Geology of the Meadowbank Iron Formation-Hosted Gold Deposit

Sherlock, R.L.[1]; Alexander, R.B.[2]; March, R.[2]; and Kellner, J.[2]
1. Canada-Nunavut Geoscience Office, Iqaluit, Nunavut.; 2. Cumberland Resources Ltd., Vancouver, B.C.

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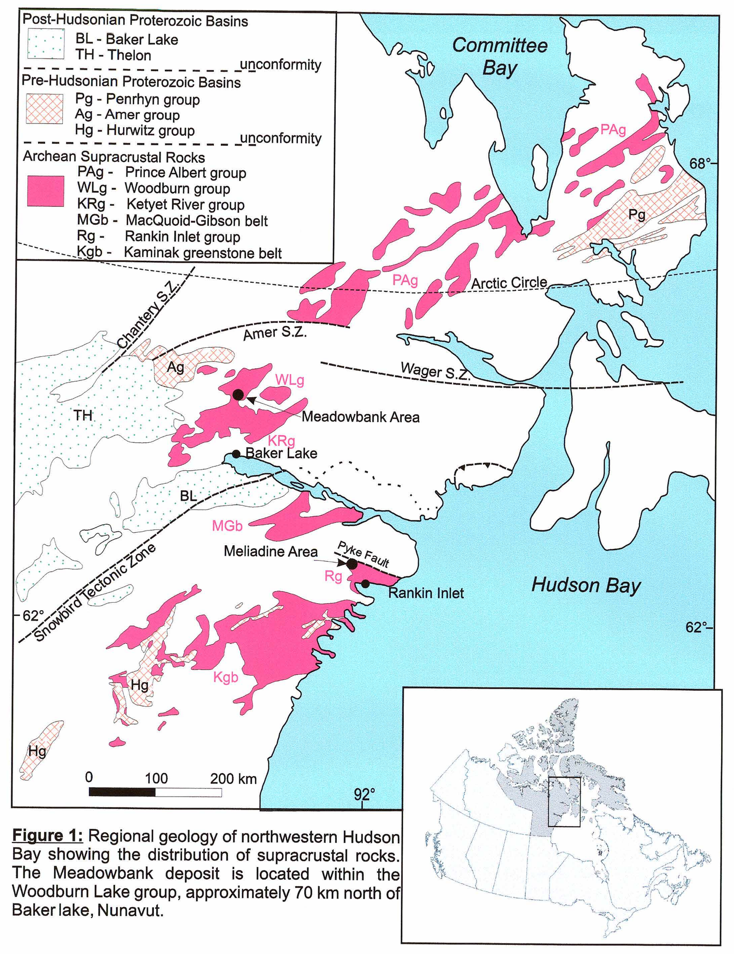

Figure 1: Regional geology of northwestern Hudson Bay showing the distribution of supracrustal rocks. The Meadowbank deposit is located within the Woodburn Lake group, approximately 70 km north of Baker lake, Nunavut.

