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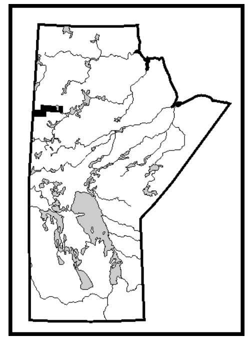
GS-6 Tectonic evolution and gold metallogeny of the Lynn Lake greenstone belt, Manitoba (NTS 64C10, 11, 12, 14, 15 and 16)



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Summary

The tectonic history of the Lynn Lake greenstone belt involves the assembly of volcanic rocks representing a variety of tectonic affinities. The assembly is the product of D_1 deformation inferred as a thrusting event, overprinted by intense D_2 transposition characterized by tight to isoclinal, horizontal folds. This period of D_2 transposition produced regional-scale ductile shear zones, which host a number of gold deposits in rheologically favourable units. The resultant D_1-D_2 structural geometry is characterized by a shallow-dipping macroscopic enveloping surface. This has significant implications for mineral exploration, as geological units can be fold repeated across geological strike. In the case of shear-hosted, stratabound gold mineralization, it can be demonstrated that there is fold repetition of favourable picrite units east of the MacLellan mine.

New U-Pb age and Nd isotope results suggest the subdivision of the Lynn Lake belt into two main terranes:

1) An older terrane is characterized by a suite of ca. 1.89 Ga volcanic and felsic intrusive rocks, which have Nd model ages >2.2 Ga and initial epsilon Nd (εNd) values of –2.3 to +1.3, indicating moderate contamination by older crust. Current tectonic models suggest that ca. 2.3 to 2.5 Ga Peter Lake Domain– and Sask craton–type or 2.7 Ga Superior-type crust, or both, were involved in the generation of these rocks. This older igneous suite includes the Lynn Lake rhyolite, dacite and dacitic mylonite from southeast Dunphy Lake, and possibly also rhyolite from east Stear Lake and dacite from southeast Snake Lake.
2) A second terrane consists of a younger suite of ca. 1.88 to 1.84 Ga volcanic and ca. 1.85 to 1.83 Ga igneous rocks, which have Nd model ages <2.2 Ga and initial εNd values of +4 to +5, indicating a juvenile origin. This suite includes rhyodacites from Gemmell and One Island lakes, tonalites from east and northeast Dunphy Lake, rhyolite from north of Motriuk Lake, dacite from east of Hughes Lake, and possibly also dacite from Sickle Lake.

The present geographic distribution of the above two terranes is not fully consistent with the previous subdivision into northern and southern belts, as was suggested by their trace-element geochemistry. Rather, the distribution of the two terranes indicates a more complex structural assembly of the Lynn Lake belt than previously known, and one that includes terrane-internal displacements.

Introduction

Elucidating the structural geometry and tectonic evolution of the Lynn Lake greenstone belt to provide an enhanced framework for conducting mineral exploration is a primary goal of geoscience research in the Lynn Lake area. Building on the structural studies conducted over the past four years, primarily in the southern Lynn Lake belt, the focus of this year's structural analysis was extended into the central portion of the northern Lynn Lake belt. This expanded coverage of structural analysis was undertaken primarily to support ongoing gold exploration efforts in the central portion of the northern greenstone belt, east of the past-producing MacLellan mine.

Previous work in the Lynn Lake belt has shown that gold mineralization in the greenstone belt is structurally controlled, hosted by D_2 shear zones, and associated with intense silicification and introduction of finely disseminated sulphide minerals prior to the peak of metamorphism (Beaumont-Smith and Böhm, 2002, and references therein). Uranium-lead geochronology and Sm-Nd isotopic studies coinciding with structural analysis have helped unravel the structural assembly of the greenstone belt, adding considerably to knowledge of the early assembly history of the belt, which is obscured by intense, post-assembly D_2 transposition.

Regional setting

The Paleoproterozoic Lynn Lake greenstone belt is located along the northern margin of the Kisseynew sedimentary basin, within the internal Reindeer Zone (Stauffer, 1984; Lewry and Collerson, 1990) of the Trans-Hudson Orogen. The various metavolcanic and metasedimentary units making up the greenstone belt represent a variety of tectonic affinities (*see* Zwanzig et al., 1999) that were structurally assembled and transposed into two east-trending, steeply north-dipping supracrustal belts during the early stages of the orogen. The supracrustal rocks in the Lynn Lake belt were initially assigned to the Wasekwan Group (Bateman, 1945), but the recent structural, geochemical, isotopic and geochronological studies (Zwanzig et al., 1999; Beaumont-Smith and Böhm, 2002) have identified the need to revise the metavolcanic stratigraphy to reflect differences in their age and geochemical and isotopic composition.

General geology

The Lynn Lake greenstone belt has been traditionally divided into east-trending northern and southern belts, which are separated by felsic intrusive rocks (Fig. GS-6-1). Based on recent trace-element geochemistry (*see* Zwanzig et al., 1999) and Nd isotopic results, however, a three-fold subdivision of the metavolcanic rocks is favoured. The original subdivision of the greenstone belt into northern and southern belts, which is based on the distribution of supracrustal rocks in the central to eastern portion of the Lynn Lake area, remains legitimate for this area and is further supported by geochemistry and Nd isotopic compositions. The third subdivision of the greenstone belt is defined by a geochemical and isotopic boundary in the western portion of the southern belt, indicating the western portion to be a separate entity (*see* below).

