Preliminary geology north of Mount Mye, Anvil District (105K/6, 105K/7), central Yukon

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ABSTRACT

The northeast Anvil area, 15 km north of Mount Mye (NTS 105K/6, 105K/7), is underlain by a conformable Cambrian-Devonian volcanic and sedimentary package with an aggregate thickness of greater than 1600 m. The lowest unit, with an exposed thickness of 120 m, consists of calcareous phyllites of the Cambrian-Ordovician Vangorda formation. Conformably overlying the phyllites is a ≥ 900-m-thick Ordovician-Silurian sequence of submarine basalt flows and volcaniclastic sedimentary rocks of the Menzie Creek formation. Volcaniclastic sediments are dominantly coarse, proximal, fragmental breccias with lesser conglomerates, sandstones, and siltstones. Carbonaceous shales with lesser siltstones, limestones, dolostones, and quartzites of the Ordovician-Devonian Road River Group (≥ 450 m) are intercalated with and overlying the basalt flows.

The east margin of the map area is a depositional edge of basalt volcanism with only scattered thin flows occurring further to the east. This depositional edge is considered to be a north-trending, west-side-down, Ordovician-Silurian syndepositional, normal fault forming the east margin of a sedimentary sub-basin infilled with volcanic rocks. Hornfelsing on the east margin of the map area indicates a large, shallowly buried, northwest extension of the mid-Cretaceous Orchay Batholith.

RÉSUMÉ

La partie nord-est de la région d'Anvil, à 15 km au nord du mont Mye (SNRC 105K/6, 105K/7), est sous-tendue par un ensemble de roches volcaniques et sédimentaires conformes d'âge Cambrien à Dévonien, dont l'épaisseur totale dépasse 1 600 m. L'unité inférieure, d'une épaisseur apparente de 120 m, consiste des phyllades calcaires de la Formation de Vangorda, d'âge Cambrien à Ordovicien. Ces phyllades sont recouvertes par une séquence conforme, de plus de 900 m d'épaisseur, de coulées de basalte sous-marines et de roches sédimentaires volcanoclastiques de la Formation de Menzie Creek, d'âge Ordovicien à Silurien. Les roches sédimentaires volcanoclastiques sont surtout des brèches grossières à blocs, de faciès proximal, avec une quantité moindre de conglomérats, de grès et de siltstones. Des shales carbonés contenant des petites quantités de siltstones, de roches calcaires, de dolomies et de quartzites du Groupe de Road River (plus de 450 m), d'âge Ordovicien à Dévonien, sont à la fois intercalés et susjacents aux coulées de basalte.

La bordure orientale de la région cartographiée constitue une limite dépositionnelle du volcanisme basaltique et il n'y a que de minces coulées éparses plus à l'est. Cette limite dépositionnelle est interprétée comme étant une faille normale syndépositionnelle d'âge Ordovicien à Silurien, orientée vers le nord, et dont le bloc ouest s'est affaissé. Cette faille définie la limite orientale d'un sous-bassin sédimentaire rempli de roches volcaniques. Des indices de métamorphisme de contact à la bordure orientale de la région cartographiée indiquent la présence, à faible profondeur, d'une extension volumineuse du batholite d'Orchay, d'âge Crétacé moyen.

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INTRODUCTION

The Anvil District (Figs. 1, 2), in central Yukon, contains the only lead-zinc mines developed in the Selwyn Basin, a major lead-zinc provenance in western Canada. The District contains five known pyritic massive sulphide deposits with a total pre-mining mineral inventory of 120.1 million tonnes averaging 9.3% combined lead and zinc (Jennings and Jilson, 1986). Exploration potential for additional massive sulphide deposits within Anvil District remains high.

The Yukon Geology Program initiated an integrated multi-disciplinary geoscience study in 1998 to provide a unified geology framework for the area to assist future exploration. Projects within this integrated study included bedrock geology mapping and compilation (Pigage, 1999a, b, c, d, this report), surficial geology mapping and basal till sampling (Bond, 1999a, b, c, d, e, f; Lipovsky and Bond, 1999), and detailed lithogeochemistry of the immediate host rocks to the massive sulphide deposits. The goal of the bedrock mapping and geological compilation project within the District is to harmonize the property geology mapping completed by exploration companies with the regional geology mapping completed by the Geological Survey of Canada. Bedrock geology will be presented on a series of 1:25 000 scale maps.

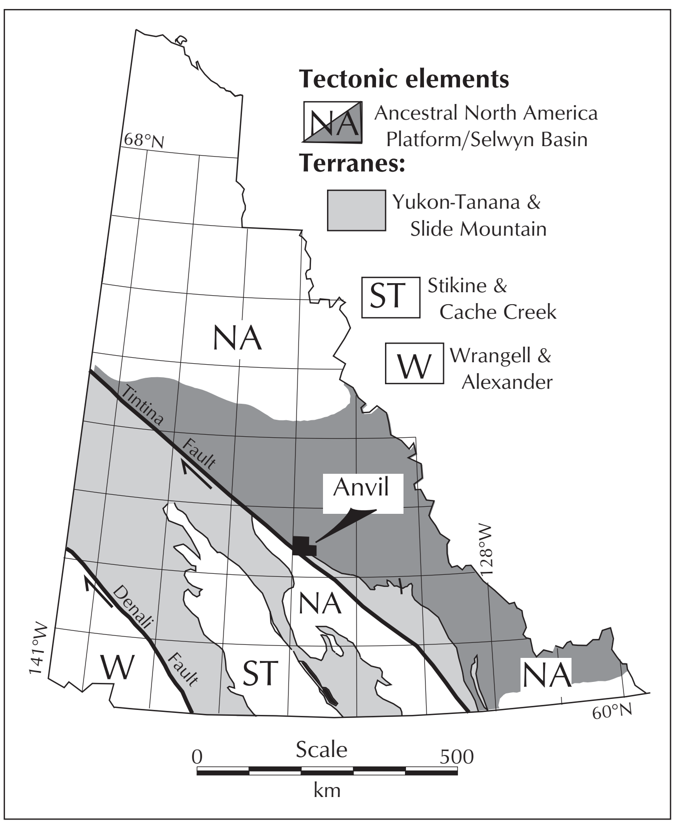

Figure 1. *Location of Anvil District in Yukon. Terrane assemblages modified from Wheeler and McFeely (1987).*

Three weeks of bedrock geology mapping was completed (Fig. 2) during the 1998 and 1999 field seasons in the northeast Anvil area, north of the Anvil Batholith. This report summarizes the bedrock geology encountered in the map area. All descriptions are based on hand sample and outcrop descriptions. Petrographic work is ongoing.

LOCATION AND ACCESS

Anvil District is located immediately northeast of the town of Faro, which is situated in Tintina Trench, a major northwest-trending physiographic feature. The northeast Anvil map area is situated 30 km northeast of the town of Faro and 15 km north of Mount Mye in NTS map sheets 105K/6 and 105K/7. Elevations in the area range from 4300 feet above sea level (a.s.l.) (1310 m) to 6600 feet a.s.l. (2010 m). Tree line occurs at the approximate elevation of 4500 feet a.s.l. (1370 m). Much of the area is above tree line, with broad, open U-shaped, grass-covered valleys separating steep ridges. Outcrop is extensive on ridge crests, especially on north-facing slopes. Within the broad valleys, outcrop is generally restricted to stream cuts. Valley bottoms are typically covered with thin to thick glacial till and glacial outwash sediments.

