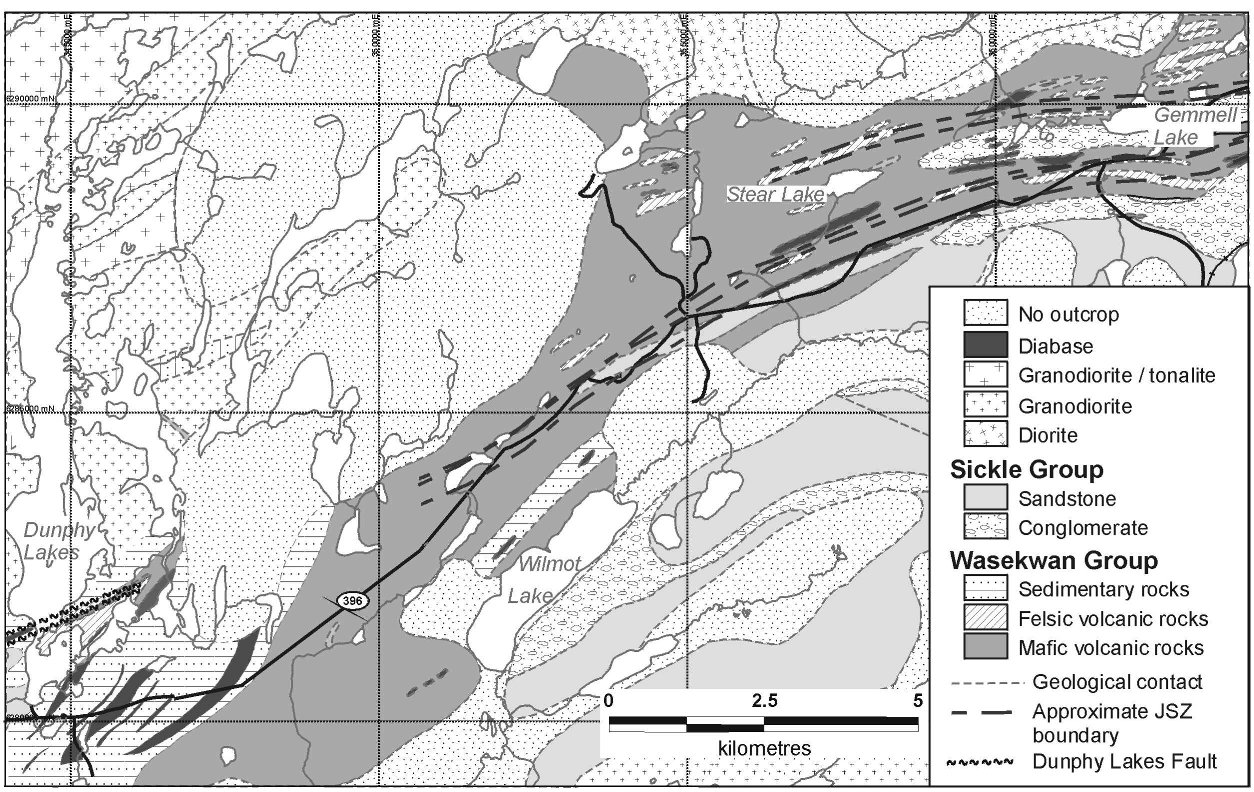

*Figure GS-12-1: General geology of the Lynn Lake greenstone belt and location of the Johnson Shear Zone (*after *Gilbert et al., 1980).*

GEOLOGICAL SETTING

The east-trending Johnson Shear Zone is located within the southern Paleoproterozoic Lynn Lake greenstone belt. It forms the boundary between the 1910 Ma (Baldwin et al., 1987) metavolcanic and metavolcaniclastic Wasekwan Group (Bateman, 1945) and the 1876 Ma (Baldwin et al., 1987) Pool Lake plutonic suite (Gilbert et al., 1980) in the central and eastern portions of the greenstone belt. The JSZ is manifest as an approximately 300 m wide zone of intense crenulation-cleavage development with an anastomosing mylonitic core. The localization of regional shear strain along the supracrustal-plutonic contact east of Gemmell Lake probably reflects a primary rheological control leading to the development of the JSZ. The absence of plutonic rocks along the southern margin of the southern greenstone belt west of Gemmell Lake removes the time-stratigraphic control that proved very useful in delineating the JSZ in the eastern portion of the greenstone belt.

