Geology and Mineral Deposits of the Ecstall Greenstone Belt, Northwest British Columbia (NTS 103 H/103 I)

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INTRODUCTION

The Ecstall Greenstone Belt is part of the Central Gneiss Complex, a 2000 kilometre long anastomosing network of medium to high-grade metamorphic volcanic, sedimentary and minor plutonic rocks enclosed by younger granitoid rocks of the Coast Plutonic Complex. A century of prospecting has located 36 sulphide mineral occurrences at surface, including 3 deposits with combined reserves of 10 million tonnes. The high mineral potential of this belt has justified a new detailed mapping project, related mineral deposit studies, and a special regional geochemistry survey program (Alldrick and Gallagher, 2000; Jackaman *et al.*, this volume). The second field season of this multi-year project focused on study of the local geologic setting of the major volcanogenic massive sulphide deposits of this mineral district, while documentation of the geology within the metavolcanic sequence continued. Companies with properties in the belt have contributed a wealth of detailed geological data to this ongoing project.

The Ecstall belt is 80 kilometres long, 3 to 20 kilometres wide, and extends from the Douglas Channel fiord north-northwesterly to the Skeena River (Figure 1).

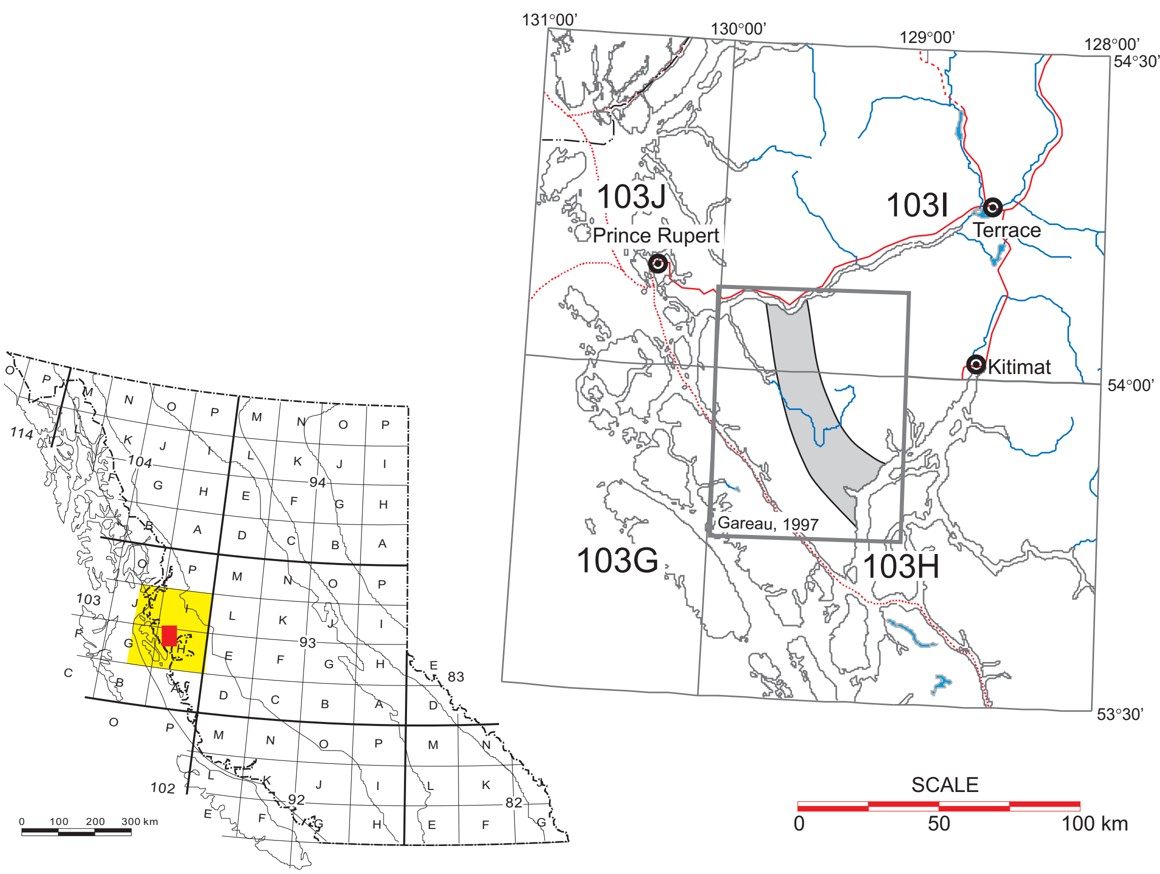

Figure 1. Location of the Ecstall belt in British Columbia.

