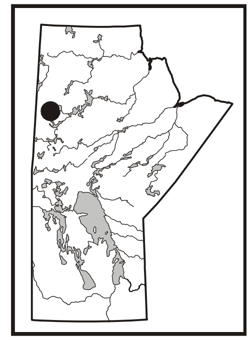
PRELIMINARY STRUCTURAL ANALYSIS AND GOLD METALLOGENY OF THE JOHNSON SHEAR ZONE, LYNN LAKE GREENSTONE BELT (PARTS OF NTS 64C/10, 11, 15)



by C.J. Beaumont-Smith and D.M. Rogge[1]

Beaumont-Smith, C.J. and Rogge, D.M. 1999: Preliminary structural analysis and gold metallogeny of the Johnson Shear Zone, Lynn Lake greenstone belt (parts of NTS 64C/10, 11, 15); *in* Report of Activities, 1999, Manitoba Industry, Trade and Mines, Geological Services, p. 61-66.

SUMMARY

The Johnson Shear Zone (Bateman, 1945) represents a regional-scale ductile-brittle shear zone along the southern margin of the Lynn Lake greenstone belt. Preliminary structural analysis has identified six generations of structural fabrics produced by discrete deformational events. The Johnson Shear Zone is a D_2 ductile shear zone characterized by the development of dextral transcurrent shear fabrics and generally steep stretching lineations. The development of narrow zones of shallowly plunging stretching lineations in the core of the shear zone reflects kinematics consistent with shear zone development in response to dextral transpression. The overprinting of dextral D_2 fabrics by dextral D_3 fabrics results in the limited reactivation of the Johnson Shear Zone. Brittle D_5 sinistral shear zone parallel deformation represents the final movement event.

Gold mineralization associated with the Johnson Shear Zone is characterized by the intense silicification of Wasekwan Group metabasalt and metasedimentary rocks and the introduction of quartz-carbonate-pyrite veinlets during the main D_2 shearing event. Subsequent deformation has not resulted in the significant remobilization of gold mineralization. The intrusion of felsic dykes during D_2 shearing may represent an important factor in the silicification process.

INTRODUCTION

The Johnson Shear Zone (JSZ) has long been recognized as a significant structural feature and an important gold-bearing structure in the southern Lynn Lake greenstone belt (Bateman, 1945; Milligan, 1960; Gilbert et al., 1980; Kenaley, 1982; Fedikow et al., 1991; Peck, 1986; Peck and Eastwood, 1997; Peck et al., 1998; Richardson and Ostry, 1996; Sherman, 1992). It hosts the exhausted Burnt Timber gold deposit and numerous smaller gold deposits and showings. Although the JSZ has been the target of gold exploration since the 1940's, the relationship between gold mineralization and deformation is poorly understood. The initiation of a program of detailed structural analysis of the JSZ and metallogenic studies into the nature and origin of gold mineralization is focused on providing insight into the processes involved in the development of shear hosted gold deposits in the Lynn Lake area. It is hoped this approach will provide new criteria to guide further exploration.

GEOLOGICAL SETTING

The Paleoproterozoic Lynn Lake greenstone belt (Fig. GS-15-1) is subdivided into Northern and Southern belts of metavolcanic rocks and subordinate metasedimentary rocks comprising the Wasekwan Group (Bateman, 1945). In the Southern belt, the Wasekwan Group is dominated by tholeiitic and calc-alkaline metabasalts overlain by rhyolitic to dacitic rocks and minor epiclastic sedimentary rocks. The Wasekwan Group is isoclinally folded into shallowly plunging overturned F_1 folds prior to the intrusion of the Pool Lake Suite (Gilbert et al., 1980). F_1 folds and S_1 foliations are the oldest structures observed in the study area and pre-date the fabrics associated with the JSZ. Unconformably overlying the Wasekwan Group and Pool Lake Suite are coarse clastic rocks comprising the Sickle Group (Norman, 1933) .

The east-trending Johnson Shear Zone is located along the southern margin of the southern Lynn Lake Belt. In the eastern portion of the belt, the JSZ is localized along the contact between the Wasekwan Group and overlying Sickle Group to the north and the Pool Lake Suite to the south. West of Gemmell Lake the JSZ appears to cut the supracrustal stratigraphy, continuing its easterly trend to the limit of the currently delineated western extent of the shear zone, a limit reflecting the western extent of current structural mapping.