West of Gemmell Lake, the JSZ is developed within the greenstone belt, affecting the supracrustal rocks, the unconformably overlying fluvial-alluvial arenaceous rocks of the Sickle Group (Norman, 1933; Gilbert et al., 1980), and numerous small plutonic bodies of undetermined age that intrude the Wasekwan Group. Age constraints on the development of the JSZ are limited, but shear-zone deformation is younger than the estimated age of the Sickle Group (1850–1540 Ma; Ansdell et al., 1999).

The metamorphic grade in the Lynn Lake greenstone belt ranges from upper greenschist facies in the eastern extent of the belt to upper amphibolite facies throughout the western portion of the belt. Peak metamorphism was attained relatively late in the deformational history, postdating the assembly of the greenstone belt and the development of the JSZ (Beaumont-Smith and Rogge, 1999). West of Gemmell Lake, the delineation of the JSZ is complicated by recrystallization associated with a middle to upper amphibolite facies metamorphic overprint that has removed many of the characteristic shear fabrics used to identify the JSZ at lower metamorphic grade.

The Wasekwan stratigraphy west of Gemmell Lake comprises a thick sequence of basaltic to andesitic volcanic and volcaniclastic rocks, thin intercalated dacitic to rhyolitic volcaniclastic units and metasedimentary rocks, which together form the Wilmot Lake volcanic and sedimentary rocks subdivision of Gilbert et al. (1980). The mafic rocks consist of massive flows and autoclastic and polymictic breccias, intercalated with minor layered volcaniclastic rocks. Thin dacitic to rhyolitic volcanic units and minor epiclastic sedimentary rocks are also intercalated with the mafic rocks. The Wilmot Lake subdivision is separated from the dacitic to rhyolitic volcaniclastic rocks of the Snake Lake dacite and the volcanic rocks hosting the Fox Lake mine by the Fox Road turbidite sequence, a thick sequence of fine-grained greywacke and conglomeratic greywacke. This sequence is interpreted to occupy the core of a large northeast-plunging synform (Gilbert et al., 1980).

The JSZ also affects the Sickle Group, which unconformably overlies the Wasekwan Group west of Gemmell Lake and forms the southern boundary of the greenstone belt in this area. The Sickle Group comprises a diverse stratigraphy of quartzofeldspathic sandstone, pebbly sandstone, hornblende-bearing sandstone and pelite, and heterolithic conglomerate. The contact between the Wasekwan and Sickle Groups is exposed in several locations along the southern boundary of the greenstone belt. The regional deformation has significantly modified the unconformity, making an assessment of the exact nature of the contact impossible. The Sickle Group also occurs as inliers within the Wasekwan Group; in the case of the large east-trending inlier centred on Gemmell lake, the contact between the two groups has experienced lower regional strain and a basal conglomerate is preserved.

STRUCTURAL ANALYSIS

The JSZ east of Gemmell Lake is characterized by the development of a mylonitic core within an approximately 300 m wide zone of intense crenulation cleavage and tight chevron folding (Beaumont-Smith and Rogge, 1999). West of Gemmell Lake, the kinematic framework remains consistent, although the shear zone is developed within the greenstone belt and appears to bifurcate into two major splays. The JSZ overprinted the assembly of the diverse tectonostratigraphy of the Wasekwan Group (Zwanzig et al., 1999) and the formation of the east-trending, overturned, antiformal geometry occupied by the Wasekwan Group prior to the intrusion of the Pool Lake suite (Gilbert et al., 1980). This complex sequence of deformations constrains the JSZ as a second- or possibly third-generation deformational event, assuming the older deformations represent discrete events. Therefore, to avoid possible confusion, the D_2 designation of Beaumont-Smith and Rogge (1999) for the JSZ will be used, since the delineation of older deformations requires additional information and techniques.

Overprinting relationships developed along the margins of the JSZ and in lower strain domains within the shear zone demonstrate the presence of an older foliation (S_1). The tight geometry of F_2 folds has generally resulted in the transposition of S_1 on the F_2 limbs, but S_1 slaty cleavage is preserved within S_2 crenulation microlithons from F_2 fold hinges and has been observed in the form of a strong clast preferred orientation in Wasekwan Group volcaniclastic rocks and Sickle Group conglomerate and pebbly sandstone (Fig. GS-12-2). The presence of S_1 can also be inferred from the widespread development of mafic tectonite at middle to upper amphibolite facies. The fine, very regular spacing of