Boasting admirable infrastructure, Ecstall lies midway between the northern port cities of Prince Rupert and Kitimat, and is close to tidewater, the Yellowhead Highway, the Skeena Railway line of VIA Rail and the national power grid (Table 1). Extensive logging road networks are established at the northern and southern ends of the belt (at the mouth of the Scotia River and at Kitkiata Inlet, respectively).

Elevation ranges from sea level to 1760 metres. Rounded ridgecrests are flanked by steep-walled glaciated valleys. Despite the precipitous terrain, it is possible to traverse the entire belt from north to south without exceeding 125 metres elevation by following a route of interconnecting valleys. Mining scenarios proposed since the 1940s have preferred haulage routes to the south to take advantage of the deep water shipping afforded by Douglas Channel (Mason, 1941b).

Rainfall is heavy; average annual precipitation at Prince Rupert is 244 centimetres (96 inches). The low elevation of the valley bottoms and their proximity to the coast leaves them free of snow through most of the year. Dense coastal rainforest covers all but the steepest slopes, where bedrock is exposed in cliffs or along avalanche tracks. Ridgecrests above 1100 metres elevation are free of trees and shrubs.

The name Ecstall comes from the Tsimshian dialect. Writers have recorded this name phonetically in English as: Eckstall, Ucstall, Oxtall, Hocsall, Hockstall, Huckstall, and Huxstall (Janet Mason, personal communication, 2000). The word means “tributary” or “something from the side”, as in “secondary matter” or “side-issue”. This label was clearly intended as a navigation aid, reminding Indians traveling up the broad estuary of the Skeena River that the equally wide mouth of the Ecstall estuary to the right-hand (south) side led to a relatively minor stream, navigable for just 56 kilometres before the first rapids were encountered.

PREVIOUS WORK

The Ecstall belt hosts 36 sulphide and 2 industrial mineral occurrences; only 21 of these are currently described in the MINFILE database. In 1890, the spectacularly exposed sulphide lenses of the Ecstall VMS deposit were discovered in Red Gulch Creek. A series of companies have investigated and developed this deposit throughout the last 100 years. Prospecting work during the 1930s and 1940s located 12 additional sulphide showings within 8 kilometres of the Ecstall deposit. Regional mapping and exploration programs conducted by Texas Gulf Sulphur Company Limited in 1957 and 1958, discovered the large Packsack (1957) and Scotia deposits (1958). For the past 20 years there has been continuous exploration work in the belt, carried out by many companies, resulting in the discovery of 21 more sulphide occurrences.

TABLE 1
KEY DISTANCES FOR DEPOSITS IN THE ECSTALL BELT

Deposit:	Scotia	Ecstall	Packsack
Elevation	758 m	182 m	242 m
Distance to:			
Ocean	27	24	18
Estuary / Tidewater	15	6	15
Hydro Powerline	10	19	29
Highway	15	39	49
Railway	15	39	49
Prince Rupert	49	72	82
Kitimat	67	60	59
Terrace	84	93	98

The first geology map of the Ecstall belt was the product of a corporate mapping program completed over a seven-year period (Holyk *et al.*, 1958) and remains unpublished. Seven geology maps relating to this area have been published by the Geological Survey of Canada over the last 35 years:

- Gareau (1991a and 1997) completed maps of the Ecstall Greenstone Belt at two scales
- Regional-scale maps have been produced by Hutchinson (1966 and 1979) and Roddick (1970b)
- Cordilleran-scale maps by Wheeler and McFeely (1991) and Read *et al.* (1991) yield important information about the regional setting of the Ecstall belt.

University research projects within the Ecstall belt have investigated a variety of geological features. Results are reported in theses by Padgham (1958), Money (1959), Turner (1961), Eldredge (1983), Krage (1984), Gareau (1991c) and Childe (1997). Research in adjacent rocks include studies by Kenah (1983), van der Heyden (1989), and Heah (1991). Geological studies continue under the supervision of M.L. Crawford at Bryn Mawr College, Pennsylvania and C. Davidson at Beloit College, Wisconsin.

New results from regional geological studies were published in Geological Society of America Special Paper 343 (Stowell and McClelland, 2000), including an important analysis of the regional stratigraphic correlation of the Ecstall stratigraphy by Gareau and Woodsworth (2000). Research by the Keck Geology Consortium, funded by the W.M. Keck Foundation, is scheduled for completion during the winter of 2000-2001 (*see* http://geology.beloit.edu/davidson/KeckBC/index.html).