The metamorphic grade of the Southern Belt ranges from upper greenschist facies in the eastern portion of the study area, increasing to upper amphibolite facies in the western portion of the belt. This has a significant effect on the JSZ as the growth of peak metamorphic assemblages largely post-dates the development of the mylonitic fabrics characterizing the JSZ. West of Gemmell Lake, recognition of the JSZ is hampered by the intense upper amphibolite facies metamorphic recrystallization of the mafic metavolcanic rocks that dominate the

[1] University of Manitoba, Winnipeg, Manitoba

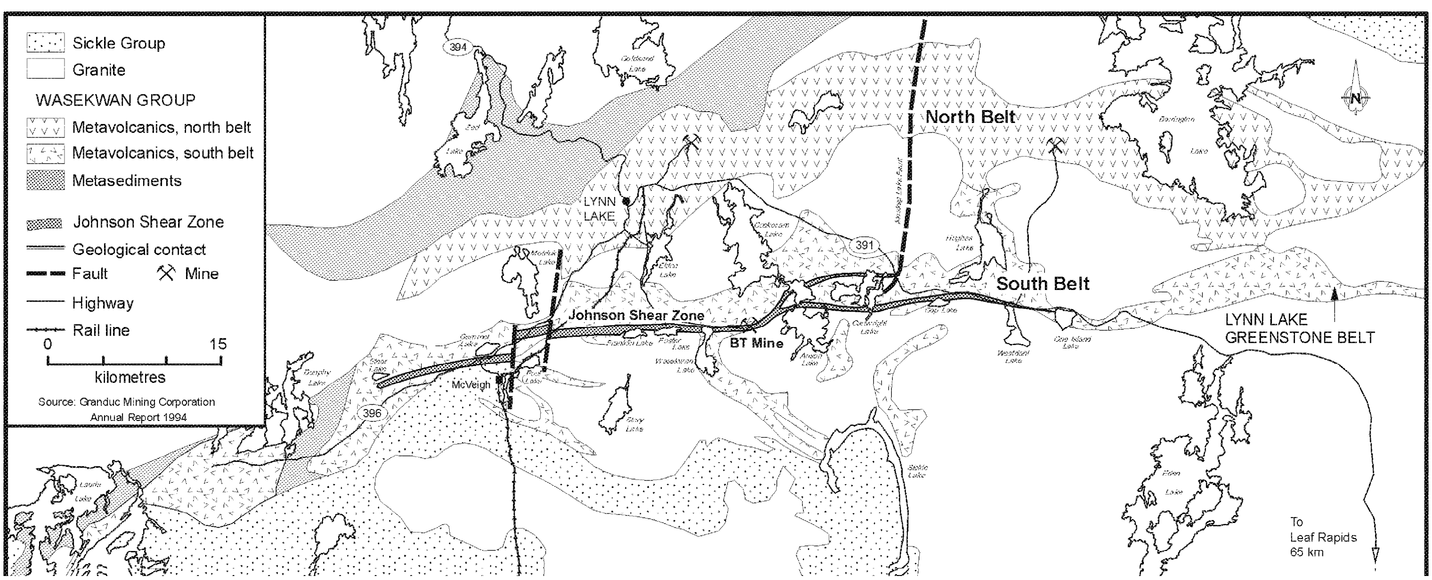


Figure GS-15-1: General geology of the Lynn Lake greenstone belt and the location of the Johnson Shear Zone. (after Peck et al., 1998) supracrustal stratigraphy. This has largely removed many of the mylonitic fabrics that define the JSZ, although intermediate and felsic metavolcanic rocks dispersed within the Wasekwan Group have experienced significantly lower degrees of metamorphic recrystallization and preserve a wide variety of mylonitic fabrics.

STRUCTURAL ANALYSIS

Detailed structural analysis has been carried out on three sections of the JSZ in an attempt to characterize the shear zone along its known strike length. This has involved detailed mapping in the Westdahl Lake area (east), the area between the BT Mine property and Foster Lake (central), and the Gemmell-Stear Lakes area (west) (Fig. GS-15-1). Structural characterization of the immediate JSZ and surrounding area has identified six generations of deformational fabrics. These appear to represent the products of discrete deformational events (D_1-D_6), although there is limited evidence for progressive ductile fabric development within the JSZ. Shear zone fabrics and kinematics identified during the detailed structural analysis of the known portion of the JSZ have been used to identify the JSZ west of Gemmell Lake. The western extension of the JSZ represents a significant geological advance, both in terms of the understanding of the structural evolution of the Lynn Lake greenstone belt and as an increase in prospective gold-bearing stratigraphy.