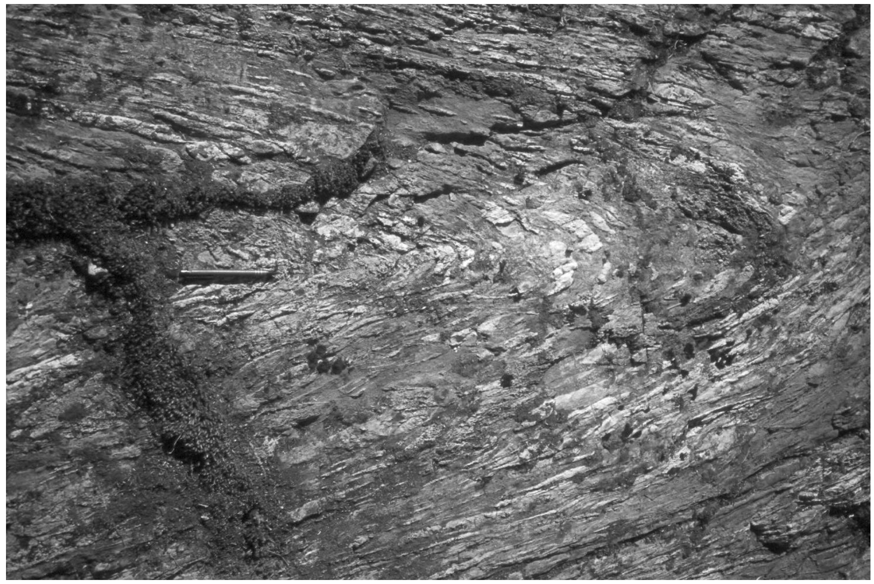

Figure GS-12-2: Overprinting of S_1 foliation, defined by clast preferred orientation, by tight F_2 fold on the margin of the shear zone. Note pen for scale.

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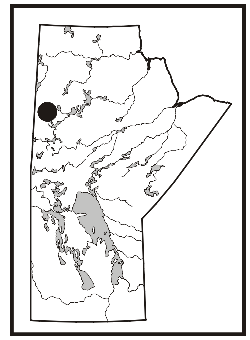

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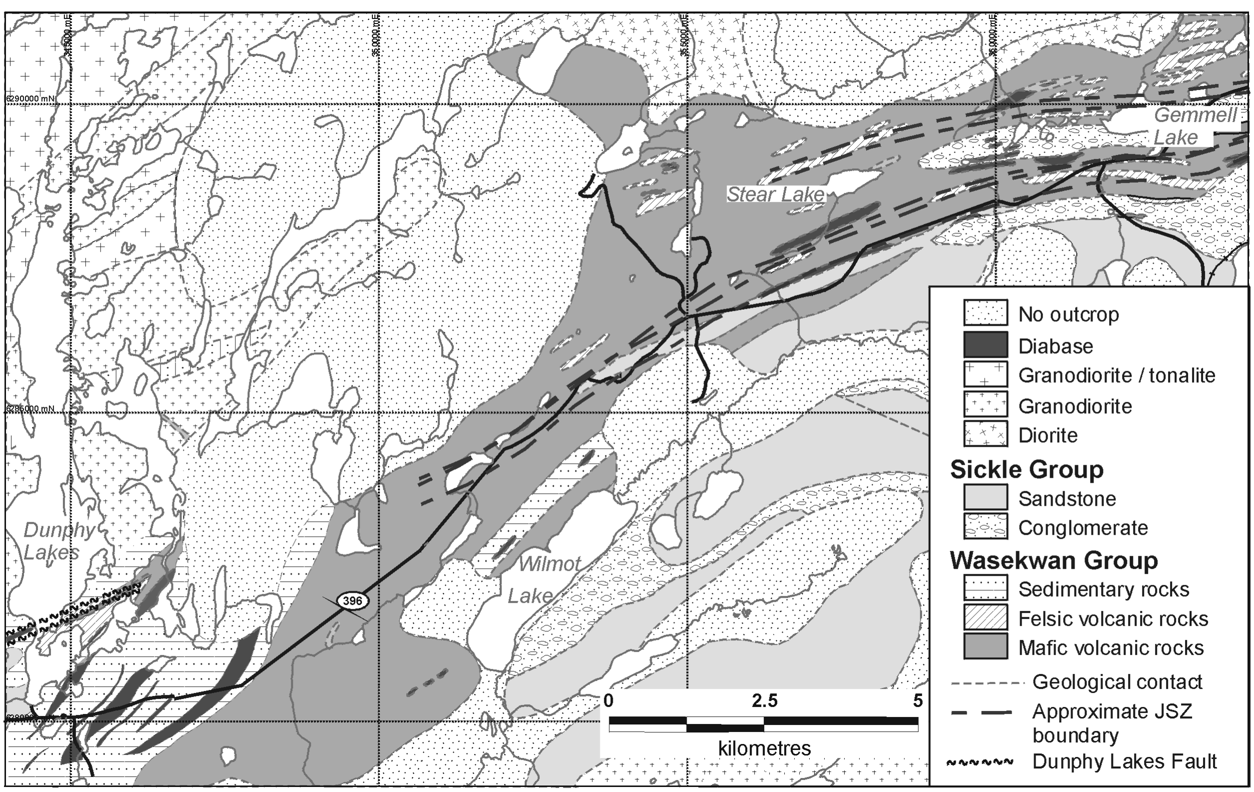