Partly overgrown exploration roads passable by ATV vehicles provide limited access to the southwest edge of the northeast Anvil area. These roads head north from the Faro mine road near the freshwater reservoir. Access to the area is most readily accomplished by helicopter. During 1998 and 1999, camps were placed using contract helicopter services based in Ross River.

PREVIOUS WORK

Regional geology for Tay River map area (105K) was completed at 1:253 440 scale by Roddick and Green (1961), and at 1:250 000 scale by Gordey and Irwin (1987). Tempelman-Kluit (1972) and Gordey (1990a, b) completed more detailed geology studies at scales of 1:125 000 and 1:50 000, respectively, in response to the interest generated by the discovery of the massive sulphide deposits in the Anvil District.

Exploration efforts in the northeast Anvil area were centred over the metasedimentary and metavolcanic rocks on the northeast flank of the Anvil Batholith (Fig. 2). Most exploration activity in the area occurred from the mid-1960s through the late-1970s. Jennings and Jilson (1986) provide an exploration overview of the geology in relation to the Anvil massive sulphide deposits. The only mineralized showing encountered to date is the KD prospect located just west of the northeast Anvil area. The KD prospect (Yukon Minfile, 1997, 105K083) consists of semi-massive to stockwork pyritic sulphide mineralization within metavolcanic rocks and has been classified as volcanogenic-massive-sulphide-type mineralization.

REGIONAL GEOLOGY

Anvil District represents the most westerly offshelf facies of the Cordilleran miogeocline, a prism of sedimentary rocks of Precambrian to Jurassic age deposited along the relatively stable continental margin of western North America. Cordilleran miogeocline stratigraphy is presented in Abbott et al. (1986). More detailed discussion of the stratigraphy and structure of the Anvil District is given in Jennings and Jilson (1986).

Anvil District (Fig. 1) is immediately east of the Yukon-Tanana Terrane (Coney, et al., 1980), the easternmost of the accreted 'suspect' terranes. The Yukon-Tanana Terrane is juxtaposed against Anvil District along the Vangorda fault (Jennings and Jilson, 1986) which Mortensen and Jilson (1985) have interpreted as a transpressive suture. Deformation and metamorphism associated with accretion of the suspect terranes was initiated during the Jurassic and culminated in the Cretaceous period (Tempelman-Kluit, 1979). More recently, strike-slip faulting along the Tintina Fault zone resulted in approximately 450 km of right-lateral strike-slip displacement during Late Cretaceous-Early Tertiary time (Tempelman-Kluit, 1970).

Tempelman-Kluit (1972) mapped a sedimentary and volcanic sequence ranging in age from Cambrian through Permian in the northeast Anvil area. A prominent basaltic volcanic package in the area was correlated with Permian (?) Anvil Range Group basalts on Rose Mountain. These volcanic rocks were considered to unconformably overlie all Cambrian through Mississippian metasedimentary rocks in the area.

More recently, Gordey (1983) showed that the basaltic volcanic rocks in the northeast Anvil map area were Cambro-Ordovician in age and could not be correlated with the Rose Mountain Anvil Range Group basalts. The northeast Anvil volcanic rocks were described further and informally named the Menzie Creek formation by Jennings and Jilson (1986).

Gordey (1983) interpreted the Menzie Creek formation in the northeast Anvil area as occurring in the hanging wall of a major subhorizontal thrust fault which separated it from the metasedimentary rocks. This fault was termed the Faro thrust and was considered to have a northeast-directed overlap of 9 km and a minimum strike-length of 18 km. Jennings and Jilson (1986) suggested that this fault might be a large gravity slide caused by uplift related to the intrusion of the mid-Cretaceous Anvil Batholith.

Detailed 1:25 000 scale geological mapping in the northeast Anvil area during 1998 and 1999 suggests that the Menzie Creek formation is part of a conformable sequence of stratigraphic units, and the Faro thrust represents intercalated volcanic and sedimentary rocks near a depositional margin to Menzie Creek volcanism.

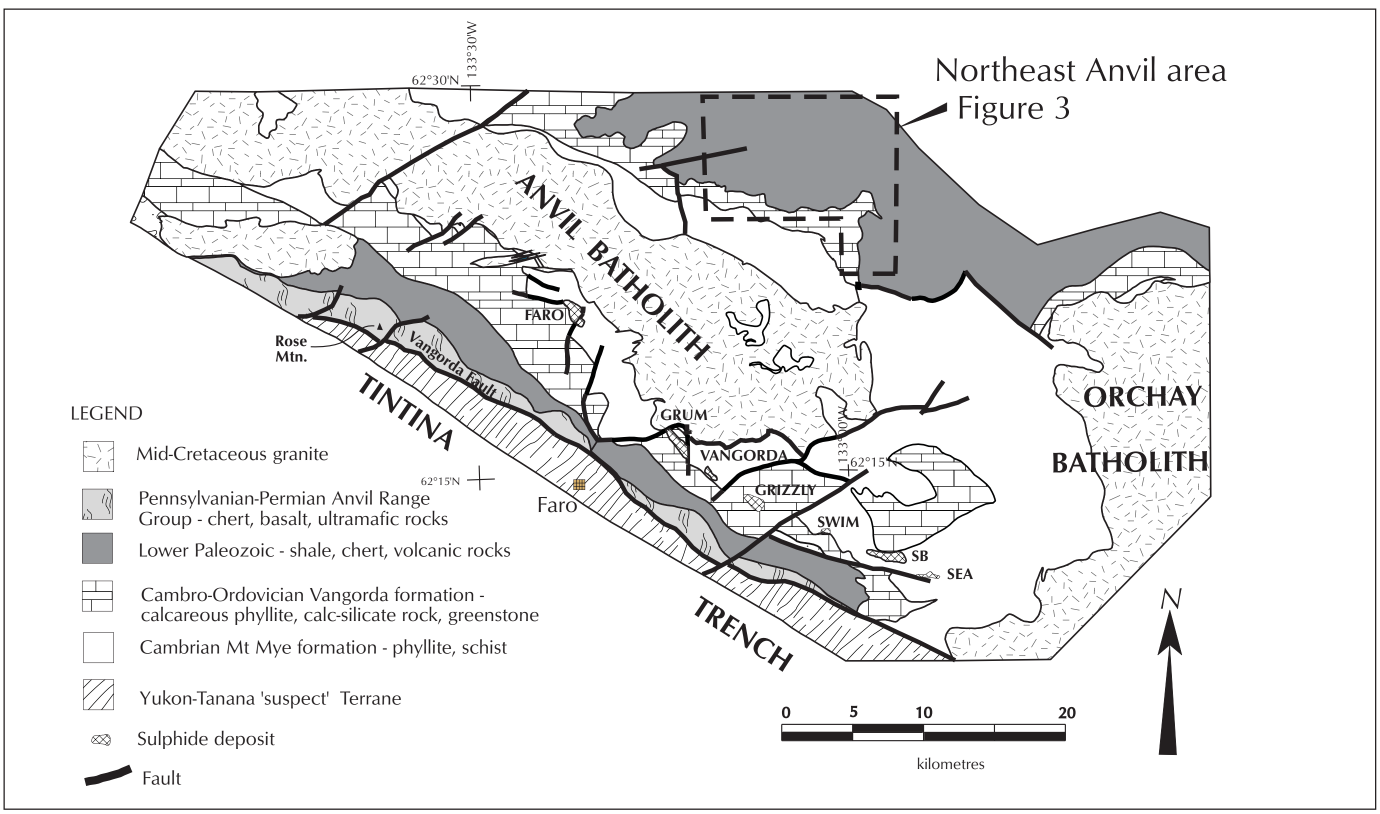

Figure 2. *Schematic geology of Anvil District, Yukon, showing the northeast Anvil map area (Fig. 3). Modified from Jennings and Jilson (1986).*