The JSZ has been previously described as a zone of intense foliation development including localized, narrow zones of mylonitic fabric development (Fedikow et al., 1991; Peck et al., 1998). Preliminary structural analysis suggests the deformational intensity comprising the JSZ has been underestimated and the JSZ represents a major D_2 ductile-brittle shear zone characterized by broad zones of mylonitic to local ultramylonitic fabrics developed within a zone of intense foliation development. The deformational history of the JSZ is accordingly complex with several periods of ductile and brittle reactivation.

The determination of the JSZ as a D_2 structure is based on overprinting relationships observed along the margin of the shear zone and the evolution of these fabrics with increased shear strain. The first generation of fabrics observed in the Lynn Lake area are associated with the steeply inclined to overturned isoclinal folding of the Wasekwan Group metavolcanic rocks. These fabrics are rarely preserved in the JSZ, having been transposed by later deformational events. Steeply plunging, Z-asymmetrical F_2 folds, representative of the regional manifestation of D_2, fold an S_1 slaty cleavage preserved along the margins of the JSZ. Increased D_2 strain associated with the JSZ results in the tightening of F_2 folds and the progressive shallowing of F_2 fold axes. The high strain core of the JSZ is characterized by shallow east- to subhorizontal-plunging F_2 isoclinal to rootless folds (Fig. GS-15-2a).

D_2 fabrics that characterize the high strain core of the JSZ comprise a wide variety of typical shear zone fabrics. The development of steeply dipping, fine tectonic layering is ubiquitous. In sedimentary and felsic metavolcanic rocks the tectonic layering consists of many generations of quartz ribbons and boudinaged and further mylonitized quartz veinlets.

Figure GS-15-2a: F_2 fold development characterizing the Johnson Shear Zone. (a) Isoclinal, shallowly east plunging F_2 folds with the possible development of sheath folds (arrow).

Figure GS-15-2b: F_2 fold development characterizing the Johnson Shear Zone. (b) Evolution of F_2 folds from tight (top) to rootless (arrow) with increased shear strain.

The tectonic layering developed in mafic and intermediate metavolcanic rocks comprises alternating fine-scale leucocratic and mafic layering. Once developed, the tectonic layering is continuously remylonitized through the successive development of isoclinal folds. Consequently, isoclinal and rootless F_2 folds are ubiquitous, the result of the preservation of F_2 folds in various stages of development (Fig. GS-15-2b).

Shear sense indicators developed along the entire strike length of the JSZ consistently indicate dextral shear sense on the horizontal surface (Fig. GS-15-3a, b). This remains consistent irrespective of the orientation of the associated stretching lineation. Stretching lineations generally plunge steeply down the dip of the mylonitic foliation; sedimentary clasts or volcanic fragments define oblate stretching lineations with a large amount of foliation-normal flattening in addition to the down-dip stretching (Fig. GS-15-4). Moderately- to shallowly-plunging stretching lineations are less common and appear to be restricted to narrow zones within the core of the JSZ (Fig. GS-15-5). The relationship between horizontal transcurrent shear and the dominance of steep stretching lineations is characteristic of transpressional shear zones that involve a large component of shear zone normal shortening in concert with the transcurrent shear (Lin et al., 1998).

A broad peripheral zone of intense foliation development associated with the JSZ consists of tight to isoclinal F_2 folds and the microcrenulation of an older foliation, forming a steeply dipping differentiated layering. Tight F_2 crenulation folds are generally shallowly-plunging chevron folds, resulting in a ridged horizontal outcrop surface. Mesoscopic observations have been insufficient to determine whether the older foliation folded by F_2 represents S_1 or if it is an earlier formed S_2 mylonitic foliation. The strain associated with the development of the zones of intense crenulation cleavage is considerable and the development of a dextral shear band cleavage is common.

