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GEOLOGICAL SURVEY OF CANADA | COMMISSION GÉOLOGIQUE DU CANADA

## DESCRIPTIVE NOTES

### INTRODUCTION

Since its discovery, the genesis of the Hemlo gold deposit, site of the largest producing gold mines in Canada, has been the subject of debate. The deposit is hosted by a heterolithic conglomerate unit (Agw) interpreted by Muir (1983), Cameron and Hattori, 1985; Goldie, 1985), the shear zone model (e.g. Hugon, 1986), the porphyry models (e.g. Kuhns et al., 1994; Johnston, 1995), and the intern model (Pan and Fleet, 1990). As part of a project to better understand the Archean geology of the Hemlo area, funded jointly by the Canadian Mining Industry Research Organization (CAMIRO), the Hemlo deposit area was mapped (Muir, 1993). Because of the mines were examined in detail. Major efforts were also made to compile the vast amount of data collected by the mine geologists, especially drill cores, level plans, and sections.

The area has been mapped in detail by several previous workers (Burk (1983) for the Teck-Corona property; A. Goldie (1985) for Golden Giant; Muir (1983) for Williams; Kuhns et al. (1994) for David Bell; Muir (1983) for Moose Lake; Muir, 1987) for most of the area). These previous maps served as a good guide for the present mapping and are partly incorporated in the present map, especially in areas where outcrops are no longer available or accessible. These maps, however, were commonly at a scale of 1:1 000 or 1:2 000 and were not designed to show the regional geology or stratigraphic significance. In contrast, the present mapping is a combination of lithological and formational mapping; rocks are assigned to different units based on both lithological associations and stratigraphic positions. As a result, a number of units are mapped, and the camp-wide geometry established in such a way is very helpful for the large-scale structural interpretation.

### GEOLOGICAL SETTING

The Hemlo gold deposit is hosted in the Heron Bay–Hemlo greenstone belt (Fig. 1) of the Wawa Subprovince of the Superior Province. The belt consists of a thick succession of mafic to felsic metavolcanic rocks, metasedimentary rocks, intermediate, and mafic–ultramafic rocks of 2732 Ma or older to ca. 2696 Ma (ages based on Corfu and Muir (1989a) and Davis (1988)). They are intruded by granodiorite–tonalite plutons of ca. 2719–2678 Ma (Corfu and Muir, 1989a).

The Hemlo area is part of the northern belt of metavolcanic rocks (Goldie, 1980). The metavolcanic rocks increase from upper greenschist facies in the western part of the belt to middle amphibolite facies in the eastern part of the belt (including the Hemlo deposit area) (Muir, 1982a, b; Kuhns et al., 1994; Jackson, 1990). Based on the work of Kuhns, Corfu and Muir (1989b) concluded that regional amphibolite-facies metamorphism occurred at ca. 2678–2676 Ma.

In the area around the Hemlo gold deposit, the supracrustal rocks include mafic and felsic metavolcanic rocks and metasedimentary rocks, which are intruded by the Pukaswka intrusive complex (2696 ± 2 Ma; Corfu and Muir, 1989a) and 2684–2688 Ma (Davis, 1988). They are intruded by the Cedar Lake pluton (ca. 2688 Ma) and the Cedar Creek stock (ca. 2684 Ma; ages from Corfu and Muir (1989a)).

The area has undergone polyphase deformation. Deformation is most intense in the Hemlo (Golden) shear zone (Fig. 2). Located spatially in and near the southern edge of the shear zone is the Hemlo (Lindsley) fault, which is probably a result of reactivation of the Hemlo shear zone.

The geometry of the Hemlo (Golden) Hemlo shear zone is different from that in the shear zone and north of it. They are described separately below and in the legend and no correlation is attempted between the two areas. To the south of the shear zone, contacts between major lithological units are mostly ductilely sheared or brittley faulted. As a result, the map pattern is dominated by mesoscopic F folds that are generally open with a locally developed axial-planar cleavage. The legend do not imply any stratigraphic sequence. In and north of the shear zone, although deformation is also strong and the rocks are ductilely folded, the stratigraphy has not been significantly disrupted and can be established, and description of units 6b to 6us below and in the legend are in stratigraphic order.