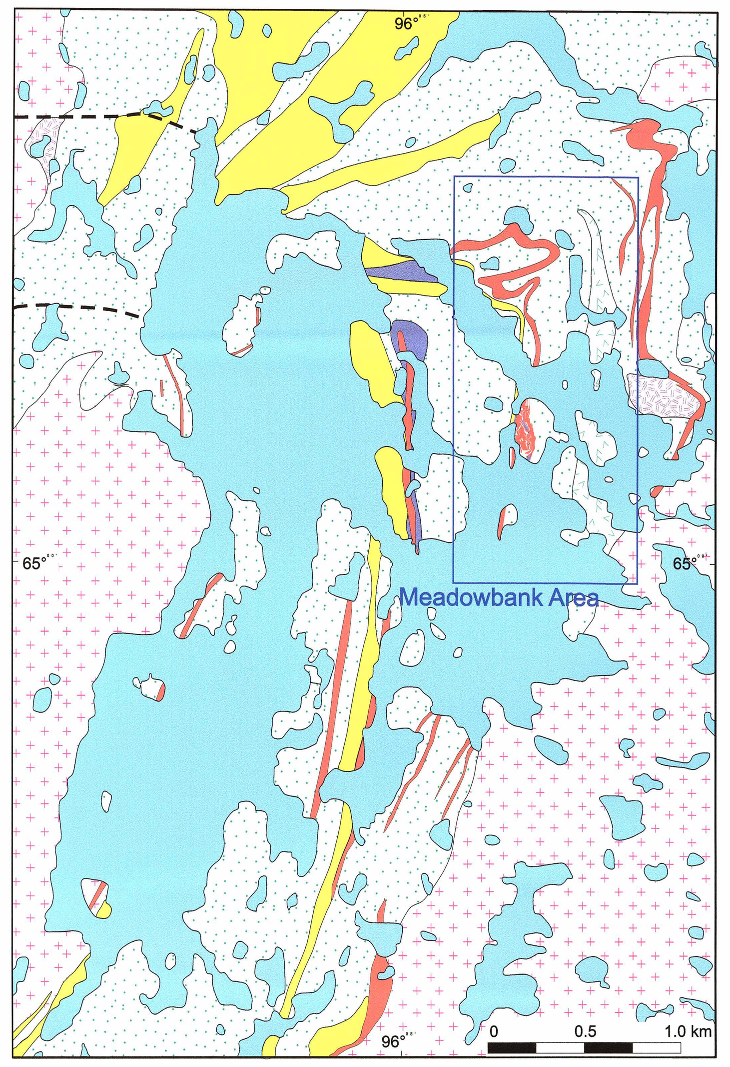

Figure 2: Simplified geological map of the Woodburn Lake group in the Meadowbank area, modified from Henderson and Henderson (1994) and Zaleski et al. (1997a; 1999a)

Common Legend

- Granitoid rocks (2.60-2.62 Ga), massive to weakly foliated
- Gabbro, massive plagioclase-amphibole intrusive
- Quartzite, quartz-pebble (oligomictic) conglomerate
- Ultramafic schist; talc-amphibolite, locally spinifex-textured
- Banded iron formation, magnetite-quartz-amphibole ± pyrrhoitite, pyrite and gold
- Intermediate-felsic volcaniclastic rocks; dacitic-rhyodacitic in composition, locally showing well- defined bedforms and blue quartz phenocrysts (2.72-2.71 Ga)
- Intermediate-felsic volcanic rock; dacite-rhyodacite in composition, massive unit likely flow or shallow intrusions, locally abundant blue quartz phenocrysts
- 45 Apparent dip of S_1/S_0 composite fabric, extrapolated from drill sections
- 60 S_1/S_0 composite fabric, dipping & vertical
- 28 F_1/F_2 fold axis
- 33 S_4 fabric,
- 39 F_4 fold axis