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alternating ferromagnesian and plagioclase-rich domains that make up the tectonites probably represents recrystallized crenulation cleavage.

The high-strain core of the JSZ is characterized by the development of anastomosing zones of mylonitic fabrics within a broader zone of intense crenulation-cleavage development. The enveloping zone of crenulation cleavage folds an older mylonitic fabric of uncertain age. This older fabric may represent mylonitic fabrics developed during earlier stages of D_2, reflecting the transient nature of shear zone development and the continual shifting (pulsation) of the high-strain portion of the shear zone. Alternately, the older fabrics may represent the products of an older (D_1) period of mylonitization. In the case of the latter, the intense crenulation and mylonitization associated with the JSZ represent the reactivation of a pre-existing shear zone of unknown age or kinematics. It is hoped that microstructural analysis will help resolve this problem.

An important characteristic of the JSZ is the development of dextral transcurrent shear-sense indicators on the horizontal surface and steeply plunging to down-dip stretching lineations (Fig. GS-12-3). The orientation of the stretching lineation on the S-surface and the ridge-in-groove striation on the C-plane (Lin and Williams, 1992) are generally subparallel. The stretching lineation developed in coarsely clastic rocks has a pronounced oblate geometry, indicating significant flattening strains. Fabrics observed parallel to the stretching lineation (X-Y plane of the finite strain ellipsoid) are generally symmetrical with the exception of shear bands, which dip more shallowly than the C-plane, suggesting a component of north over south dip-slip movement. The geometrical relationship between the shear-sense indicators and stretching lineation is generally interpreted to be the product of transpressional shear (Lin et al., 1998), a regime of shear-zone boundary-parallel transcurrent movement accompanied by a large amount of shear-zone–normal shortening.

The JSZ is overprinted by at least three discrete deformations. The most penetrative is D_3, which produced northeast–trending, open to close, Z-asymmetrical chevron folds and associated crenulation cleavages (Fig. GS-12-4). The D_4 deformation produced north-trending open folds and conjugate kink bands, and is most likely responsible for the large-scale open warps of the shear zone and the greenstone belt. The youngest structures overprinting the shear zone are D_5 pseudotachylite zones, which occur as thin (1–3 mm) shear-zone–subparallel seams or as breccia matrix within pseudotachylite-bound zones up to 30 cm wide within the shear zone (Fig. GS-12-5). The distribution of pseudotachylite has a strong spatial association with the JSZ, and it has not been identified outside the shear zone in the southern Lynn Lake belt. This association suggests that the development of pseudotachylite represents the late semibrittle reactivation of the shear zone. The sense of D_5 shear, as determined by the analysis of synthetic and antithetic Riedel shears within the pseudotachylite zones (Tchalenko, 1970), suggests predominantly sinistral strike-slip displacement of undetermined magnitude.