### SUPRACRUSTAL ROCKS SOUTH OF THE HEMLO SHEAR ZONE

**Amphibolite gneiss, amphibolite (unit Aag)**

Rocks of this unit occur in a number of areas part of the map area, at and close to the northern margin of the Pukaswa intrusive complex (unit Apic). The rocks are at least partly supracrustal in origin because they enclose, and have a gradational contact with, thin layers of amphibole-rich metawacke (unit Aaw below and in the legend). Strong gneissosity is commonly developed in the amphibolite.

The rocks are mostly gneissic. The gneissosity is defined by variations in amphibole-biotite-rich and by thin layers rich in epidote. Near the northern margin of the Pukaswa complex, the rocks contain abundant layer-parallel granitic veins and sills (Fig. 3). The granitic sheets are most likely derived by the Pukaswa complex. If this is correct, the age of the northern margin of the Pukaswa complex (ca. 2713 Ma; Corfu and Muir, 1989a) would be the minimum age of the mafic rocks.

**Amphibole-rich metawacke (unit Aaw)**

The unit is characterized by its metawacke in the Hemlo area in that it contains 10–30% amphibole (hornblende). In many places, it has a distinctively defined by variations in abundance of amphibole. Locally preserved bedding indicates a sedimentary origin.

**Felsic schist (unit Afs)**

The unit is characterized by its felsic composition and light colour. It mainly consists of feldspar and quartz with very little mafic material. A sample from this unit (DO96-44) has been dated by U-Pb method. The age of the youngest zircon dated, and thus the maximum age of the unit, is 2688 ± 2 Ma (Davis, 1996).

**Metaconglomerate (unit Amcg)**

Rocks of this unit occur in a single layer. It consists of pebble- to boulder-sized clasts in a wacke matrix. The composition of both the clasts and the matrix vary laterally. The clasts are felsic to intermediate in the west and felsic, intermediate, and mafic in the east. The matrix is commonly amphibole-rich in the east and biotite-rich in the west and intermediate- to rich mafic-wacke in the east. It is well bedded in the west and poorly bedded in the east.

The rock is generally strongly deformed. In the east, extremely flattened clasts give the rock a gneissic appearance. Locally, the rock is only moderately deformed and the primary fragmental features are clear.

**Metapelite and metagreywacke (unit Amp)**

This unit consists of pelagicolites biotite ± quartz ± garnet ± staurolite ± kyanite. Garnet is commonly present. Staurolite and kyanite are localized in more pelitic layers. Bedding, including graded bedding, is preserved in many localities, especially in the west where metagreywacke is the dominant lithology.

### SUPRACRUSTAL ROCKS IN AND NORTH OF THE HEMLO SHEAR ZONE

**Basalt (amphibolite, unit Ab)**

Amphibolite is exposed mostly in three areas: at the Golden Giant mine tailings pond, around Botham Lake, and along the Hemlo fault. Relict pillow structures are well preserved locally in all the three areas, indicating that the amphibolite is mainly metavolcanic. The contacts between the amphibolite and other units are sheared where exposed.

**Lower greywacke (unit Agwl)**

The lower greywacke unit (Agwl) is heterolithic. It is generally well bedded and contains well developed graded bedding. Individual beds grade from wacke to siltstone, and locally from wacke or siltstone to mudstone. Detrital chromite from a greywacke sample (DO96-45) yield ages that cluster at ca. 2691 Ma and ca. 2697 Ma (Davis, 1996). The former serves as the maximum age of the unit.

**Reworked volcaniclastic rocks, and calc-silicate band-rich wacke (units Av and Acw)**

These two units are stratigraphic equivalents. The reworked volcaniclastic rocks (unit Av) occur in the west. They are heterolithic and contain clasts of felsic to intermediate volcanic rocks, chert, and iron formation. The rocks are generally not well bedded. They have a gradational relationship with the Moose Lake porphyry (unit Alap) described below and to the legend. In contrast to the porphyry, they contain no or very few quartz "eyes" (Muir, 1982). A sample from this unit (DO96-39) yields zircon ages of 2699 ± 2 Ma (Davis, 1996), which serves as the maximum age of the unit.