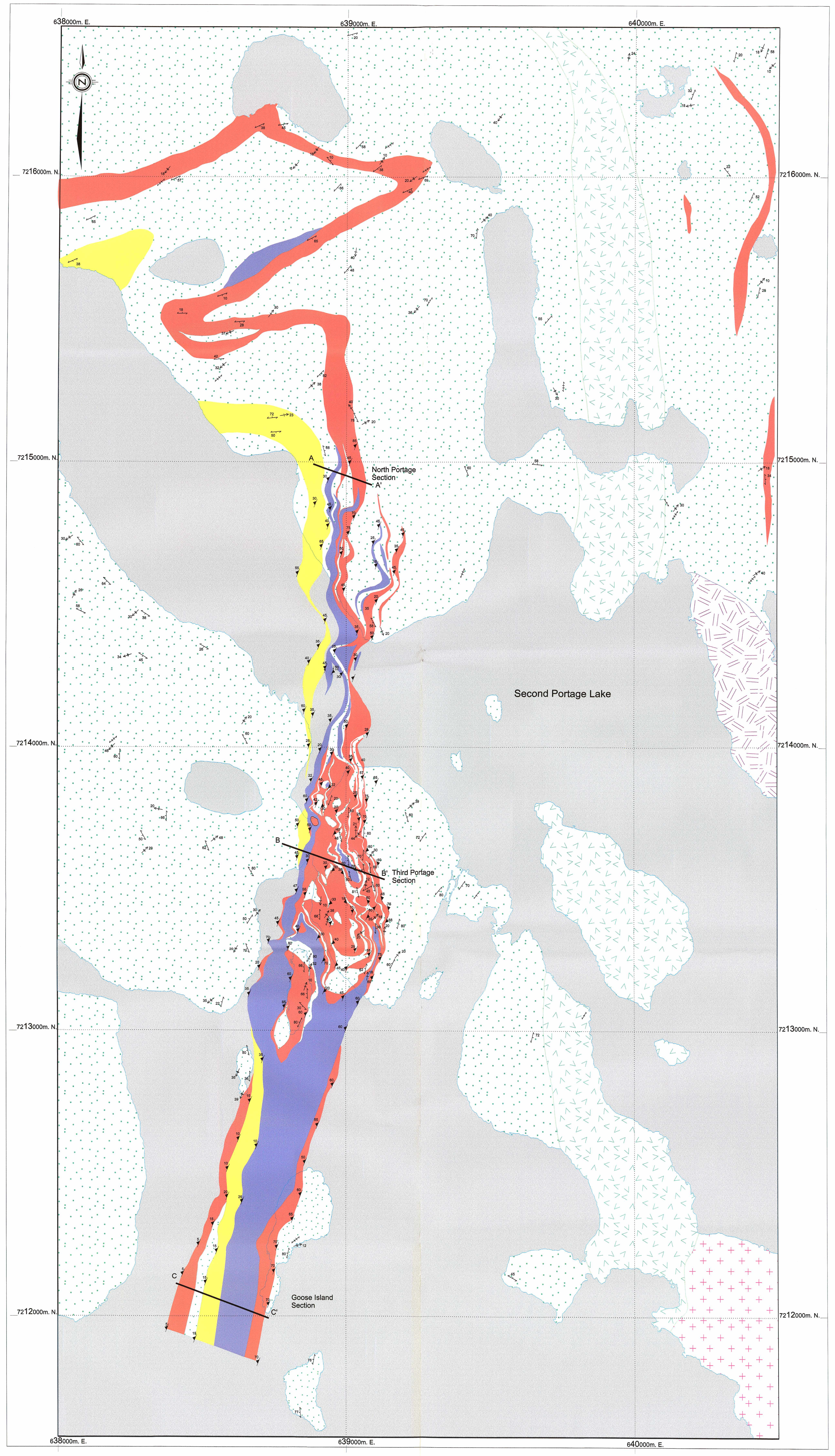

Figure 3: Detailed geology of the Meadowbank gold deposits, at 1:7,500 scale.

Figure 4. Geology of the Third Portage area showing the axial trace of the two fold sets