The northern belt consists of submarine, tholeiitic, mafic metavolcanic and metavolcaniclastic rocks interpreted to represent an overall north-facing, steeply dipping succession (Gilbert et al., 1980). The geochemistry of these rocks is dominantly arc tholeiitic to transitional enriched mid-oceanic ridge basalt (E-MORB; Zwanzig et al., 1999), with slightly contaminated Nd isotopic composition (Beaumont-Smith and Böhm, 2002). The tectonic environment for the deposition of the northern belt supracrustal rocks was interpreted to be in a continental-arc setting (*see* Beaumont-Smith and Böhm, 2002). Prior to the results presented here, the age of the northern belt was ca. 1890 Ma, based on two U-Pb zircon ages of the eastern and western portions of the Lynn Lake rhyolite (Beaumont-Smith and Böhm, 2002).

The northern belt includes the Agassiz Metallotect (Fedikow and Gale, 1982), a tectonostratigraphic assemblage consisting of ultramafic flows (picrite), banded oxide-facies iron formation and associated exhalative sedimentary rocks. The Agassiz Metallotect is a relatively narrow, strike-continuous, stratigraphic-structural unit that occurs over a 70 km strike length from immediately west of the MacLellan mine area to southwest of Barrington Lake (*see* Ma et al., 2000; Ma and Beaumont-Smith, 2001; Park et al., 2002). The Agassiz Metallotect is economically significant because it hosts all the known gold mineralization in the northern belt. There are two styles of gold mineralization associated with the metallotect:

1) Most significant in terms of the number of occurrences is the shear-hosted mineralization, generally within D_2 shear zones developed in rheologically weak picritic units. This style of mineralization is represented by the MacLellan and satellite deposits in the western Agassiz Metallotect (*see* Gagnon, 1991; Fedikow, 1986; Ma et al., 2000; Ma and Beaumont-Smith, 2001; Park et al., 2002).
2) The second style is iron formation–hosted mineralization associated with flat-lying quartz-sulphide veins, which forms the Farley Lake deposit in the western portion of the metallotect (*see* Peck et al., 1998, Beaumont-Smith et al., 2000). This style of mineralization reflects sulphidization of the host iron formation along the margins of quartz–sulphide±carbonate, post-D_4 shear veins (Beaumont-Smith et al., 2000).

The northern belt is unconformably overlain to the north by marine sedimentary rocks, the Ralph Lake conglomerate and the ca. 1880 Ma Zed Lake greywacke (Gilbert et al., 1980; Beaumont-Smith and Böhm, 2002), and is intruded by the 1876 Ma (Baldwin et al., 1987) to 1871 Ma (Turek et al., 2000) Pool Lake intrusive suite (Manitoba Energy and Mines, 1986) and younger plutons (the post-Sickle plutons of Milligan, 1960).

The southern belt is composed of submarine tholeiitic to calcalkaline metavolcanic and metavolcaniclastic rocks with minor amounts of MORB. The majority of the belt contains arc-like geochemistry and has juvenile isotopic compositions (Zwanzig et al., 1999; Beaumont-Smith and Böhm, 2002). The age of the southern belt is poorly constrained at this time. The U-Pb age determinations have been hampered by poor zircon yields in a large number of samples collected to date. Samples yielding sufficient zircons have returned ages between 1856 and 1842 Ma (Beaumont-Smith and Böhm, 2002). This age spectrum suggests that the southern belt may be significantly younger than the northern belt, further supporting the geochemical and isotopic differences between the belts. Contact relationships between the supracrustal rocks and ca. 1870 Ma intrusive rocks in the southern belt, however, suggest the presence of older (>1870 Ma) metavolcanic rocks. Accordingly, the tectonic environment for the deposition of the supracrustal rocks in the southern belt remains unresolved, but it certainly contains a component of younger, oceanic arc–like volcanic rocks.

This contrasts with the western portion of the southern belt, west of Dunphy Lakes, which is characterized by arc tholeiite and MORB geochemistry. This portion of the greenstone belt hosts the past-producing Fox Lake Cu-Zn deposit within a sequence of arc-tholeiite and minor calcalkaline metavolcanic rocks. The results presented below will