The reworked volcaniclastic rocks grade into banded wacke (unit Acw) in the east. The latter contains abundant calc-silicate bands. A vast majority of the calc-silicate bands are regular and concordant to bedding. They have been interpreted to be metamorphosed marly beds in sedimentary protolith (Burk et al., 1985; cf. Pan and Fleet, 1990). Locally, however, the calc-silicate bands are irregular and discordant to bedding. They are thought to be associated with alteration. A sample of the wacke (DO96-57) yields zircon ages of 2693.2 ± 1.1 Ma (Davis, 1996).

**Moose Lake porphyry (unit Alap)**

The Moose Lake porphyry is felsic and consists of abundant quartz (± feldspar) phenocrysts in a fine-grained matrix. The rock is commonly massive and homogeneous. Locally, it is weakly foliated and contains abundant mafic inclusions, and commonly have gradational contacts. Laterally, the unit grades from massive and fragmental to fragmental only porphyry. On weathered surfaces, the "massive" porphyry may appear heterogeneous and a primary layering is commonly present. The rock is similar to the "quartz porphyry" described by Muir (1982) in the Moose Lake area. The calc-silicate band-rich wacke (unit Acw), and on the other side by the upper greywacke (unit Agwu described below and in the legend). These observations are most consistent with a volcanic origin for the porphyry (see also Muir, 1982b, Burk et al., 1985; Kuhns et al., 1994; Johnston, 1995). Samples from this unit (DO96-40, DO96-41, DO96-42, DO96-43) yield porphyry have been dated by the U-Pb method (samples DO96-38, DO96-41, DO96-42). Their ages range from ca. 2694 to ca. 2816 Ma (Davis, 1996). Therefore, ca. 2694 Ma is interpreted as the maximum age of the porphyry.

**Upper greywacke (unit Agwu)**

The upper greywacke unit occupies the two limbs of the folded Moose Lake porphyry to the east of Moose Lake. It is heterolithic and moderately to well bedded. It mainly consists of feldspar + biotite ± garnet ± quartz. On fresh surfaces (especially underground), the rock appears dark coloured and massive; however, on weathered surfaces, bedding, including graded bedding, is commonly present. Locally, the unit contains abundant magnetite and is thus rich in sedimentary in origin (cf. Johnston, 1995). The rock generally contains magnetite. At the stratigraphic base of the unit, near its contact with the underlying Moose Lake porphyry, it contains abundant magnetite bands and locally oxide-facies iron formation. Most detrital zircons from a sample of this unit (DO96-56) yield ages that cluster at ca. 2697 Ma (Davis, 1996), which serves as the maximum age of the unit. One dated zircon has an older age of ca. 2713 Ma.

**Heterolithic conglomerate and greywacke (unit Agg)**

The unit consists of conglomerate interlayered with feldspathic greywacke. The conglomerate consists of pebble- to boulder- (mostly cobble-) sized clasts in a greywacke matrix. It is matrix to clast supported. The clasts are mainly intermediate to felsic in composition (mainly feldspar porphyry). Some mafic schist clasts are also present. The unit is interpreted to overlie the Moose Lake porphyry (unit Alap) and upper greywacke (unit Agwu), and locally contains clasts identical to the Moose Lake porphyry.

**Cummingtonite schist (unit Aas)**

Overlying the heterolithic conglomerate is a cummingtonite schist. It consists of cummingtonite, plagioclase, biotite, and minor garnet and hornblende. Locally, cummingtonite is present as porphyroblasts. Muir (1982) and Burk et al. (1985) Mg-rich cummingtonite schist has been interpreted as a metamorphosed Fe-Mg-ocs/bonate unit rich in clastic impurities (Burk et al., 1985).

### LITHOLOGIES CLOSELY ASSOCIATED WITH THE ORE ZONES

The Hemlo gold deposit is located within the broad Hemlo shear zone. The vast majority of the ore occurs in two zones in the segment of the shear zone that strikes east-southeast, referred to as the north and lower ore zones (Fig. 3). They are spatially associated with the two limbs of the folded contact between the Moose Lake porphyry (unit Alap) and the Hemlo conglomerate (unit Agg). Ore is also present in the segment of the shear zone that strikes northeast. Additional, but much less significant, ore lenses occur in the east-trending segment of the shear zone (e.g. the North zone and the Williams "C" zone), immediately adjacent to the east-southeast-trending segment (Fig. 2).