The uncertainty regarding the relative ages of fabrics that characterize the JSZ involves the cyclical nature of fabric development characterizing shear zone development and the possible reactivation of the JSZ during D_3. Beyond the boundary of the JSZ, D_3 fabrics overprint D_2 structures in a manner that suggests the two generations of structures represent discrete deformational events. Steeply-plunging F_2 folds are overprinted by steeply-dipping, northeast-trending S_3 crenulation cleavage. S_3 is generally weakly differentiated and associated with tight, Z-asymmetrical F_3 chevron folds (Fig. GS-15-6). D_3 structures represent the northeast-trending crenulation fabrics and folds described by previous workers (i.e., D_4 of Gilbert et al., 1980). Within the JSZ there is abundant evidence of the overprinting of D_2 mylonitic fabrics by D_3 (Fig. GS-15-7). The problem differentiating between the two deformations within the JSZ involves the considerable style overlap between F_2 and F_3 and the continual nucleation of folds within an active shear zone. Both generations of folds are Z-asymmetrical tight chevron folds.

The reactivation of the JSZ during D_3 is suggested by several fabric elements. Within the JSZ, northeast-trending, steeply-plunging, tight chevron folds are developed within the shear zone. The axial planes of these folds abruptly curve into the east-west orientation of the JSZ in

Figure GS-15-3a: D_2 dextral shear sense indicators developed on horizontal surfaces. (a) Dextrally rotated porphyroclast systems and shear band cleavage in volcaniclastic rhyolite.

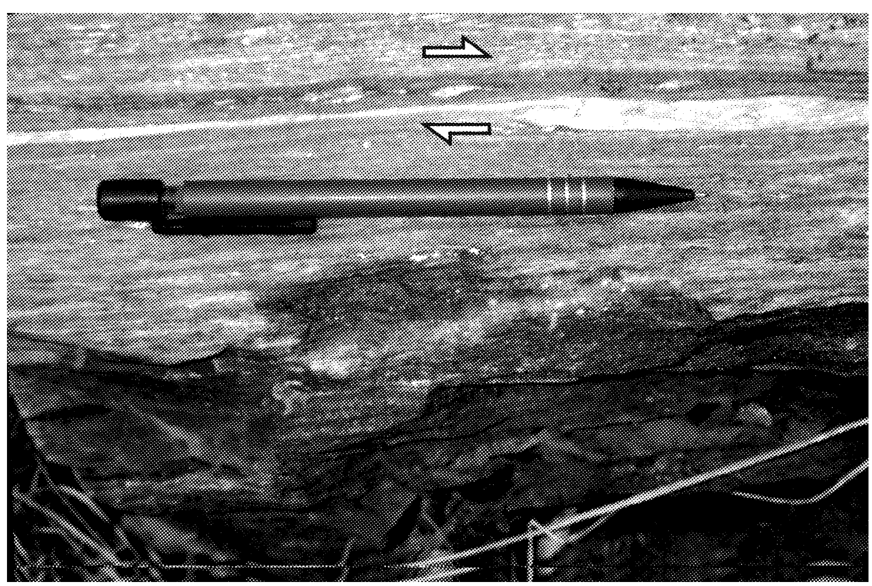


Figure GS-15-3b: D_2 dextral shear sense indicators developed on horizontal surfaces. (b) Dextrally back-rotated boudinage and shear band development in mafic tectonite.

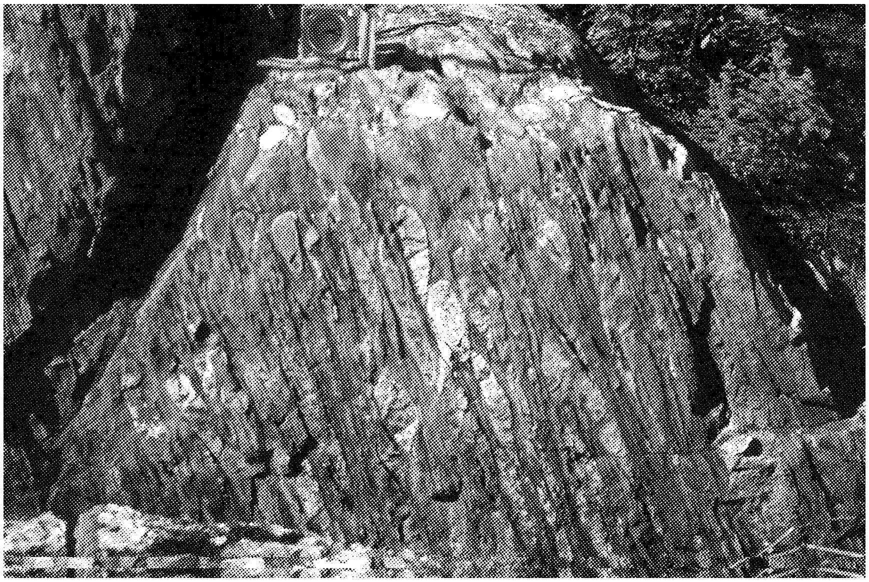


Figure GS-15-4: Steep, down-dip oblate stretching lineations developed in Sickle Group conglomerate.