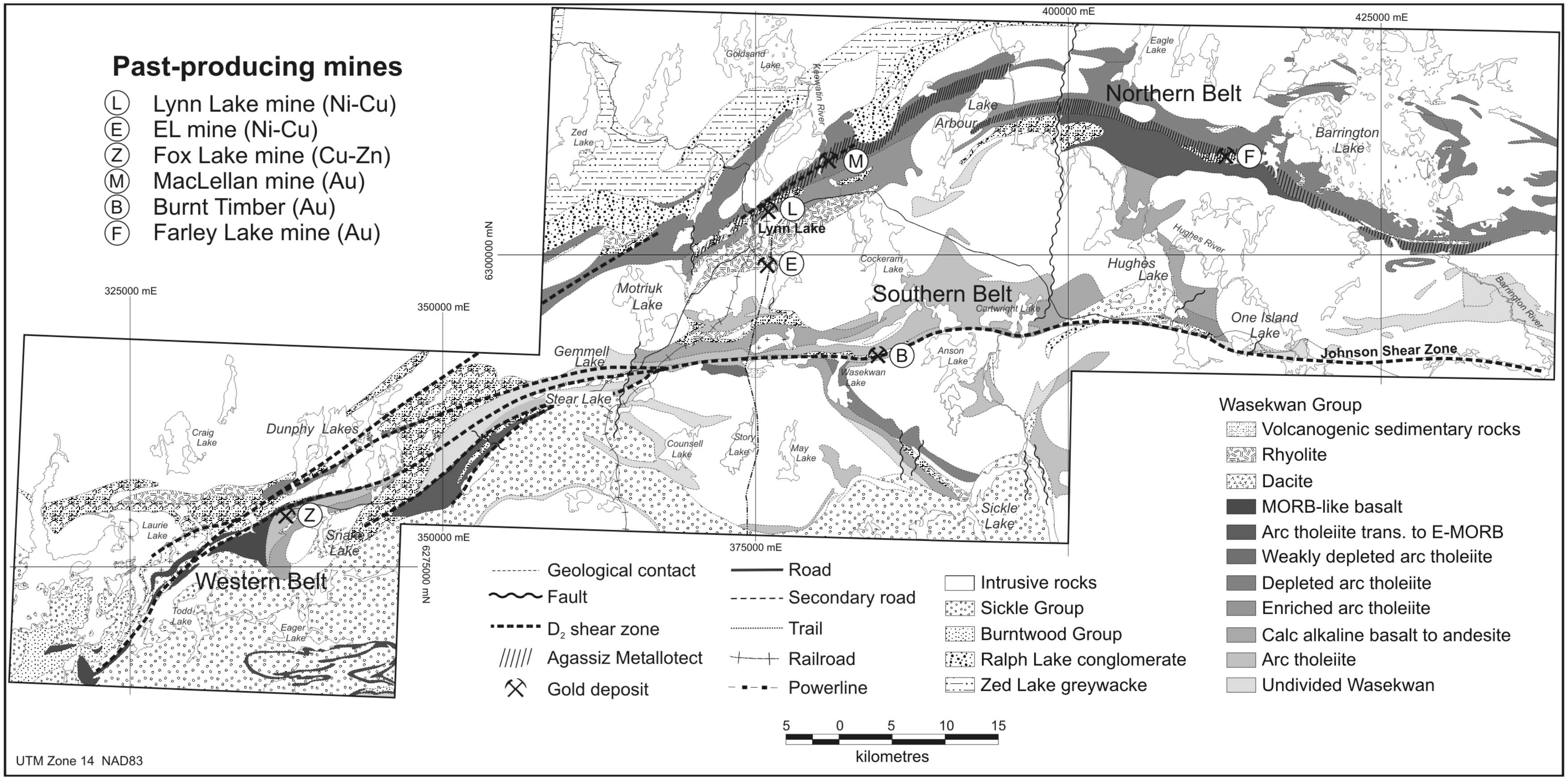

Figure GS-6-1: General geology of the Lynn Lake greenstone belt.

demonstrate the validity of this third subdivision of the Lynn Lake belt, previously suggested only by geochemical differences and structural analysis (Zwanzig, 2000) but now supported by Nd isotopic results.

The northern belt is separated from the southern and western belts by plutons of the Pool Lake suite. To the south, the southern belt is unconformably overlain and structurally underlain by Sickle Group (Norman, 1933) fluvial-alluvial conglomerate and arkosic sedimentary rocks. The Sickle Group also unconformably overlies the Pool Lake intrusive suite, and the Sickle Group basal conglomerate is characterized by a high proportion of Pool Lake–type plutonic clasts. The age of the Sickle Group has not been determined directly, but its composition, stratigraphic position and contact relations correlate well with the 1850 to 1840 Ma MacLennan Group in the La Ronge greenstone belt in Saskatchewan (Ansdell et al., 1999).

The Lynn Lake greenstone belt is intruded by several suites of successor-arc plutons. Two younger suites of plutons, which yielded ages of 1857 Ma (Machado, pers. comm., 2000) and 1832 Ma (Turek et al., 2000) to 1820 Ma (Beaumont-Smith and Böhm, 2002), do not have clearly defined contact relations, but emplacement into the Sickle Group is suggested locally. These magmatic ages are consistent with the subdivision of intrusive rocks into early, middle and late successor-arc plutons, as applied in the Flin Flon Belt (Whalen et al., 1999), and suggest a similarly complex magmatic evolution in the Lynn Lake greenstone belt.