**Ore lithology (unit Amin)**

Both the north and lower ore zones at Hemlo consist of feldspathic ore, sericitic ore, and several minor types of ore. Each is described briefly below.

The feldspathic ore is a massive to banded to fragmental rock that consists of microcline (40–55%, locally up to 90%), quartz (10–40%), muscovite, green (vanadium-rich) mica, and minor biotite (Kuhns, 1986). It normally contains 5–30% pyrite and molybdenite. The feldspathic ore is typically high grade.

The sericitic ore is a massive to banded rock that consists of quartz, muscovite (15–30%, locally up to 60%), feldspar, biotite, and green mica (Kuhns, 1986). It contains up to 10% pyrite and traces of molybdenite. Typically, the sericitic ore is not as high grade as the feldspathic ore.

The third ore lithology is present in both the north and lower ore zones and forms part of the barite ore. It is banded and has isotope signatures similar to sedimentary barite exposed west of Hemlo and is thus interpreted to be sedimentary in origin (Cameron and Hattori, 1985).

**"Mafic fragmental" (unit Amf)**

The "mafic fragmental" is commonly associated with the ore is the so-called "mafic fragmental." It occurs at the contact between the Moose Lake porphyry (unit Alap) and the calc-silicate band-rich wacke to the north (unit Acw), and consists of felsic fragments in a biotite-rich matrix. It is interpreted to be altered felsic fragmental rocks similar to those in unit Av.

### INTRUSIVE ROCKS

**Pukaswa intrusive complex (unit Apic)**

The Pukaswa intrusive complex is an extensive unit and only a small portion of it occurs in the map area. It consists of several phases of granodiorite, tonalite, and quartz diorite (Muir, 1982b, 1993) of significantly different ages, intruded by a variety of dikes (Muir, 1982b, 1993; Corfu and Muir, 1989a). Most of the rocks are massive, although some are developed foliation and lineation (gneissic). Rocks in the inner part of the complex are only weakly foliated to massive. A sample of clearly foliated and lineated granodiorite near the northern margin of the complex (C-86-10) yielded an U-Pb zircon age of 2715 ± 1 Ma, and a sample of weakly foliated granodiorite away from the northern margin (C-86-11) was dated at 2696 ± 2 Ma (Corfu and Muir, 1989a).

**Cedar Lake pluton (part of unit Agd)**

The Cedar Lake pluton is exposed partly in the eastern part of the map area. It consists of several phases of granodiorite with variable biotite-hornblende ratios, as well as pegmatite and aplite dykes (Muir, 1993). The pluton is weakly foliated to massive. Samples from the inner part and the western margin of the pluton (C-87-44 for the latter; the former is out of the map area) yielded U-Pb zircon ages of 2688 ± 3 Ma and 2687 ± 3 Ma, respectively (Corfu and Muir, 1989a).

**Cedar Creek stock (part of unit Agd)**

The Cedar Creek stock is a small intrusion exposed in the northern part of the map area. It has a composition similar to, and has generally been interpreted as a satellite intrusion to, the Cedar Lake pluton (e.g. Muir, 1993; Kuhns et al., 1994). The stock has yielded an U-Pb zircon age of 2684 ± 4/-3 Ma (sample C-87-42; Corfu and Muir, 1989a), slightly younger than the Cedar Lake pluton. The stock is weakly foliated to massive. Its contact with the host volcanic rocks is sharp. Evidence that the stock contains more magnetite and is thus much more magnetic (as shown on aeromagnetic maps).

**Dykes**

Abundant dykes are present in the Hemlo area. Their compositions, described in detail by Muir (1983), range from felsic to mafic. Quartz porphyry dykes, with coarse-grained quartz phenocrysts and light- to medium-grey groundmass, or still (unit Amd) to the north of Moose Lake, folded by the Williams property fold, as mapped by A. Guthrie (unpub. maps, Lac Minerals Exploration Limited, 1994) and Muir (1983).