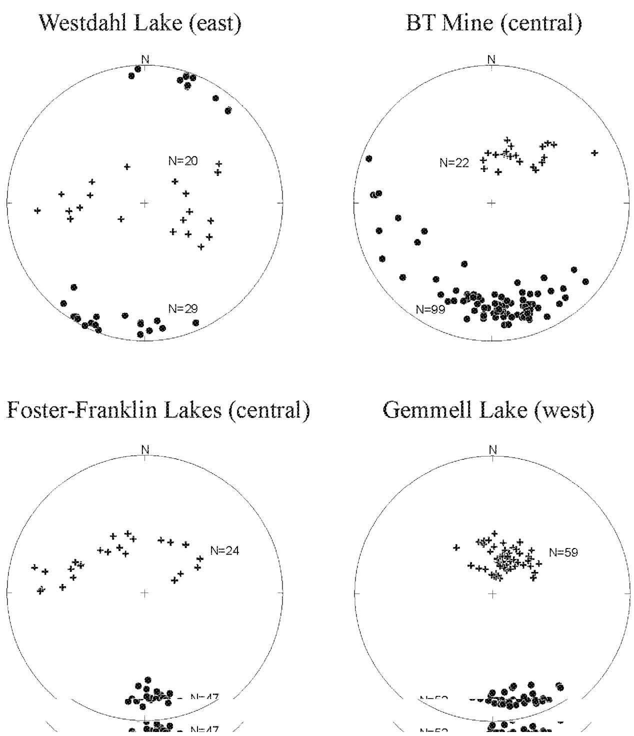


Figure GS-15-5: Lower hemisphere, equal area stereographic projections of D_2 structural data for the Johnson Shear Zone. Poles to mylonitic foliation (circles) and stretching lineations (crosses) displayed.

concert with the progressive shallowing of the F_3 fold axes. There is also an accompanying tightening of these folds. Finally, the reoriented F_3 folds are overprinted by JSZ-parallel shear band cleavage. The reactivation of the JSZ during D_3 may explain the sporadic distribution of differentiated S_3 crenulation cleavage within the shear zone and the general lack of S_3 development in zones of highest shear strain. The peak of metamorphism is broadly coincident with D_3 and it is hoped this may provide an opportunity to confirm whether D_3 reactivation of the JSZ has taken place.

The JSZ is overprinted by two generations of post-peak metamorphic open folds. D_4 structures comprise open folds and conjugate kink bands and associated weak conjugate crenulation to fracture cleavages. Locally, D_4 structures include narrow cataclasite zones. F_4 folds are oriented north-south and are associated with the regional warping of the JSZ and the Lynn Lake Belt. The final ductile deformation (D_6) consists of shallow-plunging recumbent folds. These folds are rarely seen due to their large wavelengths and the lack of large vertical exposures, but can be seen in the BT open pit. Locally D_6 is recognized with the development of a sub-horizontal crenulation lineation. These structures appear to be limited in extent and very minor in affect.

The D_2 dextral ductile movement on the JSZ is overprinted by a late, largely brittle D_5 deformation. The D_5 orientation is sub-parallel to the D_2 trend and generally has a slightly shallower, northerly dip. D_5 fabrics comprise sinistral shear fractures and rare S-asymmetrical folds with accompanying synthetic and antithetic Reidel shears. The few F_5 folds observed to date plunge moderately to the west. D_5 structures commonly form zones of cataclasite bounded by S_5 shear fractures, highlighted by the development of pseudotachylite which is formed along the shear fractures and is injected into other intersected brittle fabrics (i.e., the S_4 fracture cleavage) (Fig. GS-15-8). Pseudotachylite also commonly forms the matrix to D_5 cataclasites. The post-mineralization T_1 fault at the BT open pit (Peck and Eastwood, 1997) is most probably a D_5 structure. Pseudotachylite development appears to be restricted to the footwall region of the T_1 fault and has not been recognized east of the Muskeg Lake Fault (Gilbert et al., 1980). However, this may represent a sampling bias as the T_1 footwall is better exposed. The strong airphoto topographic linear associated with the JSZ is most probably the T_1 fault scarp with the footwall forming the prominent ridges.