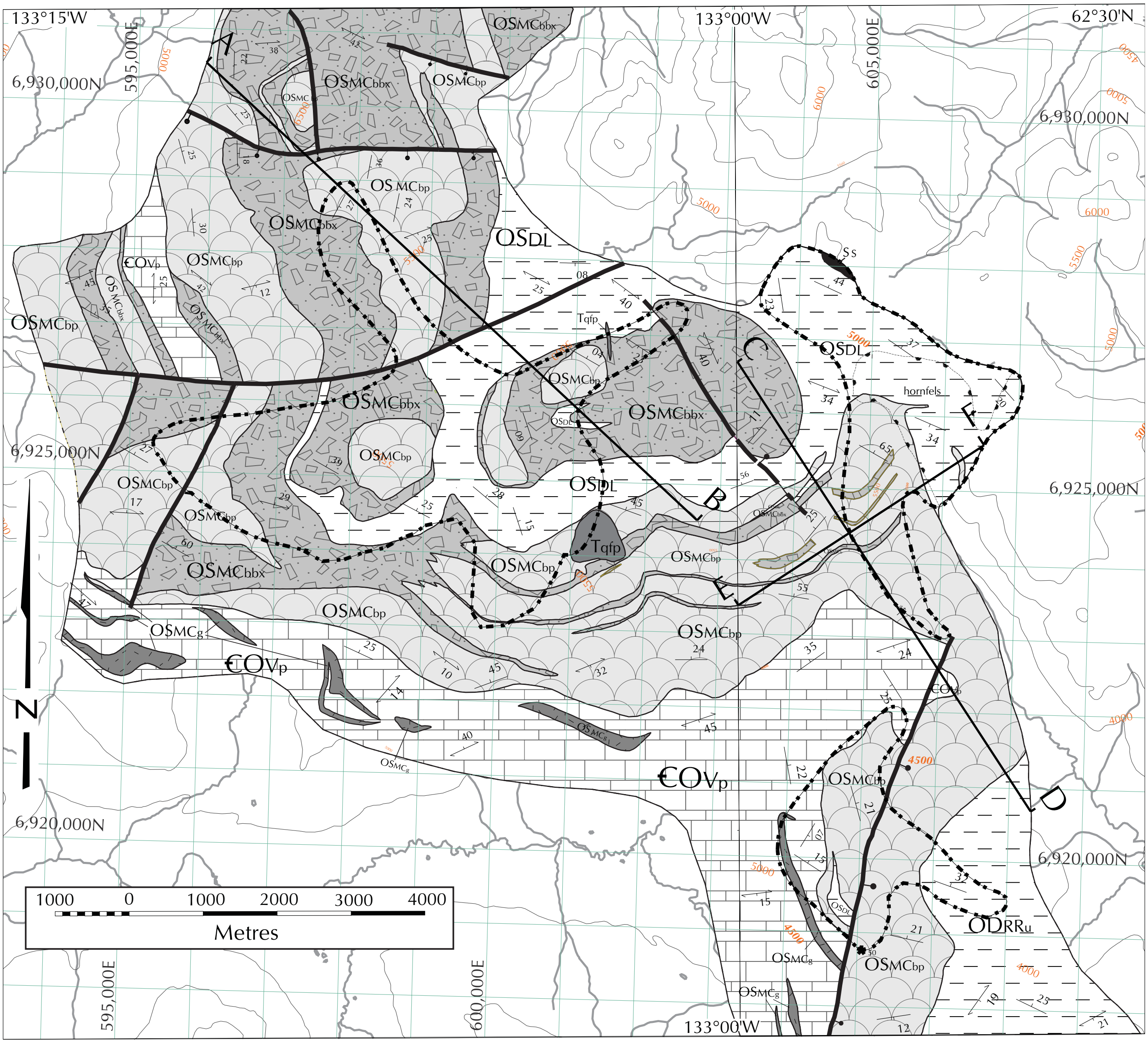

Figure 3. *Geology of northeast Anvil map area. Legend on next page.*

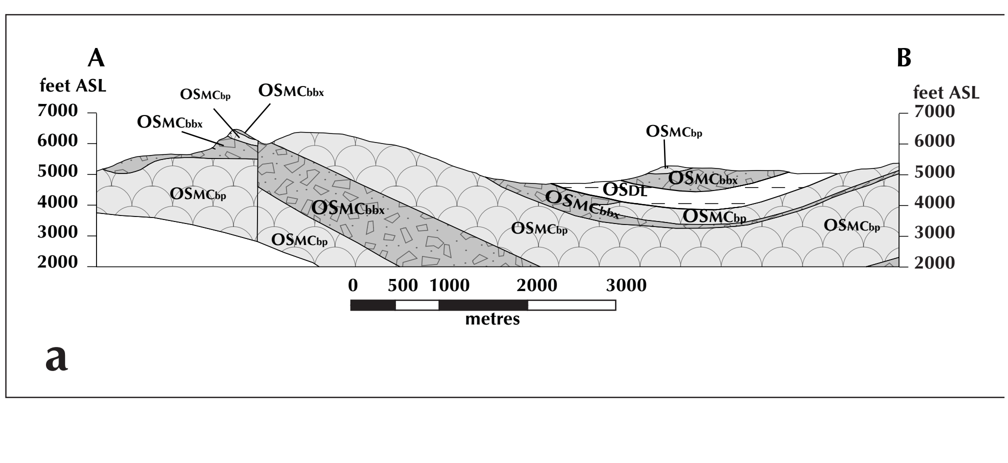

Figure 4. *Vertical cross-sections for Figure 3. Legend in Figure 3.*

ROCK UNITS

TERTIARY

Tqfp — White-weathering, aphanitic to fine-grained, flow-banded, rhyolitic quartz-feldspar porphyry.

ORDOVICIAN-DEVONIAN
UNDIVIDED ROAD RIVER GROUP

ODRRu — Dark grey to black argillite, with thin beds of medium to pale grey siltstone and fine sandstone, medium grey limestone, and basalt flows. Upper part of unit locally contains Devonian macrofossils. Includes Duo Lake Formation (OSDL) and unnamed Devonian sedimentary rocks. Steel Formation is not present.

ORDOVICIAN-SILURIAN
ROAD RIVER GROUP

STEEL FORMATION

SS — Tan- to orange-weathering, dolomitic, bioturbated, silty mudstone.