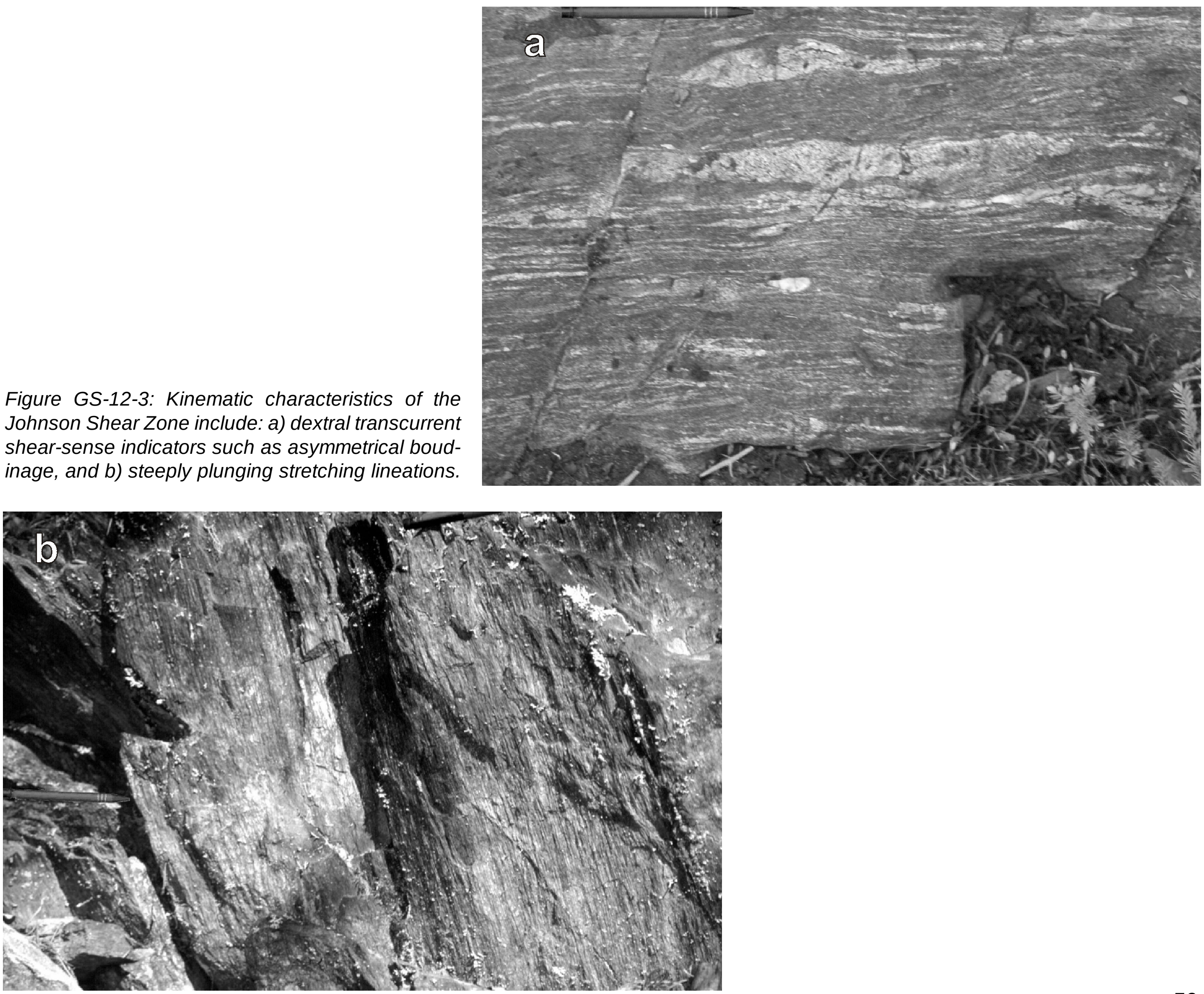

Figure GS-12-3: Kinematic characteristics of the Johnson Shear Zone include: a) dextral transcurrent shear-sense indicators such as asymmetrical boudinage, and b) steeply plunging stretching lineations.