GOLD METALLOGENY

A major focus of this study involves investigations of the controls on Au mineralization associated with the JSZ. Fieldwork has so far concentrated on gaining understanding of the deformational history of the JSZ, and although metallogenic studies are in the initial stages, several significant characteristics of gold mineralization associated with the JSZ are apparent and represent potential exploration guides.

The most significant gold deposit associated with the JSZ is the Burnt Timber (BT) deposit, located east of Wasekwan Lake. Mining operations ceased at the BT Mine in 1996 and the open pit is now largely flooded. Accordingly, the exposures of the ore zone afforded are limited. The observations that form the basis of this report include the safely accessible portions of the upper benches of the open pit and the exposed footwall of the deposit.

The BT ore zone consists of pervasively silicified and carbonatized metasedimentary rocks and metabasalt that contains fine quartz-carbonate-pyrite veinlets. The veinlets consist of quartz, several carbonate species dominated by dolomite with subordinate ferrodolomite and ankerite, and fine-grained pyrite, all of which are generally concordant to the S_2 mylonitic foliation. A strong spatial association exists in the BT footwall between the fine-scale quartz-carbonate-pyrite veinlets and the ore zone. The density of this veining increases as the ore zone is approached.

The immediate footwall of the BT deposit is separated from the ore

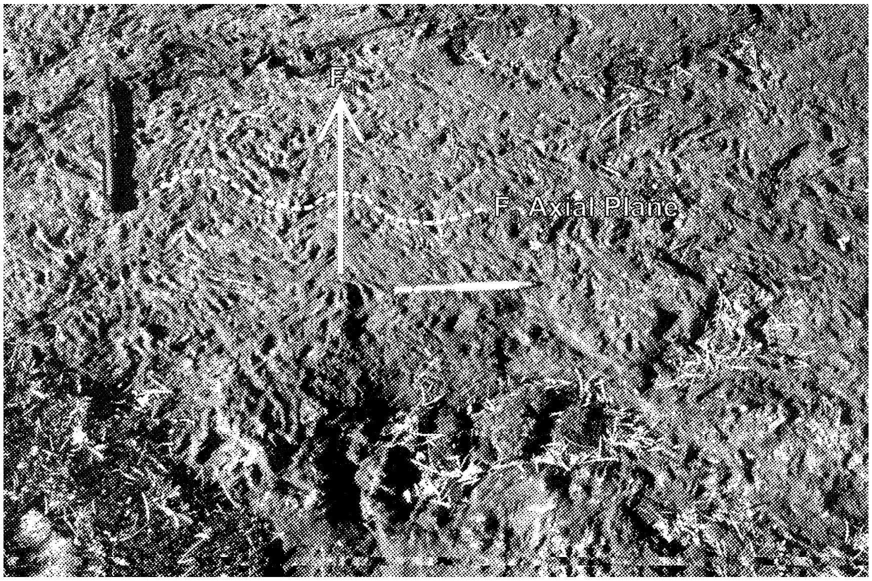


Figure GS-15-6: *Refolding of tight F_3 chevron folds by open F_4 folds.*

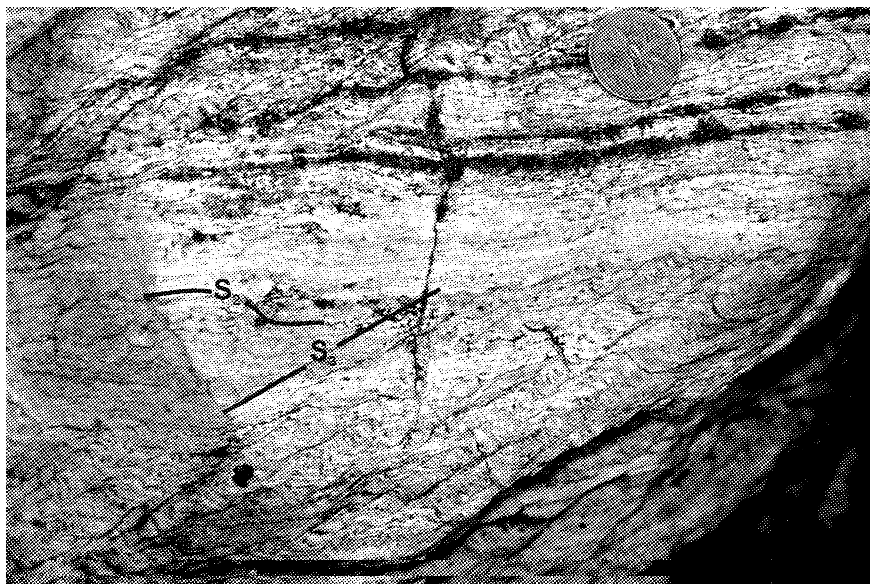


Figure GS-15-7: *S_3 crenulation of S_2 mylonitic fabric. While not discernable in photo, the mylonitic fabric contains abundant dextrally rotated quartz d-type porphyroclast systems.*

Figure GS-15-8: *D_5 cataclastic zone accompanied by the development of pseudotachylite (arrows).*

zone by the T_1 fault, a major post mineralization fault (Peck and Eastwood, 1997). Unfortunately, the level of flooding in the BT open pit and backfilling operations precludes observation of the T_1 fault. The lack of observations of the T_1 fault is significant as it represents a significant regional structure and is largely responsible for the topographic expression of the JSZ. The movement history of the T_1 fault is poorly understood. Peck et al. (1998) describe fabrics associated with the T_1 fault consistent with movement involving a component of reverse dip-slip. D_5 fabrics in the T_1 footwall suggest dominantly sinistral strike-slip T_1 movement. Accordingly, offset on the T_1 fault is unknown, but the presence of the same quartz-carbonate-pyrite veinlets which characterize the ore zone in the T_1 footwall suggests the offset is limited.