Structural setting

The structural setting of the Lynn Lake greenstone belt involves six regionally penetrative, ductile deformation events (D_1–D_6; *see* Beaumont-Smith and Rogge, 1999; Beaumont-Smith et al., 2001; Beaumont-Smith and Böhm, 2002). Structural assembly of the main metavolcanic lithotectonic elements is the product of D_1. The age of this deformation is poorly constrained, but the tectonic juxtaposition of the metavolcanic rocks occurred prior to emplacement of the ca. 1870 Ma Pool Lake suite and deposition of the Sickle Group. Intense transposition of the early fabric elements and lithological components, which occurred by tight to isoclinal folding during D_2, has largely obscured the mesoscopic products of D_1.

The D_2 deformation produced a penetrative, S_2, differentiated regional foliation present in all rock types, and thus postdates intrusion of the youngest plutons and deposition of the Sickle Group. Horizontal F_2 folding (i.e., subvertical axial plane and horizontal axis) produced steep north dips of the stratigraphy. The plunge of F_2 folds is variable but appears to vary systematically as a function of D_2 strain. In areas of lower D_2 strain, the plunge of F_2 is generally shallow but increases with increasing D_2 strain. The shallow F_2 plunge in areas of lower D_2 strain suggests that D_1 produced a structural geometry characterized by shallow dips of the metavolcanic stratigraphy, which were steepened to subvertical as a result of tight to isoclinal F_2 folding. Accordingly, the structural geometry of the greenstone belt is largely the product of D_1-D_2 interference.

The steepening of F_2 plunge corresponds to development of D_2 shear zones throughout the greenstone belt. This reflects the evolution from fold-dominated deformation, during the early stages of D_2 shortening, to dextral shear-zone development during the later stages of the deformation. The most significant D_2 shear zones are the Johnson Shear Zone (Bateman, 1945), located along the southern margin of the southern greenstone belt, and a similar zone associated with the Agassiz Metallotect (Ma et al., 2000; Park et al, 2002), located in the northern belt. The Johnson Shear Zone (JSZ) is a dextral transpressive shear zone that has been delineated eastward to the Adams Lake area and westward to the Dunphy Lakes area (Beaumont-Smith et al., 2001, and references therein). The JSZ hosts the known gold deposits and occurrences in the southern belt. Similarly, D_2 shear was an important process in the development of the Agassiz Metallotect. Recognition of D_2 shear zones in both the northern and southern belts demonstrates the regional nature of the D_2 shear-zone development.

Deformations overprinting D_2 have had little macroscopic effect on the orientation of D_2 fabric elements or D_2 structural geometry. The D_3 and D_4 deformations are characterized by tight S- and Z-asymmetric chevron folds and associated crenulation cleavage, respectively. The D_3 fabrics trend northwest, whereas D_4 fabrics trend northeast. Although mesoscopic D_3 and D_4 fabric elements are regionally penetrative, these deformations have not significantly reoriented the regional D_2 structural trend. Exceptions to this are found in the Boiley Lake area, where the distribution of the Wasekwan Group south of the Johnson Shear Zone is controlled by a large, F_3, S-asymmetric fold (Anderson et al, 2001), and in the MacLellan mine area, where the Agassiz Metallotect is folded by a macroscopic, northeast-trending F_4 fold (Park et al., 2002)

The kilometre-scale open folds of the regional east-west D_2 structural trend are the result of D_5. Mesoscopic fabrics associated with this deformation include open F_5 conjugate folds, kink bands and open crenulations. A north-trending, spaced S_5 fracture cleavage is also common. These structures are penetrative at the regional scale but not the mesoscopic scale.

The final deformation (D_6) involves the brittle-ductile reactivation of D_2 shear zones, characterized by the development of pseudotachylite zones that overprint all other fabric elements. The reactivation is dominated by sinistral transcurrent movement within narrow zones in the D_2 shear zones. The T_1 fault in the footwall of the Burnt Timber gold deposit is a D_6 structure (*see* Peck et al., 1997, 1998).

Regional metamorphism

Metamorphic grade in the Lynn Lake belt increases westward across the belt from upper greenschist facies in the Hughes and Barrington lakes area to upper amphibolite facies in the Laurie Lake area. The relationship between deformational fabrics and metamorphic porphyroblasts indicates that regional metamorphic pattern is the product of at least two thermal events.

The oldest metamorphic event (M_1) reflects contact metamorphism associated with emplacement of the three suites of intrusive rocks, and the development of M_1 porphyroblasts is therefore closely tied to their associated plutons. The M_1 metamorphism represents multiple thermal events that postdate D_1. The M_1 porphyroblasts locally preserve internal foliations that predate the matrix S_2 foliation. Textural relationships indicate that S_2 matrix fabrics consistently overprint M_1 porphyroblasts. Similarly, locally developed M_1 calcsilicate zones are folded by F_2 folds, or are overprinted by or boudinaged parallel to S_2. This reflects the relatively closely spaced temporal distribution of the intrusive events vis-à-vis the timing of the respective deformations.

The regional metamorphic event (M_2) overprints M_1 porphyroblasts and is broadly coincident with D_3. The timing of M_2 does not correlate with any known magmatic event in the belt, and is characterized by the growth of low-pressure, moderate- to high-temperature assemblages.