DUO LAKE FORMATION

OSDL — Dark grey to black, graptolitic argillite. Contains thin beds of medium to pale grey siltstone and fine sandstone, medium grey limestone, and basalt flows.

MENZIE CREEK FORMATION

OSMCb — Dark grey-green basalt. Undivided. Includes massive and pillowed flows, monolithic breccias, and volcaniclastic sandstones and siltstones. Interbedded with undivided Road River Group (ODRRu), Duo Lake Formation (OSDL), and Vangorda formation (COVp).

OSMCbp — Dark grey-green basalt. Includes massive and pillowed flows with minor monolithic breccias and volcaniclastic interbeds. Basalt flows locally contain white calcite amygdules. Interbedded with undivided Road River Group (ODRRu), Duo Lake Formation (OSDL), and Vangorda formation (COVp).

OSMCbbx — Dark grey-green basalt breccia. Monolithic breccias with lesser volcaniclastics and sandstone, siltstone and tuff interbeds. Minor massive and pillowed flows. Interbedded with undivided Road River Group (ODRRu), Duo Lake Formation (OSDL), and Vangorda formation (COVp).

OSMCg — Dark green, massive to foliated gabbro. Ranges from coarse-grained to fine-grained. Locally magnetic. Forms subvolcanic dykes and sills to Menzie Creek basalts.

CAMBRIAN-ORDOVICIAN
VANGORDA FORMATION

€OVp — Soft, silvery grey, calcareous phyllite with bands of medium crystalline grey marble, dark grey to black phyllite, and dark green gabbro sills and dykes (OSMCg). Greenschist facies equivalent of calc-silicate (COVcs). Regionally correlated with Rabbitkettle Formation.

€OVcs — Pale green and dark purplish brown, thinly banded calc-silicate rock with lesser bands of marble, black schist, and dark green gabbro sills and dykes. Amphibolite facies equivalent of calcareous phyllite (COVp). Regionally correlated with Rabbitkettle Formation.

SYMBOLS

Geological contact..

Faults...

Normal fault (dot on downthrown side)........

Metamorphic boundary (symbol on higher grade side)..... hornfels

Line of cross-section... A B

Bedding.. 15

S_1 slaty cleavage.. 15

Area of detailed mapping................................

Figure 3. *continued*

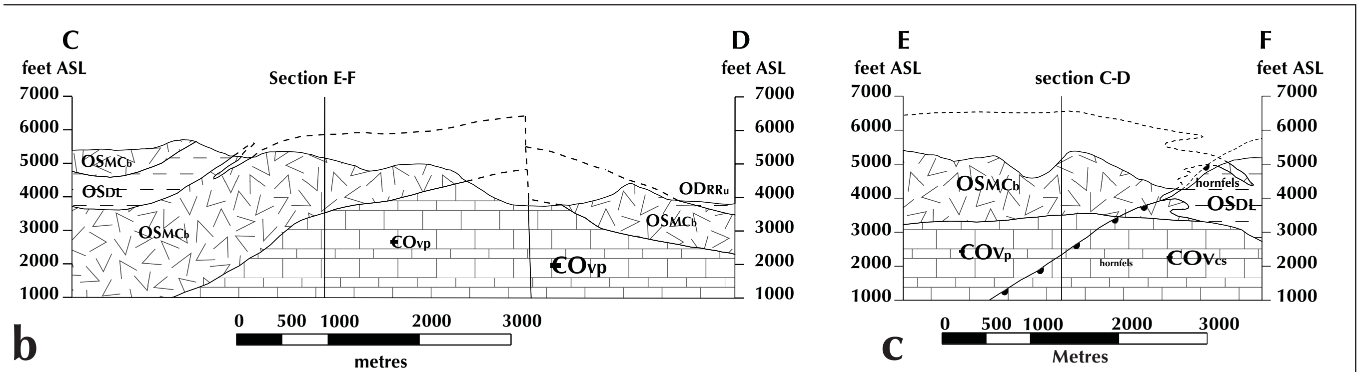

Figure 4. *continued*

NORTHEAST ANVIL GEOLOGY

INTRODUCTION

Volcanic and sedimentary units in the northeast Anvil area form a succession with a composite thickness of greater than 1600 m. Basaltic volcanic rocks of the Menzie Creek formation underlie most of the area. Fieldwork was directed towards looking at contacts between the Menzie Creek formation and underlying and overlying sedimentary units as well as documenting internal lithology variations within the Menzie Creek volcanic rocks.

Figure 3 shows the geology for the northeast Anvil area. Irregular outlines display the areas of geological mapping completed during the 1998-1999 field seasons. Geology outside the outlines is based on geological mapping completed by Jilson (1977). Figure 4a, b and c are vertical cross-section drawings interpreted from the geology map.

All units contain a single deformation foliation (S_1) consisting of a slaty cleavage. The S_1 slaty cleavage is moderately to well developed in the pelites, and poorly to moderately developed within the volcanic rocks. It most commonly dips moderately to the south and southwest, although local east to northeast dips are present. S_0 bedding and S_1 foliation intersections have a general north to northeast vergence. The entire sequence is interpreted to be structurally upright, based on rare stratigraphic top indicators and comparison to regional stratigraphy. Stratigraphic thicknesses are a minimum because of the pervasive S_1 foliation. The timing of development of the S_1 foliation is loosely constrained to be post Upper Paleozoic (Jennings and Jilson, 1986). Locally, pelitic rocks contain later deformation fabrics with weak development of a crenulation cleavage associated with small chevron-style folds. These later cleavages are rarely developed, do not give consistent orientations, and may be related to more than one period of compressive stress deformation.

The northeast Anvil area is generally within the subgreenschist facies of metamorphism. Low-pressure hornfelsing occurs along the east margin of the map area and will be discussed further.

STRATIGRAPHY

VANGORDA FORMATION (COV_p)

The Vangorda formation (Jennings and Jilson, 1986) is the lowermost unit exposed in the northeast Anvil area. Pale silvery grey, calcareous phyllite weathers recessively, forming scree slopes with abundant soft, silvery grey chips in the southeast part of the area. Cliffs commonly have a drusy, opaque white surface coating consisting of calcite. Phyllites are thinly laminated on a 1-2 mm scale with laminae being marked by dark grey striping within a light grey matrix. Discontinuous, 1-15-cm-thick beds of quartzose siltstone or fine limestone (Fig. 5) constitute 10-30% of the phyllite and are directly responsible for its calcareous nature.

Rare 1-2-m-beds of dark grey to black phyllite are present locally. A 50-m-thick bed of dark grey- to tan-weathering, finely laminated, dolomitic, siltstone occurs in the upper part of the formation. The formation also contains poorly foliated, fine- to medium-grained, dark green gabbro sills ranging up to 15 m in thickness. The medium-grained sills display a relict igneous texture consisting of white feldspar phenocrysts in a dark green chloritic matrix. They are interpreted as subvolcanic equivalents of the overlying Menzie Creek formation.

The lower contact of the Vangorda formation is not exposed in the northeast Anvil area. Mapping immediately to the southwest indicates it is conformably underlain by purplish brown-weathering, noncalcareous phyllites and schists of the Mount Mye formation (Jennings and Jilson, 1986). The upper contact with the overlying the Menzie Creek formation is conformable with local interbedding of volcanic rocks and phyllites over a 10- to 30-m interval.