Mafic dykes are commonly fine grained, dark coloured, and rich on the surface and underground. They range from less than 10 cm to about 20 m wide. They cut the ore and alteration zones and are generally undeformed. They consist of two major groups, dark-grey porphyry dykes with coarse-grained feldspar phenocrysts and light- to medium-grey dykes with fine-grained feldspar phenocrysts (Muir, 1983). The former are commonly more voluminous than the latter. A sample of the latter (C-87-1), collected from underground in the David Bell mine, has yielded an U-Pb zircon age of 2677 ± 1 Ma (Davis, 1996).

Muir (1983) suggested that these dykes (unit Pd) cut the Archean structural trend in the area. Most of them strike approximately northerly and are part of the Matachewan dykes of ca. 2121 Ma (Buchan et al., 1996). One major dyke strikes northwesterly and is probably part of the Matachewan dyke swarm of 2473–2446 Ma (age from Heaman (1995)).

### STRUCTURE

Based on styles and overprinting relationships, four generations (S- to D-) of ductile structures, as well as brittle faults, are recognized in the Hemlo area (Muir, 1982a, b, 1983). The structures are described briefly by Muir (1983), Kuhns et al. (1987), Structures of the area have also been described by Hugon (1986), Muir (1983), Kuhns et al., (1994), and Mcmillan(eem(1996).

**Deformation of the ore body**

Detailed underground work shows that the orebody is affected by D, and later generations of deformation. Both D, and D, structures are widespread in the ore. Both the feldspathic and sericitic ore have generally well developed S fabrication. The fabrication is defined by white mica and by compositional layering (Fig. 3–5).

Underground mapping in the north ore zone (Kuhns et al., 1994; Muir, 1983; Muir, 1984) has shown that the main ore zone is folded by F, at the orebody scale. The orebody is thickened by the folds and as much as four times thicker than the adjacent unmineralized rocks. The variation in thickness of the orebody at Hemlo is mainly due to folding. The folds are also strongly noncylindrical.

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The map was compiled mainly based on the author's mapping in the summers of 1995–1996. Previous maps (A. Guthrie, unpub. maps, Lac Minerals Exploration Limited, 1994; Burk, 1987; Muir, 1993) served as a good guide for the present mapping and are partly incorporated in the present map, especially in areas where outcrops are no longer available or accessible. Particularly, the geology of the Williams deposit is based on A. Guthrie (unpub. maps, Lac Minerals Exploration Limited, 1994) and Muir (1983) and A. Guthrie (unpub. maps, Lac Minerals Exploration Limited, 1994).