Results from the 2003 field season

Fieldwork undertaken in the 2003 field season focused on extending the understanding of the structural and tectonic evolution gained from work in the southern Lynn Lake greenstone belt into the central portions of the northern belt. This involved detailed structural analysis of the western and central portions of the northern belt and, in particular, attempted to further delineate the Agassiz Metallotect west and east of the MacLellan mine area. Previous structural analysis in the MacLellan mine area showed that the deformational history is similar throughout the greenstone belt (see Ma et al., 2000, 2001; Park et al., 2002). The most significant finding of the previous work is that fold interference between D_1 and D_2 structures represents the primary control on the structural geometry (i.e., the 3-D distribution of geological units). A main objective of this summer's fieldwork was to better define the macroscopic enveloping surface, a key component to constraining the macroscopic structural geometry.

At mesoscopic scale, geological units and structures in the western and central portions of the northern belt strike generally southwest and dip steeply northwest. This attitude is largely the result of D_2 transposition and does not reflect the macroscopic geometry of the supracrustal rocks. As previously demonstrated, D_2 transposition is the product of tight to isoclinal, generally horizontal F_2 folds. West of the MacLellan mine, the distribution of marker units is best described as strike discontinuous. This is best demonstrated by a thin unit of volcaniclastic sedimentary rocks that extends west from the Minton Lake area to the Margaret and Sheila lakes area (Fig. GS-6-2). The D_2 structural elements observed in this marker unit are characterized by shallowly plunging, isoclinal F_2 folds; steeply dipping, bedding-parallel S_2 foliation; and local shear-zone development. Transposition of bedding (S_0) is apparent in well-exposed areas where individual beds can be followed sufficient distances to show that they are large-scale lenses (strike discontinuity). Further to this, younging directions in apparently well-bedded turbidites are either inconsistent or, more commonly, the younging direction is indeterminate. At macroscopic scale, the distribution of this sedimentary marker unit is discontinuous along geological strike. This feature and the abundant mesoscopic evidence of upright, horizontal, F_2 isoclinal folding suggest that the strike-parallel gap in this unit reflects the intersection of its enveloping surface with the erosion surface resulting from the periclinal nature of macroscopic F_2 folds. This sedimentary marker unit demonstrates the intensity of D_2 transposition at mesoscopic scale and the geometry of F_2 folds at macroscopic scale, which in turn are represented at mesoscopic scale. Unfortunately, although the distribution of this unit demonstrates that F_2 has a major control on the distribution of geological units, it does not provide sufficient information to infer the orientation of the macroscopic enveloping surface in this area.

Information regarding the geometry of the macroscopic enveloping surface was gained in an area southwest of Arbour Lake. Although the central portion of the northern belt is characterized by very poor exposure, the Arbour Lake