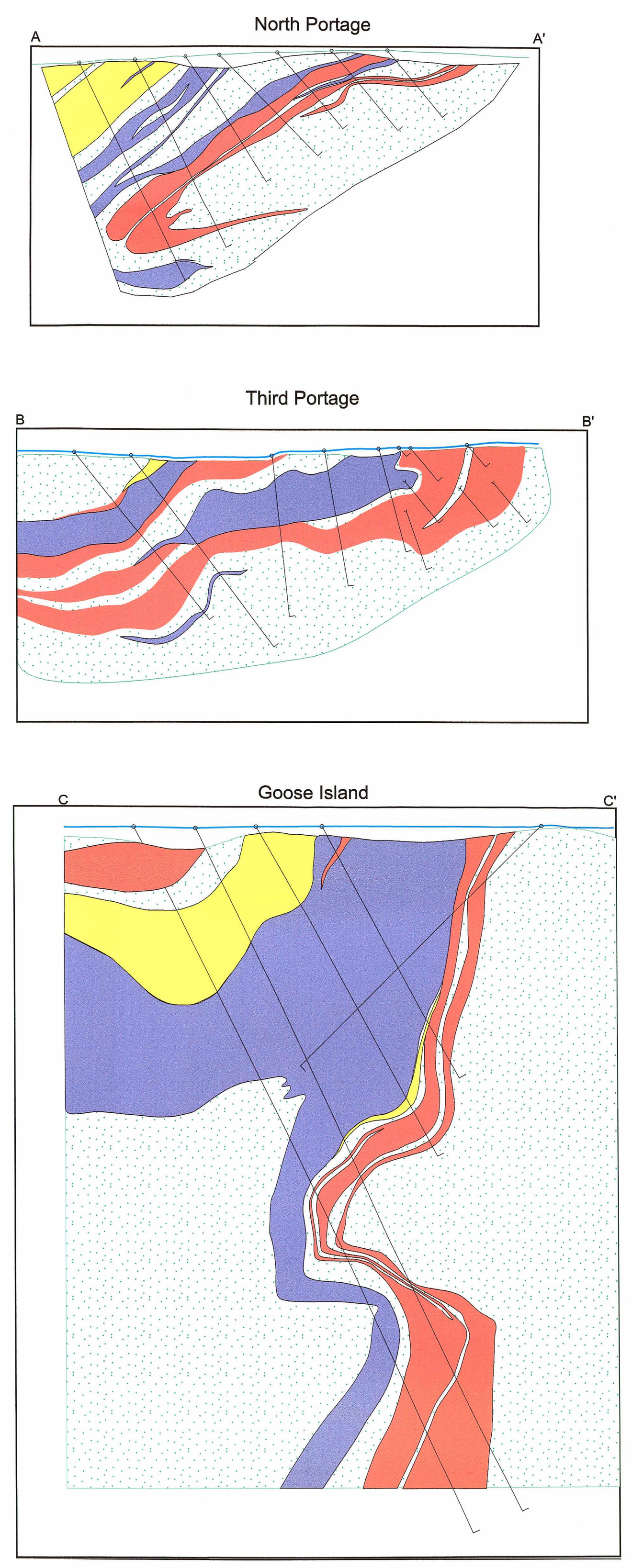

Figure 5. Cross sections through the Meadowbank gold deposits. A-A' is through the North Portage deposit; B-B' is a section through the Third Portage deposit; and C-C' is through the Goose Island deposit. In all three areas gold mineralization is best developed in high strain zones localized at or near the structural footwall of the ultramafic rocks within the iron formation-felsic volcaniclastic sequence.

INTRODUCTION

The geology of northwest Hudson Bay consists of Archean and Proterozoic supracrustal sequences and plutonic rocks (Figures 1 & 2). The Archean supracrustal sequences (e.g. Woodburn Lake and Prince Albert groups) are intruded by (ca. 2.60 Ga) orogenic granites, which are in turn unconformably overlain by pre-Hudsonian Proterozoic basins (e.g. Amer and Hurwitz groups). Post-Hudsonian basins (e.g. Baker Lake and Thelon Basins) unconformably overly both sequences forming an overlap assemblage (Hoffman, 1990). The Woodburn Lake group, which hosts the Meadowbank gold deposits, is Archean in age, but has been overprinted by the Paleoproterozoic Hudsonian orogeny (Henderson et al., 1991), the significance of which with respect to gold metallogeny is uncertain.

The Meadowbank area (Sherlock et al., 2001; Figures 2 & 3) has been the focus of exploration activities since its discovery by Asamera Minerals Inc. in 1987 (Armitage et al., 1996). Most of the work in recent times (1995-1999) has focused on definition of the Third Portage, North Portage, Goose Island and the Bay Zone deposits, collectively referred to as the Meadowbank deposits. Gold at the Meadowbank deposits is hosted by complexly deformed iron formations and felsic-intermediate volcaniclastic rocks. Currently a classified resource of about 2 million ounces of gold has been defined (Cumberland Resources Inc. Press Release, March 29, 2000).

This map (Figure 3) was produced through a combination of surface mapping, trench mapping and extrapolation of geology, as interpreted from drill sections, to the surface.

LITHOLOGIES

The Woodburn Lake group (Figures 2 & 3) includes quartzite and oligomictic conglomerate, ultramafic to mafic volcanic rocks, felsic to intermediate volcanic rocks and derived sediments with interbedded iron formation (Henderson et al., 1991; Zaleski et al., 1997b; 1999b; Sherlock et al., 2001). Several phases of deformation have affected the stratigraphy with four events recognized regionally (Pehrsson et al., 2000) two of which have affected the geometry of the Meadowbank gold deposits.