Figure 5. *Thin limestone beds in phyllite, Vangorda formation. S_1 slaty cleavage is subhorizontal.*

The exposed thickness of the Vangorda formation in the map area is 120 m. The overall map pattern indicates a minimum thickness of 210 m. Jennings and Jilson (1986) suggest a possible thickness of 1000 m based on mapping in the entire Anvil District. The fine-grained nature of the phyllites and the thinly interbedded siltstones and limestones suggest deposition in relatively deep water with a regular influx of limestone and siltstone material by turbidity currents (Jennings and Jilson, 1986).

The Vangorda formation forms a widespread unit within the Anvil District. The Anvil District massive sulphide deposits straddle the lower contact of the Vangorda formation with the Mount Mye formation (Jennings and Jilson, 1986). This unit was mapped by Tempelman-Kluit (1972) as the upper member of Unit 3. Gordey (1990a, b) mapped it as the Rabbitkettle Formation (Gabrielse, et al., 1973). Jennings and Jilson (1986) correlate the Vangorda formation with the Rabbitkettle Formation but note that the Vangorda phyllites are more argillaceous than typical Rabbitkettle.

The Vangorda formation within the Anvil District is unfossiliferous. Fossils collected from the overlying the Menzie Creek formation (Tempelman-Kluit, 1972; Gordey, 1983, 1990a) in the northeast Anvil area range from Tremadoc (lower Early Ordovician) through Llandoverian (lower Early Silurian). The Rabbitkettle Formation in Nahanni map sheet 105I, 200 km east of the northeast Anvil area, ranges in age from probable Late Cambrian to late Middle Ordovician (Gordey and Anderson, 1993). The local fossils and regional correlation indicate a Late Cambrian through lower Early Ordovician age for the Vangorda formation.

MENZIE CREEK FORMATION (OSMCb)

Conformably overlying the Vangorda formation is a thick, resistant, grey-weathering basaltic volcanic unit informally named the Menzie Creek formation (Jennings and Jilson, 1986). The Menzie Creek formation forms the major unit encountered in the northeast Anvil area. Massive and pillowed, locally amygdaloidal flows are interbedded with volcaniclastic sedimentary rocks consisting dominantly of monolithic basalt breccia with lesser conglomerate, sandstone, and siltstone. These different lithologies laterally vary dramatically in thickness and amount within the map area. Minor intercalated black phyllite, bedded black chert, limestone, and dolostone occur locally throughout the unit.

Menzie Creek massive and pillowed flows form cliff outcrops consisting of black, dark brownish green, bluish green, or bluish olive-green, aphanitic to porphyritic basalt. Porphyritic varieties contain minor fine white feldspar and/or dark green mafic phenocrysts up to 5 mm across; typically the mafic phenocrysts are altered to fine, dark green chlorite. Many of the basalts are amygdaloidal, with amygdules up to 1 cm across infilled with white calcite, dark green chlorite, or white calcite rimmed by chlorite. Individual flows are not readily visible in outcrop. The

Figure 6. *Pillow basalt flow, Menzie Creek formation. Note rock hammer for scale.*

Figure 7. *Isolated pillows in chloritic matrix, pillow basalt flow, Menzie Creek formation. Note rock hammer for scale.*

S_1 slaty cleavage is poorly developed to absent within the massive and pillowed flow units.

Pillow lavas contain varying proportions of pillows, ranging from flows consisting dominantly of pillows (Fig. 6) to those with isolated pillows in a dark green chloritic matrix (Fig. 7). Pillows range up to 1.5 m across although diameters less than 0.5 m are more common. Rarely reddish chert occurs irregularly in the matrix. Commonly amygdules within the pillows are radiating and may form pipes. Pale green rinds up to 2 cm thick are locally visible on the pillow margins.

Massive and pillow basalt flows occur throughout the northeast Anvil area. Units consisting dominantly of flows range from a few metres thick to tens of metres thick. These flow units constitute the dominant lithology in the east part of the map area.

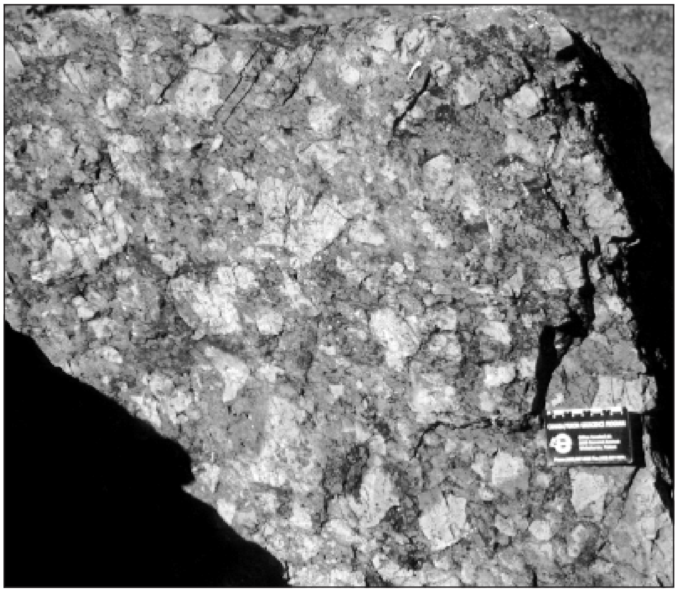

Figure 8. *Monolithic basalt breccia, Menzie Creek formation.*

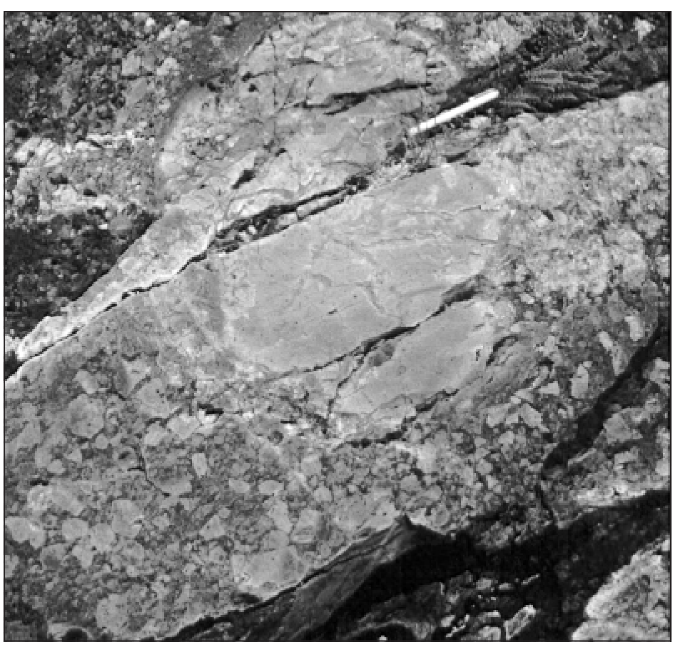

Figure 9. *Isolated pillow in monolithic basalt breccia, Menzie Creek formation. Pencil magnet in upper right corner of outcrop is 12.5 cm long.*

Monolithic basalt breccias (Fig. 8) consist of angular basalt fragments typically up to 50 cm across within a dark green chloritic matrix. Some fragments display pillow-margin rinds. Locally, the breccias contain a small proportion of nearly complete pillows among the clasts (Fig. 9). Breccias are generally nonstratified and do not display primary bedding. Typically the S_1 slaty cleavage is moderately to well developed within the chloritic matrix of the breccia units.