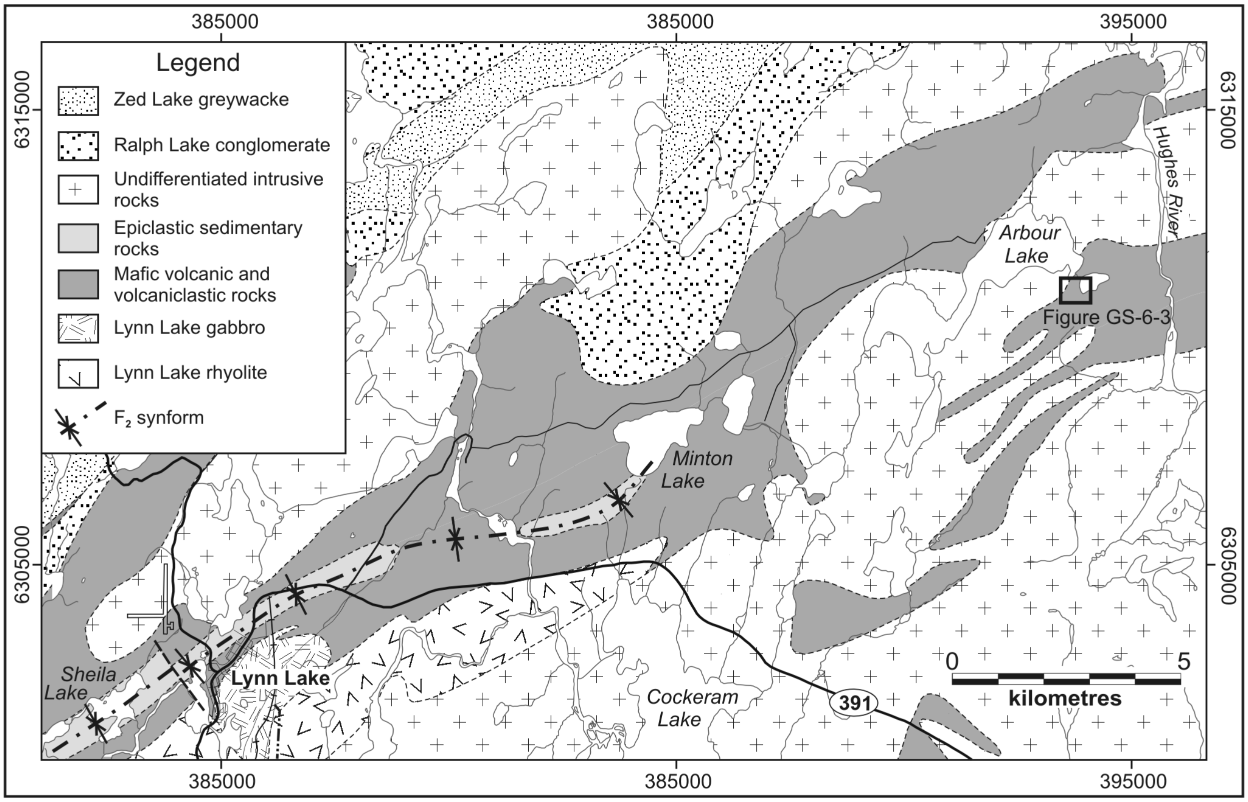

Figure GS-6-2: Geology of the western portion of the northern Lynn Lake greenstone belt.

area recently experienced a large forest fire and the level of exposure has slightly improved. Once again, this area is characterized by upright, tight to isoclinal, horizontal F_2 folds and associated layer-parallel S_2 foliation. The distribution of a thin picrite marker unit outlines a series of shallow-plunging F_2 folds (Fig. GS-6-3). Unlike the previous example, the enveloping surface associated with F_2 in the Arbour Lake area is oriented at a high angle to the regional strike of the greenstone belt, which is parallel to the F_2 axial planes (S_2). The large angular relationship between the enveloping surface and F_2 fold axes suggests that the macroscopic enveloping surface is subhorizontal. This is also supported by the location of the Agassiz Metallotect in this area, defined by the presence of picrite, which represents a second unit south of its eastward strike extension of the MacLellan mine unit along the north shore of Arbour Lake.

The effect of horizontal F_2 folding and the resultant transposition in the northern greenstone belt are very significant in terms of gold exploration. Gold mineralization in the northern belt is strongly controlled by the distribution of picrite. With very few exceptions, picrite units are very highly strained and D_2 shear-zone development is commonplace. This reflects the rheological properties of picrite and, accordingly, the localization of D_2 strain within the relatively weak (soft) picrite, resulting in shear-zone development (*see* Park et al., 2002). The F_2 fold repetition of picritic units and subsequent development of late-stage D_2 shear zones within these units could potentially result in the development of parallel mineralized zones. A D_2 fold model for the distribution of the Agassiz Metallotect in the eastern portion of the northern greenstone belt represents a relatively simple model consistent with the current state of understanding of the tectonic history of the Lynn Lake belt. This model also introduces additional exploration opportunities by highlighting exploration potential of strike-perpendicular repetitions of the Agassiz Metallotect at a variety of scales.

Isotope geology

The aim of continued Sm-Nd isotope and U-Pb geochronology studies in the Lynn Lake belt is to provide an improved understanding of the timing and nature of deformational, metamorphic and mineralizing events, particularly the development of gold-bearing shear zones.

In addition to previous sampling (Beaumont-Smith et al., 2001), 17 new samples of 15 to 30 kg of clean, relatively unaltered and homogeneous rock material were collected for Sm-Nd isotope and/or U-Pb geochronology studies during the 2002 field season. The sample distribution was designed to address the difficulty in adequately dating the

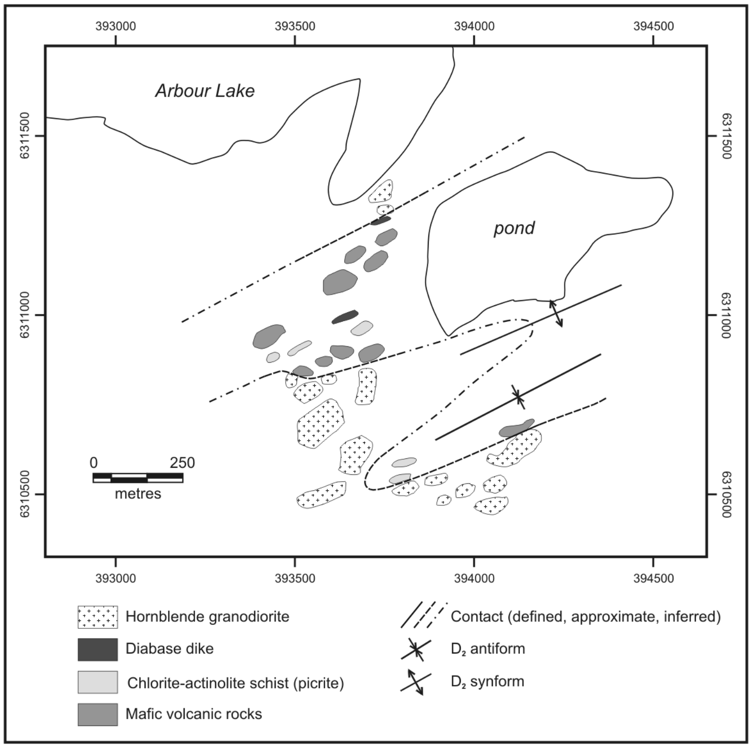

Figure GS-6-3: Map demonstrating F_2 fold repetition of a picrite unit south of Arbour Lake.

southern belt and testing the age and isotopic continuity of the northern and southern belts, with particular focus on geochemical changes in the western portion of the southern belt.