Felsic-Intermediate Volcanic Rocks (IV)

The felsic to intermediate volcanic rock package is the dominant lithology recognized in the Meadowbank area. Its age ranges from 2.72 to 2.71 Ga (Davis and Zaleski, 1998; Zaleski et al., 2000). Two subtypes are recognized:

- Massive felsic flows to subvolcanic intrusives (Figure 3) are recognized to the east, in the structural footwall of the mineralized intervals at Third Portage. This unit is blue quartz and plagioclase feldspar phyric with a groundmass of fine-grained quartz and biotite.
- Bedded volcaniclastic rocks (Figure 3) comprise the bulk of the map area. Bedforms range from 1 cm to 3 m thick and rarely show unambiguous internal sedimentary structures, such as graded beds. The beds are well sorted and homogenous in composition but are not graded, suggesting mass flow emplacement. Alternatively these may represent agglomerated volcaniclastic beds. Beds are composed mainly of quartz and feldspar grains, which display a granular clastic texture, along with an assemblage of epidote-biotite-chlorite-muscovite. Locally blue quartz and plagioclase feldspar phenocrysts are recognized, similar to the massive units.

Iron Formation

Intervals of iron formation comprising an assemblage of magnetite, quartz and amphibole (grunerite/cummingtonite) are interlayered with the felsic-intermediate volcaniclastic rocks. Several iron formations have been identified, including the East BIF, Central and West BIF (Figures 2 & 3). Of these only the Central BIF is auriferous. In areas of low strain, beds within the iron formation are typically 0.2 to 10 cm thick and consist of alternating monomineralic layers of magnetite, quartz ± amphibole. To the south, near Goose Island, garnet and biotite are developed in the iron formation, suggesting higher metamorphic grades. Locally where auriferous, magnetite has been replaced by pyrrhotite and lesser pyrite.

Quartzite

Massive to bedded and foliated quartzite are exposed (Figures 2 & 3) in the western portion of the Meadowbank area in the structural hangingwall of the immediate deposit stratigraphy. The bedded material has centimeter-scale bed forms defined by selvages of muscovite. The foliated quartzite lacks bedforms and has correspondingly more muscovite, defining the foliations.

At the base of the quartzite, oligomictic conglomerates have been intersected in drill core. These units range from less than 1 to over 10 meters in thickness. Local graded bedding provides younging directions, indicating that the quartzites are unconformably overlying the ultramafic schists. The conglomerates are dominated by quartzite fragments but also contain dark grey siliceous and fuchsite-rich fragments.

Ultramafic Rocks

The ultramafic rocks comprise a massive sequence of talc-amphibolite-chlorite with textural variations in the size and color of the amphiboles. This unit does not crop out in the immediate Meadowbank area but is commonly intersected in drill core. Only rarely are primary features such as spinifex textures preserved. Massively crystalline amphibole-rich rocks, with minor talc, are common near the footwall contact of the ultramafic package. Locally, within the ultramafic sequence, mafic volcanic intervals have been identified.

Intrusive Rocks

The supracrustal rocks at Meadowbank are bracketed to the east and west by large biotite-bearing granitoid bodies (Figure 2). These rocks range in age from 2621± 2 to 2599 ± 5 Ma (Ashton, 1988) and are dated at 2612 ± 4 (Roddick et al., 1992) in the immediate Meadowbank area. These intrusives locally preserve the dominant S_1 fabric described below. Locally, quartz and feldspar phyric dykes are intersected in drill core between the Third and North Portage deposits. These bodies are discontinuous, having been rotated into the transposition fabric, and locally contain Cu-Au mineralization (Sherlock et al., 2001). Narrow undeformed lamprophyre dykes are also recognized in drill core.