The timing of veinlet formation is coeval with D_2 shearing. The veinlets are parallel to the S_2 mylonitic foliation, locally experiencing D_2 boudinage and are affected by S_2 shear band cleavage. The veinlets are folded by F_3 and cross-cut by S_3 parallel barren quartz veins. The small-scale F_3 folding of the mineralized veinlets is also reflected in the ore distribution on BT open pit level plans (Peck and Eastwood, 1997). Large-scale moderately northeast plunging F_3 folds exposed in the north-east wall of the open pit fold high-grade silicified bands hosted by mafic phyllonites. Little evidence exists for possible gold remobilization during later brittle deformation. D_5 structures generally involve the development of pseudotachylite and quartz or quartz-pyrite veining associated with S_5 has not been observed.

A second spatial association between gold mineralization and the JSZ involves the distribution of strongly boudinaged felsic dykes in the BT deposit area. The dykes exposed in the footwall metabasalt comprise quartz-feldspar phyric dykes with rusty pyritic margins. These dykes are well foliated and boudinaged during D_2, and are also present within the ore zone (granitic dykes of Peck and Eastwood, 1997). This association is of uncertain significance and further geochemical and mineralogical investigations are planned and may resolve this issue. Irrespective of the possible importance of the intrusion of felsic dykes during D_2 shearing, the silicification of mylonitized rocks and the introduction of quartz-carbonate-pyrite veinlets during D_2 represents an important exploration guide in the search for BT-style mineralization. The intrusion of felsic dykes during D_2 shearing appears to represent an important control on gold mineralization in several other gold deposits associated with the JSZ, including the Bonanza Deposit in the Cartwright Lake area and the McBride Deposit east of Gemmell Lake. Further fieldwork is planned next year to characterize these deposits.

The presence of felsic dykes elsewhere along the strike length of the JSZ is rare, but boudinaged quartz-feldspar or feldspar phyric felsic dykes also accompany zones of silicification and quartz-carbonate-pyrite veining similar to the style of mineralization at the BT Mine. The most continuous example of this style of mineralization identified this field season occurs within a metasedimentary unit between Gap and Westdahl lakes. With a strike length of 5.5 kms, this package of mylonitized metasedimentary rocks contains zones of quartz-carbonate-pyrite veining and local silicification. The association between intense silicification and the intrusion of felsic dykes is demonstrated in several locations, with the most intense silicification developed east of Gap Lake along the Lynn Lake to Leaf Rapids highway. This portion of the JSZ is largely untested by diamond drilling and represents very prospective stratigraphy for BT style mineralization.