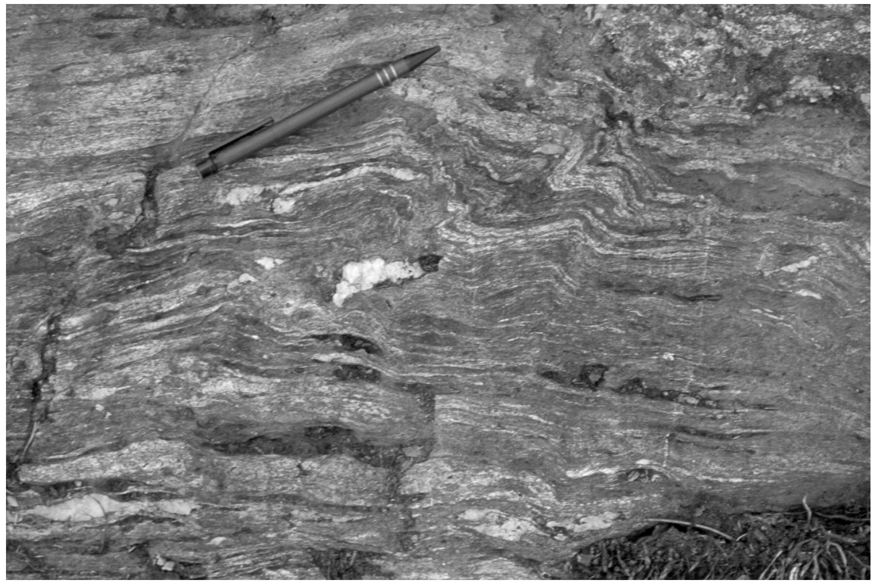

Figure GS-12-4: Close F_3 fold and axial-planar crenulation cleavage overprinting the S_2 mylonitic fabric.

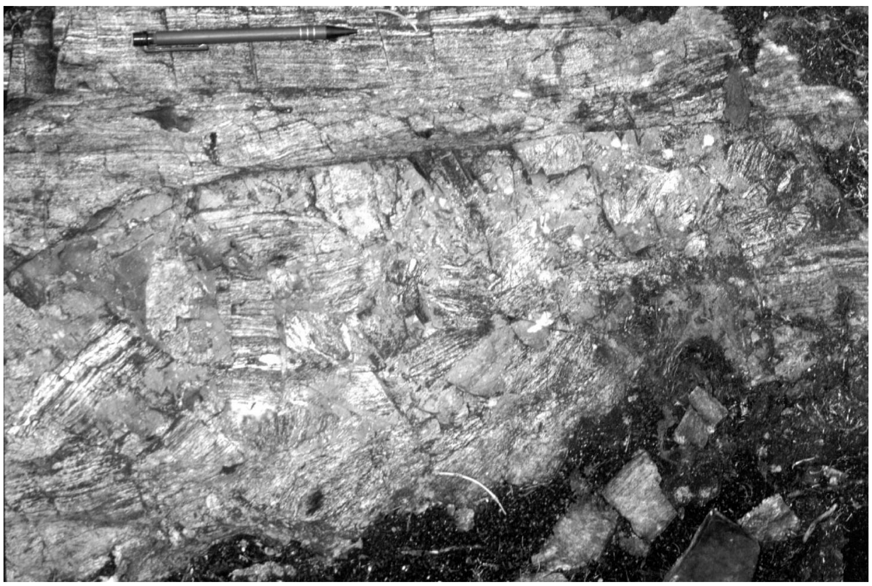

Figure GS-12-5: D_5 pseudotachylite breccia developed in Sickle Group feldspathic greywacke.

The lack of a regional rheologic boundary west of Gemmell Lake appears to have resulted in, or coincided with, the division of the shear zone into two major splays. One zone follows the south side of Gemmell Lake and proceeds west, south of Stear Lake. The delineation of the southern JSZ splay is facilitated by the presence of an inlier of Sickle Group arkosic and pebbly greywacke immediately north of Highway 396, between Stear Lake and Wilmot Lake. Originally interpreted as Wasekwan Group (Gilbert et al., 1980), additional outcrop exposed during recent forest fires exposes pebbly greywacke containing granodioritic clasts typical of the Sickle Group. This unit occupies the footwall to the JSZ and displays a marked south to north increasing strain gradient. The delineation of the JSZ west of Wilmot Lake is hampered by extensive glacial cover, but it is recognized again along the southeastern shore of east Dunphy Lakes. This westernmost exposure of the JSZ trends along the strike of the Dunphy Lakes Fault (Gilbert et al., 1980) and probably represents the eastern strike extension of the fault. The Dunphy Lakes Fault was inferred by Gilbert et al. (1980) to address stratigraphic juxtaposition east of the Fox Lake mine and has not been observed directly (H. Zwanzig, pers. comm., 2000).