New Nd isotope and U-Pb age results

New U-Pb age results (Table GS-6-1) indicate a complex magmatic and tectonometamorphic history for the Lynn Lake belt lasting more than 100 m.y. Previous results (Beaumont-Smith et al., 2001; Beaumont-Smith and Böhm, 2002) suggested an age and isotopic boundary between the northern and southern belts, reflecting the accretion of an older, contaminated northern belt and a complexly assembled southern belt composed of (assumed) older and (dated) younger, juvenile volcanic rocks.

The results presented here indicate that the age and isotopic complexity of the southern belt is also present in the northern belt. A refined age of 1886 ±2 Ma for the central portion of the Lynn Lake rhyolite is only marginally younger than the 1892 ±3 Ma age of the geochemically and Nd isotopically similar eastern part of the Lynn Lake rhyolite (Beaumont-Smith and Böhm, 2002), suggesting a cogenetic formation of the central and eastern portions of the Lynn Lake rhyolite body. Both rhyolite samples are characterized by slightly negative initial εNd values of –0.2 to –0.3 and Nd model ages of ca. 2.5 Ga, implying a moderate degree of crustal contamination (Goldstein et al., 1984; *see also* explanations in Zwanzig and Böhm, 2002). Evidence for a complex assembly history of the northern belt comes from a quartz-phyric rhyolite north of Motriuk Lake that yielded an age of 1864 ±4 Ma and a strongly positive εNd value of 3.9 at the time of crystallization. This sample indicates that the northern belt represents a collage of older contaminated and younger juvenile volcanic rocks, similar to the southern belt.

In the western belt, supracrustal deposition is dated at 1891 ±2 Ma with dacitic volcanism at southeast Dunphy Lake. This is contemporaneous with rhyolitic volcanism in the northern belt at Lynn Lake (Beaumont-Smith and Böhm, 2002) and granodiorite emplacement in the Boiley Lake area, suggesting that this early intrusion is synvolcanic in nature. Neodymium isotopic composition of metavolcanic rocks from the western belt supports weak crustal contamination, with the Dunphy and Snake lakes dacites yielding initial εNd values of 1.3 and –1.6, respectively (Table GS-6-1).

The southern belt, in comparison, is dominated by Nd isotopic compositions indicating a juvenile environment (Beaumont-Smith and Böhm, 2002), supporting the subdivision of the western and southern belts. New data include a 1881 +3/–2 Ma calcalkaline dacite from east of Hughes Lake with a positive initial εNd value of +4 and a Nd model age of ca. 2.1 Ga, indicating very minor contamination by pre-1.9 Ga crust. The ca. 1881 Ma dacite from Hughes Lake

Table GS-6-1: Summary of new Nd isotope and U-Pb geochronology results, Lynn Lake greenstone belt.

Sample	UTM (Northing/Easting, NAD83, Zone 14)	T_{DM}, Nd (Ga)	εNd (Ma)	U-Pb age
Southeast Dunphy Lake dacite	345228 6281409	2.64	-2.3	
Southeast Snake Lake dacite	340675 6276557	2.57	-1.6	
Central Lynn Lake rhyolite	373750 6300048	2.49	-0.3	1886 ±2
Rhyolite (Central Lynn Lake Belt)	359571 6288812	N/A	0.4	
Southeast Dunphy Lake mylonitic dacite	344922 6281763	2.31	1.3	1891 ±2
Boiley Lake granodiorite	363989 6284202	N/A	4.9	1891 ±1
Boiley Lake rhyolite	363434 6283907	N/A	3.9	
Dacite from east of Hughes Lake	408745 6298862	2.12	3.8	1881 +3/-2
Rhyolite from north of Motriuk Lake	365383 6300995	2.09	3.9	1864 ±4
Northwest Gemmell Lake rhyodacite	362078 629023	2.06	4.5	1856 ±2
Northeast Dunphy Lake hornblende tonalite	344808 6287385	2.06	3.8	1847 ±2
One-Island Lake rhyodacite	415824 6292194	2.11	3.9	1843 +9/-6
East Dunphy Lake hornblende-biotite tonalite	344411 6285518	2.09	3.6	1829 ±2
Southwest Sickle Lake rhyodacite	391815 6280803	N/A	4.6	
North Sickle Lake dacite	396762 6285261	N/A	5.0	

is therefore the first dated volcanic sample that predates the ca. 1876 to 1871 Ma Pool Lake intrusive suite (Gilbert et al., 1980) in the southern belt. The Pool Lake intrusive suite that cuts across the main units in the area is postdated by the 1864 ±4 Ma quartz-phyric rhyolite north of Motriuk Lake, 1856 ±2 Ma rhyodacite at Gemmell Lake, and ca. 1843 Ma rhyodacite at One Island Lake. This younger generation of felsic to intermediate volcanic rocks is characterized by initial εNd values of approximately +4 and Nd model ages of ca. 2.1 Ga, suggesting a juvenile mantle origin.