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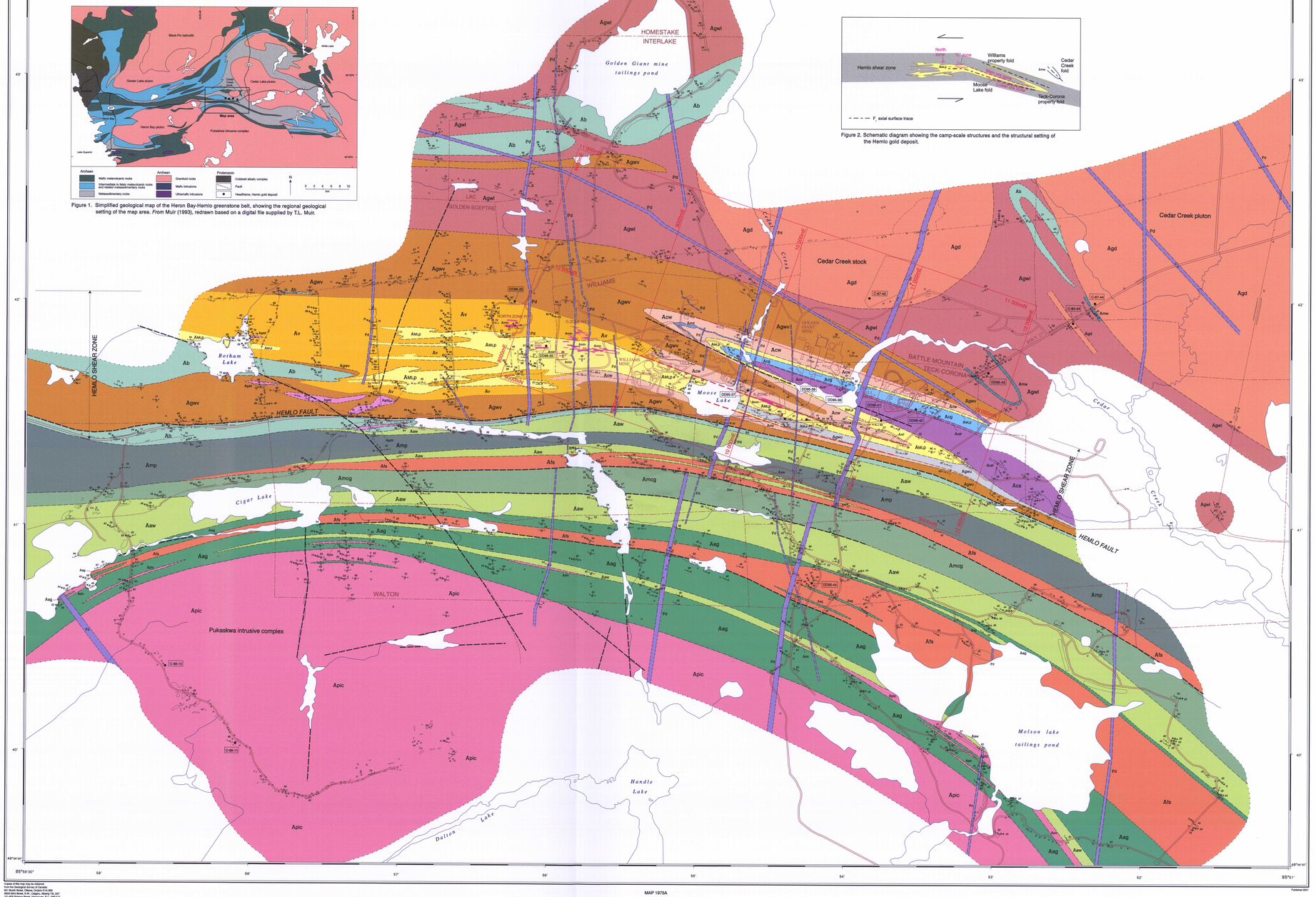
Figure 1. Simplified geological map of the Hemlo greenstone belt, showing the regional geological setting of the map area. *From* Muir (1993), redrawn based on a digital file supplied by T.L. Muir.




Figure 2. Schematic diagram showing the camp-scale structures and the structural setting of the Hemlo gold deposit.




## LEGEND

**PROTEROZOIC**

Pd — *Diabase dykes*

**ARCHEAN**

**INTRUSIVE ROCKS**

*(Order of units has no stratigraphic significance)*

Agdd — *Feldspar-porphyry dykes and small intrusions, granodioritic in composition*

Amd — *Mafic dykes or sills*

Agd — *Felsic plutons: biotite-hornblende granodiorite*

Apic — *Pukaslwa intrusive complex; hornablende-biotite granodiorite, tonalite, and quartz diorite; strongly foliated near its northern contact*

**SUPRACRUSTAL ROCKS IN AND NORTH OF THE HEMLO SHEAR ZONE**

*(Order of units has stratigraphic significance)*

Acs — *Cummingtonite schist, with local felsic schist (unit Acst)*

Acg — *Heterolithic conglomerate and greywacke. The conglomerate consists of mainly feldspar porphyry and some mafic schist clasts in a greywacke matrix. Unconformable on units Agwu and Aaa.p.*

Agwu — *Upper greywacke: greywacke generally containing magnetite. Magnetite bands (locally iron-formations) are abundant near its contact with the Moose Lake porphyry (unit AMLp).*

AMLp — *Moose Lake porphyry:quartz ± feldspar porphyry, fragmental-massive, containing abundant quartz ± feldspar phenocrysts; sericitized and/or feldspathized near the ore zones*

Acw — *Calc-silicate band-rich wacke: feldspathic siltstone to wacke with abundant calc-silicate bands, sericitized and well banded near the ore zones. Stratigraphic equivalent of and in gradational contact with unit Av*