Monolithic breccias occur as rare thin beds in the east part of the map area. In the north and western parts of the area, they constitute the dominant lithology and form prominent cliff outcrops. In one locality, the breccias form an unstratified unit over 200 m thick.

Locally, basalt flows and monolithic breccia units are strongly quartz-carbonate altered with rare pale green mariposite grains in a bright orange- to tan-weathering quartz-carbonate matrix. In some instances alteration is spatially associated with late steep faults. In other locations timing of alteration relative to deformation is uncertain. On the eastern edge of the map area, hornfelsing of the Menzie Creek basalts is delineated by the

Figure 10. *Epiclastic volcanic sandstone bed, Menzie Creek formation.*

extensive development of fine disseminated purplish brown biotite (see Fig. 3).

Epiclastic volcanic conglomerates, sandstones, and siltstones are locally interbedded with basalt flows and monolithic breccias in minor amounts. These lithologies (Fig. 10) are generally only a few metres thick although rarely they range up to 20 m in thickness. Occasional graded beds give a stratigraphic top upright structural orientation. Coarse clasts are predominantly volcanic rock fragments. Rare dark grey to black, noncalcareous, silty phyllite, black bedded chert, pale grey limestone, and tan-to orange-weathering dolostone occur as 1-10-m beds at different stratigraphic levels within the volcanic sequence.

The Menzie Creek formation has a total thickness of approximately 900 m in the east edge of the northeast Anvil area. Aggregate thickness of the unit increases to the north and west. The lower contact with the Vangorda formation is conformable with interbedding of basalt and calcareous phyllite over a 10-30-m-interval. The upper contact with overlying carbonaceous phyllites of the undivided Road River Group in the southeast part of the map area has interbanding of basalt and phyllite over a 10-m-interval. Menzie Creek volcanic rocks are intercalated with black phyllites of the Duo Lake Formation (lower Road River Group) along the east margin of the map area. Gordey (1983) interpreted these relations as structural contacts with Menzie Creek volcanic rocks being thrust over the black phyllites along the Faro fault. In this report, the author suggests that these contacts are stratigraphically conformable, and the east side of the notheast Anvil area contains the depositional margin to Menzie Creek volcanism. These stratigraphic relations will be discussed in more detail in a separate section below.

Primary depositional textures within the flow units indicate submarine volcanism. Epiclastic volcanic sedimentary rocks and intercalated shales, limestones, and dolostones also delineate a subaqueous depositional environment. Jennings and Jilson (1986) suggested that lithologies in the upper part of the formation might be interpreted as indicating shoaling of the volcanic pile with time. The predominance of flow units on the east part of the map area indicates that submarine vent(s) for the Menzie Creek formation were preferentially located along the east margin of the northeast Anvil area.

Figure 11 displays discriminant diagrams prepared using NEWPET (Clarke, 1993) of volcanic flow and breccia units at different stratigraphic levels within the Menzie Creek formation. In all diagrams, the samples form tight clusters indicating alkali basalt compositions from a within-plate tectonic setting. Fossils from intercalated phyllites and limestones in the map area (Tempelman-Kluit, 1972; Gordey, 1983) range in age from lower Early Ordovician (Tremadoc) through early Lower Silurian (Llandoverian).

Menzie Creek volcanism therefore extends through this time interval. Basaltic volcanic rocks ranging in age from Cambrian to

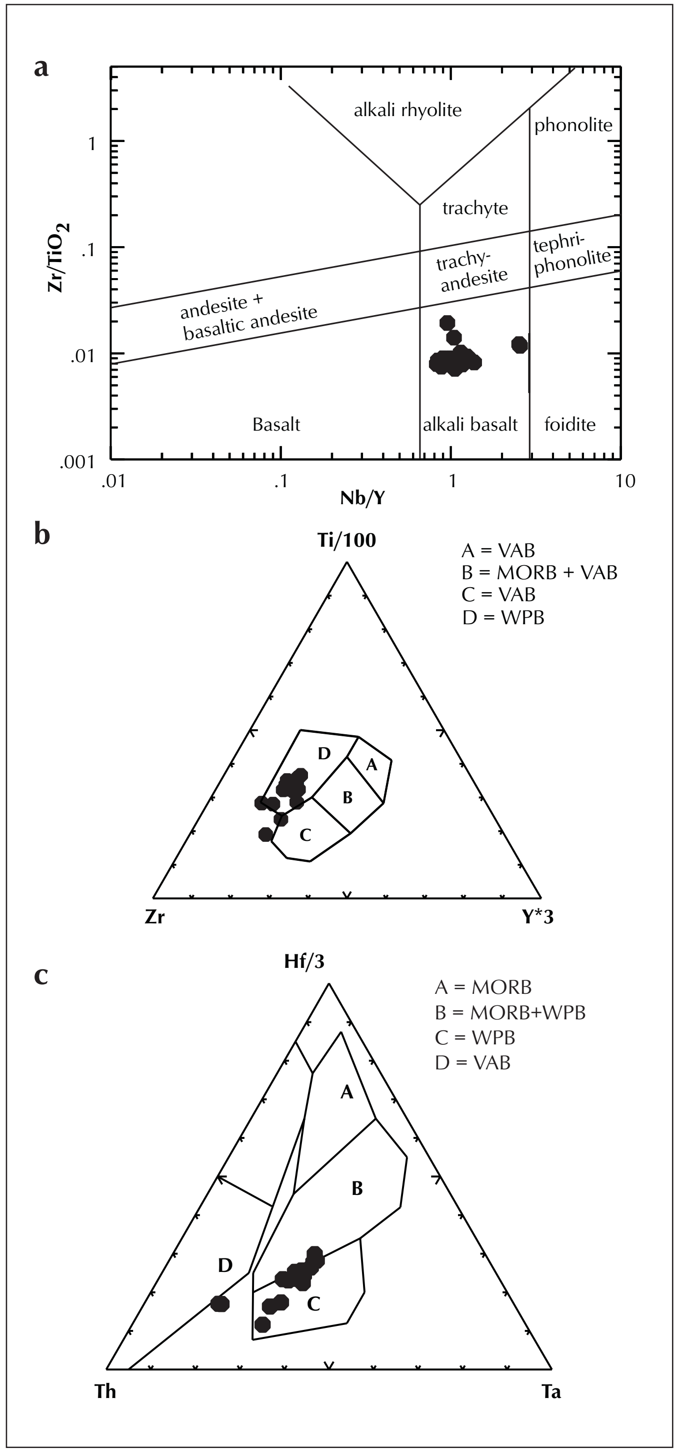

Figure 11. *Discriminant diagrams for representative basalt samples from Menzie Creek formation. a) Composition diagram using Zr/Tio$_2$ vs Nb/Y from Winchester and Floyd (1977, Fig. 6) as revised by Pearce (1996). b) Tectonic setting diagram using Ti-Zr-Y from Pearce and Cann (1973). c) Tectonic setting diagram using Hf-Th-Ta from Wood (1980, Fig. 1a); VAB=volcanic-arc basalt, MORB=mid-ocean ridge basalt, WPB=within-plate basalt.*

Middle Devonian with similar compositions and tectonic setting have been described in several localities in the northern Cordillera (Goodfellow at al., 1995). The lower Paleozoic volcanic rocks are consistent with interpretation of Selwyn Basin as a passive continental rift that underwent episodic extension and associated volcanism.