The 1847 ±2 Ma age of a tonalite from northeast Dunphy Lake can be added to multiple periods of felsic plutonism at ca. 1876, 1871, 1857 and 1831 Ma that have been previously dated in the Lynn Lake belt (Baldwin et al., 1987; Turek et al., 2000; Machado, pers. comm., 2000). A new sample from a syn-D_2 tonalite dike that intrudes folded 'Wasekwan' metasedimentary rocks at east Dunphy Lake yielded a zircon age of 1829 ±1.5 Ma, and is therefore likely related to the ca. 1831 Ma Fox mine tonalite (Turek et al., 2000).

To further constrain the timing of deformational events and the related emplacement of gold mineralization, U-Pb dating of sphene has been applied to a syenite dike in the eastern Lynn Lake belt. The dike cuts 1818.6 +1.2/–1.4 Ma, syn-D_2 granodiorite and yielded a sphene age of 1766 ±15 Ma, similar to the 1758 ±8 Ma age of syn-D_4 tonalite dikes from the southwest Lynn Lake belt (Beaumont-Smith and Böhm, 2002).

Discussion

New U-Pb geochronological and Nd isotopic data indicate that the tectonic assembly of the Lynn Lake greenstone belt was complex and involved supracrustal rocks deposited in a variety of tectonic settings. The emerging tectonic history, based on detailed structural analysis and isotopic studies, involved the accretion of at least two arc systems to the southern margin of the Hearne Craton. The three geochemically and isotopically distinct belts constituting the Lynn Lake greenstone belt represent a supracrustal collage, the belts demonstrating considerable internal complexity, with both contaminated and juvenile environments represented.

This internal complexity appears to be the product of the D_1 deformation that assembled the supracrustal collage. Although D_1 is overprinted by intense D_2 folding and resultant transposition, the horizontal geometry of F_2 folding and the shallow-dipping D_2 enveloping surface suggest that the bulk of the internal greenstone-belt complexity predates D_2 and is probably the result of D_1 thrusting. This style of D_1 deformation produced a shallow-dipping enveloping surface that was preserved through subsequent D_2 transposition. Also supporting this interpretation is the lack of significant complexity between the metavolcanic rocks and their related volcaniclastic (greenstone) and younger supracrustal rocks, which would be expected if D_2 played a mayor role in the assembly of the greenstone belt.

Economic considerations

One of the major findings of the structural analysis and gold metallogenic studies in the Lynn Lake greenstone belt is the critical role D_2 played in the development of gold mineralization (*see* Beaumont-Smith and Rogge, 1999;

Beaumont-Smith and Böhm, 2002, and references therein). The distribution of geological units is primarily controlled by D_2 throughout the greenstone belt. The macroscopic enveloping surface appears to be a shallow (subhorizontal) surface, although mesoscopic structures are steeply dipping. The bulk of the gold mineralization in the Lynn Lake belt is shear hosted, associated with the development of steeply dipping D_2 shear zones during the late stages of D_2 transposition. Many of the currently delineated D_2 shear zones exploit rheological boundaries. This is demonstrated in the southern belt by the Johnson Shear Zone, which is the result of the localization of regional D_2 deformation along the supracrustal-intrusive boundary of the southern belt (Beaumont-Smith and Rogge, 1999). In the northern belt, D_2 shear-zone development reflects the localization of D_2 strain into picrite units within the Agassiz Metallotect. Accordingly, the recognition of F_2 fold repetition of the Agassiz Metallotect in the Arbour Lake area has a major impact on gold exploration in the northern belt, which may explain the lack of success in delineating the strike extensions of the Agassiz Metallotect.

The development of D_2 shear zones during the late stages of D_2 has the effect of creating steeply dipping zones of secondary porosity, which cut through the greenstone belt. From a regional perspective, the Lynn Lake greenstone belt is located in the hangingwall of a major D_2 collision zone, which has thrust the Lynn Lake greenstone belt and successor-arc plutonic rocks over Kisseynew Basin metasedimentary rocks (*see* White at al., 2000). This geometry, in concert with the development, prior to the peak of regional metamorphism, of major D_2 shear zones that represent conduits for metamorphic fluids derived from the underthrusted sedimentary rocks, represents a very favourable crustal architecture for the development of mesothermal, shear-hosted gold mineralization within the Lynn Lake greenstone belt.

Conclusions

The Lynn Lake greenstone belt is the product of a complex tectonic history involving the accretion of a minimum of two island-arc systems to the southern margin of the Archean Hearne Craton. The island arcs include an older (ca. 1892–1886 Ma), moderately contaminated arc and a younger (ca. 1857–1846 Ma), dominantly juvenile arc. Subsequent intense D_2 transposition of the assembled arc supracrustal rocks and successor-arc plutonic rocks at ca. 1815 Ma produced the present east-west, steeply dipping attitude of the greenstone belt. Importantly, the regional enveloping surface remained subhorizontal during D_2, reflecting an upright, shallow-plunging F_2 fold geometry. This results in the F_2 fold repetition of geological units, an important consideration for gold exploration due to the development of late-stage D_2 shear zones within rheologically favourable units and the shear-hosted nature of gold mineralization in the greenstone belt.

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