METAMORPHISM

The metamorphic assemblages at Meadowbank are characterized by chlorite-muscovite-biotite-calcite in the volcanosedimentary strata; interpreted to reflect regional greenschist facies metamorphic conditions. The iron formations are characterized by an assemblage of quartz-amphibole-magnetite ± sulphides. To the south, at Goose Island, the iron formations are characterized by a quartz-amphibole-biotite-garnet mineral assemblage. This suggests a transition from greenschist, at Third Portage, to lower amphibolite metamorphic assemblages at Goose Island with the garnet isograd transecting Third Portage and Goose Island deposits.

STRUCTURE

The volcanosedimentary sequence at the Meadowbank area is polydeformed with four events recognized regionally (Pehrsson et al., 2000) two of which have significantly affected the geometry of the mineralized bodies. We have adopted the deformation nomenclature of Pehrsson et al. (2000).

A composite transposition fabric (S_0/S_1) is the principal fabric observed in the Meadowbank area. The degree of transposition observed indicates that compositional layering preserved throughout the area should not be considered primary. The earliest event recognized D_1 (D_1/D_2 in the terminology of Pehrsson et al., 2000) is considered here as a progressive event with refolding or buckling of the transposition fabric, generating tight to isoclinal folds (F_1/F_2) which exhibit moderately west dipping enveloping surfaces in the Third Portage area (Sherlock et al. 2001). The axial trace of these early folds is shown in Figure 4. The culmination of the progressive deformation event involves the development of penetrative planar fabrics and local high strain zones. These high strain zones, often exploit lithologic contacts where rheologic contrasts have focused strain gradients into the volcanosedimentary rocks. These fabrics are commonly spatially related to gold mineralization. In the North Portage, Third Portage and Goose Island sections (Figure 5) the strata are folded about a NE verging antiform-synform pairs. The higher strain zones are often localized along fold limbs at the ultramafic-volcanosedimentary contacts due to contrasts in the mechanical properties of the strata. Grunerite porphyroblasts are commonly deformed by these high strain zones.

D_4 deforms and refolds earlier deformation fabrics. F_4 geometries are typically open to close, angular to subrounded and often "S" shaped in the Meadowbank area. Axial surfaces are upright, NE-SW trending and doubly plunging and locally controlled by the orientation of the earlier fabrics. The axial trace of F_4 is shown in Figure 4. Fold interference patterns are common resulting from the superposition of upright F_4 folds on tight and inclined F_2 folds. A spaced to penetrative axial planar cleavage (S_4) is locally well developed and overprints earlier fabrics as well as crenulating amphibole rosettes. Significantly D_4 folds and deforms mineralized envelopes, suggesting that it is a post-mineralization event.

MINERALIZATION

Gold is contained within sulphide-bearing iron formation (Armitage et al., 1996; Kerswill et al., 1998; Kerswill, 2000; Sherlock et al., 2001), characterized by disseminated to semimassive pyrrhotite-pyrite which preferentially replaces magnetite (Armitage et al., 1996). Gold is also contained within felsic-intermediate volcanic package as disseminated pyrrhotite and pyrite along with narrow blue-grey quartz-sulphide veins. Gold mineralization often shows a strong spatial relationship to high strain zones described above.

Armitage et al. (1996), based on whole rock and mineral chemistry, has shown that auriferous iron formations are characterized by a mineral assemblage of cummingtonite and biotite with pyrrhotite-pyrite-magnetite and quartz. Barren, but sulphidic, iron formations are characterized by an assemblage of grunerite ± hornblende + stilpnomelane with pyrrhotite, pyrite, quartz and magnetite. Whereas barren, nonsulphide-bearing, iron formations are characterized by quartz and magnetite. Based on these mineral assemblages and their relationship to gold mineralization, Armitage et al. (1996) have suggested that mineralization is related to syn-deformation metasomatic fluids that have altered the iron formation with the introduction of Mg-K-Ca-S-As-Cu and Au. Based on the fabric relations recognized gold, and associated sulphides, were introduced into dilation sites during progressive D_1-D_2 deformation (Sherlock et al. 2001). The mechanical contrast between the ultramafic and volcaniclastic rocks partitioned strain which allowed fluid influx and the resulting alteration assemblages to be concentrated in the higher strain corridor adjacent to the ultramafic rocks. The progressive nature of deformation event resulted in the various relationships between sulphide minerals and deformation fabrics.

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