ROAD RIVER GROUP

The eastern margin of the northeast Anvil area is underlain by dark grey to black, noncalcareous phyllite, tan-weathering, bioturbated, dolomitic siltstone, and lesser massive to argillaceous limestone, and massive quartz sandstone and dolostone. The carbonaceous phyllites can be traced laterally westward into the central part of the map area where they are intercalated with Menzie Creek volcanic rocks. Regionally, these units (Gordey, 1990a, b; Jennings and Jilson, 1986) are correlated with the Road River Group (Gordey and Anderson, 1993). In the northern part of the map area, Road River Group can be subdivided into two formations, the lower Duo Lake Formation (Cecile, 1982) and the upper Steel Formation (Gordey and Anderson, 1993). In the extreme southeast part of the area, the Steel Formation is missing, and the sequence of carbonaceous siltstones and phyllites forming the undivided Road River Group includes interbedded limestones and dolostones of probable mid-Devonian age (Tempelman-Kluit, 1972). Stratigraphic descriptions of these three units are presented below.

DUO LAKE FORMATION (OSDL)

Dark grey to black, noncalcareous, siliceous phyllite to siltstone of the Duo Lake Formation (Cecile, 1982) is the dominant lithology on the northeast margin of the map area. The phyllites weather pale grey, commonly with faint pinkish to reddish hues. The unit mostly forms rounded scree slopes of medium grey phyllite chips which often display a strong pencil rodding resulting from intersection of S_0 bedding with the S_1 slightly irregular slaty cleavage. In the central part of the map area, the phyllites are interbedded with volcanic rocks of the Menzie Creek formation.

On the east margin of the northeast Anvil area, the dark phyllites are intercalated with lesser amounts of coarsely recrystallized, medium grey to off white, massive and argillaceous limestone, black bedded chert, and medium grey, noncalcareous, finely laminated, pinstriped siltstone. These lithologies locally are up to 6 m thick. A massive, grey to white quartz sandstone bed up to 15 m thick containing lenses of grey- to tan-weathering dolostone occurs within the carbonaceous phyllites in the central part of the map area. The sandstone rarely forms prominent cliffs on ridge tops; more commonly it occurs as rubble resting in phyllite chip scree.

On the east edge of the map area, outcrops of the Duo Lake Formation are strongly hornfelsed. Phyllites are strongly rust-brown weathering and moderately magnetic from fine disseminated pyrrhotite. Fresh surfaces display a purplish tinge from fine biotite. Hornfelsed pinstriped siltstones commonly have a light grey to off white bleached appearance.

The Duo Lake Formation on the east edge of the area has a thickness of at least 700 m. The tongue of Duo Lake phyllites extending toward the west is about 300 m thick. Fossils from the tongue of black phyllite intercalated with the Menzie Creek volcanic rocks in the central part of the map area delineate an age range from Arenigian (upper Early Ordovician) to Llandoverian (lower Early Silurian; Tempelman-Kluit, 1972; Gordey, 1983). The massive quartz sandstone mapped in this immediate area occurs in close proximity to the fossil localities and would have the same approximate age. The Duo Lake Formation in the type area (Misty Creek Embayment) has an age range from earliest Early Ordovician to late Early Silurian (Cecile, 1982). Both upper and lower contacts in the type area are diachronous. In the Nahanni area, the Duo Lake Formation ranges in age from Arenigian (Early Ordovician) to mid-Wenlockian (early Late Silurian; Gordey and Anderson, 1993).

STEEL FORMATION (SS)

In the extreme northeast part of the map area, black phyllites, cherts, and pinstriped siltstones of the Duo Lake Formation are conformably overlain by massive, tan-weathering, pale grey, slightly dolomitic, bioturbated siltstones of the Steel Formation (Gordey and Anderson, 1993). In the map area, the Steel Formation siltstones consist of rubble of large angular blocks on a broad plateau. The upper contact of the unit occurs to the east and northeast of the map area. Mapping by Gordey (1990b) indicates the Steel Formation in this immediate area is less than 30 m thick.

The age of the Steel Formation in the type area (Gordey and Anderson, 1993) is poorly constrained to be of definite Ludlovian (mid-Late Silurian) age, but may range from late Wenlockian (Mid-Silurian) to Earliest Devonian. The unit has poor fossil control in the northeast Anvil area; it is younger than the underlying the Duo Lake Formation.

UNDIVIDED ROAD RIVER GROUP (ODRRu)

Undivided Road River Group overlying the Menzie Creek formation is mapped in the extreme southeast part of the northeast Anvil area. The dominant lithologies are carbonaceous silty phyllites identical to the phyllites described above for the Duo Lake Formation. The Steel Formation is not present in this area. The carbonaceous phyllites contain intercalated tan-weathering grey dolostone, white-weathering quartz sandstone, and light grey to white limestone units which are lithologically identical to the massive quartz sandstone, dolostone, and limestone beds described for the Duo Lake Formation.

The lower contact of the undivided Road River Group with the Menzie Creek formation appears conformable with interbanding of phyllite and basalt over a 5-m-thickness. The upper contact has been eroded and is therefore not exposed. A minimum thickness of 460 m is indicated from map patterns. A dolostone-quartzite unit within the carbonaceous phyllites immediately southeast of the map area contains macrofossils with a probable late Middle Devonian age (Tempelman-Kluit, 1972). This unit therefore has an upper age, which is younger than the Duo Lake and Steel formations.

Carbonaceous phyllites and cherts of the undivided Road River Group and Duo Lake Formation were deposited in a quiet, euxinic marine basin. Presence of burrowing organisms in the Steel Formation indicates the marine basin was oxygenated during the Steel Formation deposition.

INTRUSIVE ROCKS

RHYOLITIC QUARTZ-FELDSPAR PORPHYRY (Tqfp)

The east central part of the northeast Anvil area contains a crudely circular intrusive plug of aphanitic, quartz-feldspar porphyry with an approximate diameter of 700 m. Further north, thin, vertical, north-trending dykes of the same intrusive unit are present. Fresh surfaces are dark reddish purple, and weathered surfaces are pale grey. The porphyry contains scattered 1-2 mm phenocrysts of white feldspar, grey quartz, and magnetite. Delicate mm-scale flow banding within the intrusive plug is crudely parallel to the marginal contact. The intrusive weathers as coarse, blocky rubble. The porphyry has been dated using whole rock K-Ar with an intrusive cooling age of 54.3 ± 1.2 Ma (Hunt and Roddick, 1991).

STRUCTURE

The Menzie Creek formation consists dominantly of volcanic flow units in which it is extremely difficult to determine S_0 bedding. The Duo Lake Formation is recessive weathering and does not form outcrops with readily visible bedding. Mapping during the 1998-1999 field seasons was partly directed towards trying to determine S_0 bedding for the different units.