The eastern strike extension of the Dunphy Lakes Fault, now the southern JSZ, is exposed along the northern limb of a macroscopic F_2 antiform cored by Snake Lake dacite (Gilbert et al., 1980). Detailed mapping of this area (also recently burned) confirms the fold interpretation originally advanced by Gilbert et al. (1980). The Dunphy Lakes Fault (JSZ) forms the contact between the dacite and the banded oxide-facies iron-formation and siliceous sedimentary rocks to the north and transects the dacite along the northern Z-asymmetrical limb of the fold. The shear zone is recognized by an approximately 20 m wide zone of intensely foliated and quartz-veined porphyritic dacite within a broad zone of strongly foliated dacite. The foliation development includes abundant asymmetrical pressure fringes around the phenocrysts, quartz-ribbon development in the matrix and a large amount of very fine quartz veins. The quartz veins are isoclinally folded, and asymmetrical boudinage of the veins and rare shear bands have been identified. Dextral transcurrent shear-sense indicators and steeply plunging to down-dip stretching lineations characterize the shear zone, consistent with the JSZ kinematic framework.

Interpretation of the Dunphy Lakes Fault as the western continuation of the JSZ has several significant stratigraphic and structural implications. The Dunphy Lakes Fault is interpreted to merge with or become the Todd Lake Fault in the Fox Lake mine area (Gilbert et al., 1980). Reconnaissance mapping of the Todd Lake Fault along the north shore of Todd Lake indicates that this structure maintains many of the characteristics of the JSZ. Most importantly, the Todd Lake Fault displays pre–peak metamorphic dextral transcurrent shear-sense indicators and steep stretching lineations consistent with the dextral transpressional kinematic framework that characterizes the JSZ. The Todd Lake Fault forms the structural hanging wall of the Fox Lake volcanogenic massive sulphide (VMS) deposit and has been previously described as a largely ductile D_2 fault (Olson, 1986). The recognition of the Dunphy Lakes and Todd Lake faults as the western strike extension of the JSZ adds significantly to potential auriferous stratigraphy, and the understanding of the kinematics of the JSZ provides constraints on the search for additional VMS mineralization associated with the Fox Lake deposit, north of the JSZ.

The second JSZ splay forms a parallel zone of mylonitic fabrics that transects Gemmell Lake and continues west, north of the Sickle Group outlier that underlies Gemmell Lake (Fig. GS-12-1). This northern branch of the JSZ is poorly exposed but is recognized by the development of an approximately 100 m wide zone of intensely foliated felsic and mafic volcanic rocks with mylonitic fabrics that demonstrate the same kinematic framework as the southern branch (Fig. GS-12-6). The northern branch has been traced in scattered outcrop for a distance of approximately 5 km west of Gemmell Lake. Delineation of the northern splay farther to the west has been hampered by very limited outcrop, but it appears traceable by aeromagnetics where it passes through the southern end of Irene Lake.

GOLD MINERALIZATION

One of the most significant findings from this summer's fieldwork is the identification of auriferous stratigraphy within the JSZ west of Gemmell Lake. Stratabound gold mineralization is hosted by a 1 to 25 m thick felsic pyroclastic unit, intercalated with porphyritic gabbro, in the Gemmell Lake to Stear Lake portion of the JSZ (Beaumont-Smith and Edwards, GS-13, this volume). The felsic pyroclastic unit is dacitic in composition, locally garnetiferous and comprises various volcanic facies spanning a range from fine ash tuff to coarse lapilli tuff. Although tightly folded and highly sheared, the facies variation appears to be primarily lateral; vertical facies variation is minimal.

Gold mineralization is shear-hosted and associated with fine-grained acicular arsenopyrite ± finely disseminated pyrite in zones of silicified sheared dacite. The silicification is in the form of syn-shear quartz ribbons and quartz veins. The quartz ribbons form parallel to the mylonitic shear planes and, locally, the density of quartz ribbons produces bulk silicification. The quartz veins represent a spectrum of emplacement ages with respect to shear-zone development. The veins appear to nucleate as fine veinlets parallel to the S-surface, followed by their transposition parallel to the C-planes. Later stages of vein emplacement involve strongly asymmetrically boudinaged, coarsely polygonized quartz veins, with shear bands forming the terminations of the individual boudins (Fig. GS-12-7). Associated with the silicification is weak sericitic alteration, generally recognized by a beige weathered colour and increase in muscovite content (metamorphosed sericite). The weathered surface locally takes on a slight greenish hue, possibly reflecting a fuchsitic component to the alteration. Similar arsenopyrite-associated gold mineralization is reported in the east Dunphy Lakes