Av — *Reworked volcaniclastic rocks: felsic-intermediate volcaniclastic rocks, mostly reworked, locally fragmental, containing no or very few quartz "eyes"; generally not well bedded*

Agwv — *Unit Agwl interlayered with Av*

Agwl — *Lower greywacke (Agwl): biotite ± amphibole metawacke, metasiltstone, commonly with graded-bedding. Locally rich in biotite and hornblende (mafic wacke, unit Amv)*

Ab — *Basalt (amphibolite): metamorphosed mafic volcanic rocks, amphibolite; relict pillow structures are commonly preserved; containing diabase dykes*

**SUPRACRUSTAL ROCKS SOUTH OF THE HEMLO SHEAR ZONE**

*(Order of units has no stratigraphic significance)*

Amp — *Metapelite and metagreywacke: biotite-garnet±staurolite±kyanite schist*

Amcg — *Metaconglomerate with felsic-intermediate-mafic clasts and feldspathic wacke or mafic wacke as matrix*

Afs — *Felsic schist: light-coloured quartz-feldspar schist, poorly bedded*

Aaw — *Amphibole-rich metawacke: biotite-amphibole feldspathic wacke, variable biotite/amphibole ratio*

Aag — *Amphibolite gneiss, amphibolite: metamorphosed mafic volcanic rocks, amphibolite; greatest near the Pukaswa intrusive (unit Apic)*

**ROCKS ASSOCIATED WITH THE ORE ZONES**

Amin — *Surface gold mineralization; updip projection of ore zones*

Amf — *Mafic fragmental,' consisting of felsic clasts in a biotite-rich matrix, interpreted to be altered felsic fragmental of unit Av. Mostly mineralized to subore grade*

U-Pb geochronology sample location and number of Davis (1988) . . . . . DO96-41

U-Pb geochronology sample location and number of Corfu and Muir (1989a) . . . . . C-86-44

Lithological contact (approximate, inferred) . . . . . .

Gradational lithological contact (approximate, inferred) . . . . . .

Limit of mapping . . . . . .

Outcrop, area of continuous/discontinuous outcrop visited . . . . . .

Bedding (top unknown, known, overturned) . . . . . .

Fold axial plane ($F_1$, $F_2$, $F_3$) . . . . . .

$F_2$ fold hinge ("Z", "S", "U" fold) . . . . . .

$F_3$ fold hinge ("Z" fold) . . . . . .

$F_4$ fold hinge ("Z" fold) . . . . . .

Fold hinge (generation unknown "U" fold) . . . . . .

Fold hinge (asymmetry unknown) ($F_1$, $F_2$, $F_3$, $F_4$, generation unknown) . . . . . .

Foliation ($S_1$, $S_2$, $S_3$) . . . . . .

Mineral/stretching lineation ($L_1$, $L_2$, generation unknown) . . . . . .

Shear bands (dextral) . . . . . .

Brittle fault (approximate) . . . . . .

Mine grid with location co-ordinate . . . . . 11 000 m N

Property boundary and name . . . . . HOMESTAKE

Railway . . . . . .

Power line . . . . . .

Highway, road, trail . . . . . .

Building . . . . . .

*Geology compiled by S.Lin based on mapping in 1995-96 and additional information from T. L. Muir (1993), A. Guthrie (unpub. maps, 1994) and R.R. Burk (1987)*

*Digitized by S. Lin and M. Hudon*

*Digital cartography by R.L. Allard, Earth Sciences Sector Information Division (ESS Inlo)*

*Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada*

*Digital base map from Ontario Base Map (1:20k). Maps from the mines for the mine area and modification based on air photos*

*Mean magnetic declination 2001, 6° 18'E, increasing 3.2' annually*

Published 2001

MAP 1975A

GEOLOGY

# THE HEMLO GOLD CAMP

ONTARIO

Scale 1:10 000/Echelle 1/10 000

metres 250 0 250 500 750 1000 metres

Universal Transverse Mercator Projection
North American Datum 1927
©Her Majesty the Queen in Right of Canada, 2001

Projection transverse universelle de Mercator
Système de référence géodésique nord-américain, 1927
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Selected levels and sections accompany this map

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1975A 1972