Figure 3 shows field S_0 bedding measurements within the Menzie Creek formation and the Duo Lake Formation. S_0 bedding overall dips moderately northwest in the eastern part of the area, and east or northeast in the western part of the area. In all cases the lower Menzie Creek formation dips uniformly beneath the mapped westward extending tongue of the Duo Lake Formation phyllite. Map patterns and S_0 bedding measurements define a broadly warped structural basin with the core of the basin being located northeast of the map area. Age ranges from fossil localities are consistent with the Menzie Creek formation and the Duo Lake Formation forming a conformable sequence with younger fossils being structurally higher than older fossils.

MENZIE CREEK–DUO LAKE STRATIGRAPHIC RELATIONS/GROWTH FAULT

The central portion of the northeast Anvil area contains a 300-m-thick tongue of the Duo Lake Formation intercalated within the Menzie Creek formation. Immediately east of the map area, the Menzie Creek formation is absent (Gordey, 1990b). A north-northwest-trending stream valley at the east edge of the map area (Fig. 3) contains detailed stratigraphic relations between basalt and carbonaceous phyllite which have a bearing on interpretation of the Duo Lake-Menzie Creek stratigraphic relations in this area.

Outcrops on the ridge west of the valley define a 300-m-thick section of Menzie Creek volcanic rocks with S_0 bedding dipping shallowly to moderately northwest. Outcrop and subcrop at higher elevations consist dominantly of massive and pillow basalt flows with only minor interbedded volcaniclastic sedimentary rocks. Outcrops near the valley bottom consist of massive and pillow basalt flows with black phyllite and chert constituting roughly 20-30% of the exposures.

In contrast, the ridge on the east side of the stream valley consists dominantly of Duo Lake phyllites, cherts, and siltstones, defining a 275-m-thick section. The phyllites contain at least three thin beds of massive to pillowed Menzie Creek basalt typically ranging up to 10 m in thickness. The basalt beds have carbonaceous shales both overlying and underlying them. Figure 12 illustrates the basal contact of one of the basalt horizons; the contact is not sheared and the S_1 slaty cleavage passes from the phyllite to the basalt with only slight refraction. These structural and stratigraphic relations strongly suggest the contact between the Menzie Creek basalts and the Duo Lake phyllites is conformable.

Basalt units on both the east and west sides of the valley were sampled for lithogeochemistry. All analyses from this area plotted as part of the cluster of the Menzie Creek formation compositions illustrated in Figure 11. The thin basalt flows on the east side of the valley are definitely part of the same eruptive sequence as the thick volcanic pile further to the west.

These different observations indicate that this stream valley marks an east depositional margin to a thick Menzie Creek volcanic succession. Figure 4c is an east-west cross-section illustrating this interpretation. The Menzie Creek formation is laterally equivalent to the Duo Lake Formation with only thin tongues of Menzie Creek volcanic rocks extending east across the present stream valley. Similarly the Duo Lake phyllite within the Menzie Creek volcanic rocks in the central part of the northeast Anvil area represents a conformable depositional tongue of shale extending westward into the volcanic succession. This east Menzie Creek depositional margin also coincides with the predominance of Menzie Creek flow lithologies as opposed to epiclastic volcanic sedimentary rocks in the northeast Anvil area.

A reasonable paleogeography during Ordovician-Silurian time to explain the described stratigraphic variations would be a north-trending, syndepositional, west-side-down, normal fault along the east depositional edge of Menzie Creek volcanism. This syndepositional fault would correspond to the eastern limit of a depositional sub-basin containing the thick Menzie Creek volcanic pile and would provide a conduit for eruption of the

Figure 12. *Carbonaceous shale conformably overlain by pillow basalt.* S_0 *bedding dips gently to the left.* S_1 *slaty cleavage dips about 45 degrees to the left. Note rock hammer for scale.*

Menzie Creek basalts. Similar syndepositional faults within Selwyn Basin during Devonian time have been verified through detailed geologic mapping (Abbott, 1982; Turner and Rhodes, 1990).

Gordey (1990a, b) documented a dramatic westward thickening of the Steel Formation from less than 30 m to greater than 900 m about 5 km north of the northeast Anvil area, in the northwest corner of map sheet NTS 105K/7 and the southeast corner of map sheet NTS 105K/10. This thickening is on trend with the interpreted Ordovician-Silurian growth fault and is consistent with a west-side-down active growth fault at the sea floor in early Silurian time.

METAMORPHISM – HORNFELSING

Biotite-bearing, hornfelsed phyllites of the Duo Lake Formation and basalts of the Menzie Creek formation outcrop along the east margin of the northeast Anvil area. Intrusive rocks do not outcrop in the immediate area of the hornfelsed units.

Gordey (1990a, b) has mapped a regionally extensive Cambro-Ordovician unit (CO_t) consisting dominantly of resistant, dark grey-weathering, massive to laminated, blocky, white to light grey, quartzose siltstone and chert extending southeast from the northeast Anvil area to the margins of the mid-Cretaceous Orchay Batholith (see Fig. 2). He considered this unit to be older than the Duo Lake Formation and stratigraphically equivalent to the Menzie Creek and Vangorda formations. The southwest margin of this unit corresponds to the hornfelsed sedimentary rocks of the Duo Lake Formation and volcanic rocks of the Menzie Creek formation on the east margin of the northeast Anvil area. The CO_t unit, as mapped, probably demarcates the aerial extent of hornfelsing northwest of the mid-Cretaceous Orchay Batholith and indicates a large shallowly buried northwest extension to the batholith.

SUMMARY AND CONCLUSIONS

Volcanic and sedimentary units in the northeast Anvil area form a Cambrian through Devonian succession with a composite thickness of greater than 1600 m. Oldest exposures in the area are calcareous phyllites of the Cambrian-Ordovician Vangorda formation. The Vangorda formation is conformably overlain by basaltic volcanic rocks of the Menzie Creek formation. Menzie Creek volcanic rocks are intercalated with and overlain by carbonaceous phyllites of the Road River Group. Basalts of the Menzie Creek formation underlie most of the map area.

Contact relations between the Menzie Creek formation and Road River Group are not readily visible because of the recessive nature of the Road River phyllites. Gordey (1983) suggested that the Menzie Creek formation consistently structurally overlies the Road River with the contact between them being a major subhorizontal thrust fault, which he called the Faro fault. Detailed mapping in northeast Anvil area during the 1998 and 1999 field seasons indicates that S_0 bedding in the Menzie Creek formation and the intercalated Road River Group has a consistent uniform orientation with contacts between basalt and phyllite being conformable stratigraphic contacts within a homoclinal interbedded sequence.

The east margin of the map area is a depositional edge of Menzie Creek basalt volcanism with only scattered thin flows occurring further to the east. This depositional edge is considered to be a north-trending, Ordovician-Silurian, west-side-down, syndepositional growth fault forming the east margin of a depositional sub-basin. The sub-basin is infilled with a thick sequence of Ordovician-Silurian alkali basalt flows and epiclastic volcanic sedimentary rocks with lesser intercalated carbonaceous shales.

Hornfelsing on the east margin of the northeast Anvil area delineates the aerial extent of a large, shallowly buried northwest extension of the mid-Cretaceous Orchay Batholith.

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