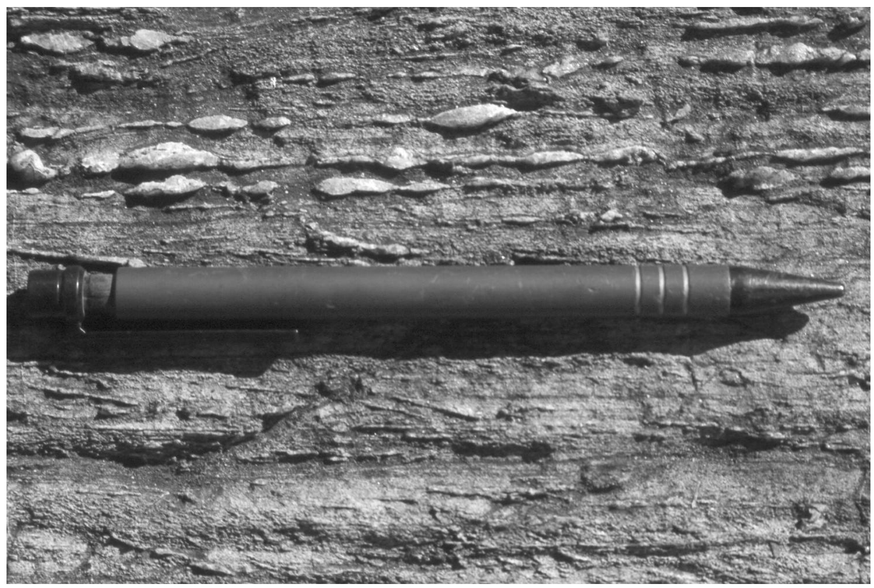

Figure GS-12-6: Dextral asymmetrical boudinage of quartz veins in felsic volcaniclastic rock affected by the northern splay of the Johnson Shear Zone.

Figure GS-12-7: Dextral shear bands and asymmetrical boudinage of quartz veins in moderately sericitized and mineralized, dacitic, fine ash tuff.

portion of the southern JSZ, along the contact between mylonitic Snake Lake dacite and interbedded oxide-facies iron-formation and siliceous sedimentary rocks (Ferreira, 1993).

A second mineralized zone has been outlined north of Wilmot Lake, along Highway 396. The mineralization in this portion of the JSZ is associated with moderately to intensely Fe-carbonatized, silicified and sheared mafic volcanic rocks. The exact nature of the mineralization has yet to be determined, but appears to consist of finely disseminated pyrite within intensely silicified zones. The silicification and carbonatization occur as syn-shear veins, although the silicification has a spatial relationship with the emplacement of syn-shear feldspar-phyric felsic dykes and locally is sufficiently intense to produce bulk silicification. Silicified and sheared mafic volcanic host rocks have a pronounced purplish hue, suggesting the presence of very fine-grained biotite resulting from potassic metasomatism accompanying the silicification. The mineralization and alteration in this area are strikingly similar to those characterizing the BT deposit.

These widely spaced examples of shear-hosted gold mineralization associated with felsic and mafic volcanic rocks demonstrate the potential for the discovery of additional mineralization within the newly delineated western portion of the JSZ. The dacite pyroclastic unit west of Gemmell Lake occupies the same position within the southern JSZ as a similar unit immediately south of Gemmell Lake identified in 1999. This observation dictates a strike length for the zone exceeding 5 km in an area of discontinuous outcrop. The BT-style alteration, hosted by mafic volcanic rocks, can be traced for several kilometres along Highway 396 before leaving the road where it becomes lost under heavy glacial cover. The strike length of this alteration system is unknown.

CONCLUSIONS

The Johnson Shear Zone (JSZ) has been delineated west of Gemmell Lake and, with the incorporation of the Dunphy Lakes–Todd Lake fault system (based on their similar kinematic framework), this gives the JSZ a strike length of more than 100 km. The JSZ is a major D_2 structure characterized by the development of dextral transcurrent shear-sense indicators and steep stretching lineations. The kinematics of the JSZ are interpreted to be the result of dextral transpression. There is increasing evidence that the JSZ represents the D_2 reactivation of an older shear zone.

The western strike extension of the JSZ hosts several newly discovered zones of gold mineralization. Sheared mafic volcanic rocks in the Wilmot Lake area display alteration and mineralization similar in style to the BT deposit. A second, previously unrecognized mineralization style involves gold associated with finely disseminated acicular arsenopyrite and accompanied by syn-shear silicification and sericitization of dacitic volcaniclastic rocks. The discovery of gold mineralization along the western strike continuation of the JSZ west of Gemmell Lake demonstrates the exploration potential of the JSZ beyond its previous known extent.

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