CONCLUSIONS

Preliminary structural analysis of the Johnson Shear Zone identifies six generations of ductile and brittle fabrics. The Johnson Shear Zone represents a major D_2 structure characterized by dextral shear fabrics and steep to shallow stretching lineations, consistent with its development in response to dextral transpression. Reactivation during D_3 produced further dextral shear fabrics. The final movement involves D_5 largely brittle sinistral movement, highlighted by the development of pseudotachylite and cataclasite in a shear zone parallel orientation.

Intense silicification and the introduction of quartz-carbonate-pyrite veinlets during the main D_2 shearing event characterize gold mineralization associated with the Johnson Shear Zone. There is little evidence for any significant gold remobilization during subsequent deformation. The possible involvement of felsic dykes in the silicification event is speculative but represents a potentially important exploration guide.

Further structural investigations will focus on microstructural analysis of the Johnson Shear Zone. Gold metallogenic studies will focus on geochemical and mineralogical controls on the mineralization and will include the characterization of the alteration associated with the BT deposit. This work will be expanded next year to include the other major gold deposits associated with the JSZ.

ACKNOWLEDGEMENTS

The authors wish to thank Paul Pawliw, Ken Atkin, Martin Eastwood and staff of Black Hawk Mining for their assistance. The input and enthusiasm of Mr. Paul Pawliw greatly advanced the fieldwork and his knowledge of the Lynn Lake area proved invaluable. Dan Ziehlke of Stryder Resources/Union Gold is thanked for the many stimulating discussions. Herman Zwanzig is thanked for leading an excellent field trip of the Lynn Lake greenstone belt. The thorough reviews of Eric Syme and Mark Fedikow greatly improved the manuscript. Dave Peck and Shoufa Lin are thanked for laying the groundwork for this project.

REFERENCES

Bateman, J.D. 1945: McVeigh Lake area, Manitoba; Geological Survey of Canada, Paper 45-14, 34 p.

Fedikow, M.A.F., Ferreira, K.J., and Baldwin, D.A. 1991: The Johnson Shear Zone - A regional metallogenetic feature in the Lynn Lake area; Manitoba Energy and Mines, Mineral Deposit Thematic Map Series, Map 91-1.

Gilbert, H.P., Syme, E.C., and Zwanzig, H.V. 1980: Geology of the metavolcanic and volcaniclastic metasedimentary rocks in the Lynn Lake area; Manitoba Energy and Mines, Geological Paper GP80-1, 118 p.

Kenaley, D.S. 1982: Petrology, geochemistry and economic geology of the selected gold claims of rocks in the Wasekwan Lake area, Lynn Lake district, Manitoba, Canada; M.Sc. thesis, University of North Dakota, 306 p.

Lin, S., Jaing, D., and Williams, P.F. 1998: Transpression (or transtension) zones of triclinic symmetry: natural example and theoretical modelling; *in* Holdsworth, R.E., Strachan, R.A. and Dewey, J.F. (eds.), Continental Transpressional or Transtensional Tectonics, Geological Society, London, Special Publications, 135, p. 41-57.

Milligan, G.C. 1960: Geology of the Lynn Lake district; Manitoba Mines and Natural Resources, Mines Branch Publication 57-1, 317 p.

Norman, G.W.H. 1933: Granville Lake district, northern Manitoba; Geological Survey of Canada, Summary Report, Part C, p. 23-41.

Peck, D.C. 1986: The geology and geochemistry of the Cartwright Lake area: Lynn Lake greenstone belt, northwestern Manitoba; M.Sc. thesis, University of Windsor, 270 p.

Peck, D.C. and Eastwood, A.M. 1997: Geochemical and structural analysis of gold mineralization at the Burnt Timber Mine, Lynn Lake; *in* Report of Activities, 1997, Manitoba Energy and Mines, Geological Services, p. 50-60.

Peck, D.C., Lin, S., Atkin, K., and Eastwood, A.M. 1998: Reconnaissance structural studies of the Au Metallotects in the Lynn Lake greenstone belt (parts of NTS 64C/10, C/11, C/15); *in* Report of Activities, 1998, Manitoba Energy and Mines, Geological Services, p. 69-74.

Richardson, D.J. and Ostry, G. 1996: Gold deposits of Manitoba; Manitoba Energy and Mines, Economic Report ER 86-1 (second edition), 114 p.

Sherman, G.R. 1992: Geology, hydrothermal activity and gold mineralization in the Gemmell Lake area of the Early Proterozoic Lynn Lake greenstone belt, Manitoba; M.Sc. thesis, University of Windsor, 148 p.