Studies of VMS deposits in the North American cordillera have recently been completed by Newberry *et al.* (1997) and Massey (1999). Global studies of VMS deposits were reported in Barrie and Hannington (1999) and a new volume devoted to research on ore deposits in highly metamorphosed terranes has just been published (Spry, *et al.*, 2000).

Objectives of the current mapping program include: establish a detailed lithostratigraphic succession within the four large stratigraphic packages documented by Gareau (1997), study the relationships between this detailed lithostratigraphy and the mineral occurrences of the belt, trace out prospective strata, and investigate a possible coeval relationship between the intrusive Big Falls tonalite and the metavolcanic package. In the 2000 field season, a team of two mapped in the central part of the belt, investigating the Ecstall, Scotia and Packsack deposits, and some of the smaller prospects.

REGIONAL GEOLOGIC SETTING

The geologic setting of the Ecstall belt is shown in Figures 2 and 3. The Ecstall Greenstone Belt is part of the Central Gneiss Complex, an anastomosing network of high-grade metamorphic rocks enclosed by younger granitoid rocks of the Coast Plutonic Complex (Figure 2). Together these two complexes comprise the Coast Crystalline Belt or Coast Belt. The following summary is adapted from Greenwood *et al.*(1992), Woodsworth *et al.* (1992), Read *et al.* (1991) and Gareau (1991b,c).

Plutonic rocks of the Coast Plutonic Complex (CPC) make up more than 80% of the Coast Belt; the remainder is metavolcanic rocks, metasedimentary rocks and granitoid gneisses of the Central Gneiss Complex (CGC). Plutonic rocks of the CPC range in age from Late Silurian to Eocene (Woodsworth *et al.*, 1992). In general, the oldest plutons are exposed along the western edge of the CPC and the ages of plutons young progressively to the east. Rocks range in composition from granite to gabbro, but 70% of all plutonic rocks lie within the compositional range of tonalite-quartz diorite-diorite. Among the circum-Pacific plutonic terranes, the CPC is the largest, the most mafic, and the most deficient in K-feldspar.

Metamorphic rocks of the Central Gneiss Complex range in age from Proterozoic through Paleozoic and typically occur as screens or pendants surrounded or intruded by the plutonic rocks of the CPC (Figure 2). Evidence of Paleozoic regional metamorphism is preserved locally (e.g. Alldrick and Gallagher, 2000; Gareau and Woodsworth, 2000), but intense mid-Mesozoic and early Tertiary metamorphism, deformation and plutonism have obscured evidence of earlier events in many places. Most metamorphic effects can be attributed to regional metamorphism, but contact metamorphism from the adjacent plutons can also create a metamorphic overprint (e.g. Gareau, 1991a).

The Prince Rupert-Terrace corridor is the most extensively studied and best understood area of the Coast Crystalline Belt (Greenwood *et al.*, 1992; Stowell and McClelland, 2000). This is also the most deeply exhumed part of the Central Gneiss Complex; metamorphic grades range up to kyanite-amphibolite, sillimanite-amphibolite and granulite facies in different parts of this area (Read *et al.*, 1991). Within the Ecstall belt, Gareau (1991b,c) has documented a southwest to northeast progression from lower amphibolite facies to granulite facies, with most rocks falling within the kyanite-amphibolite (upper amphibolite) facies.

The mid-Devonian volcanic arc that evolved into the Ecstall Greenstone Belt likely developed in a similar setting as the extensive volcanosedimentary successions of the Yukon-Tanana terrane (Gareau and Woodsworth, 2000). The regional geologic history of the Ecstall belt is outlined in a separate report (Alldrick *et al.*, this volume) and summarized in Figure 4; Devonian volcanism, sedimentation and comagmatic intrusions are followed by three or four poorly-constrained phases of deformation and four well-dated plutonic episodes. The Jurassic to Eocene plutonic and metamorphic history of the Coast Crystalline Belt is consistent with a model of east-dipping subduction beneath a single, allochthonous Alexander-Wrangellia-Stikinia superterrane, emplaced against North America in Middle Jurassic time (van der Heyden, 1989)

GEOLOGY OF THE ECSTALL BELT

Summary

The Ecstall belt is a north-northwest trending, high-grade metamorphic belt bounded by the elongate mid-Cretaceous Ecstall pluton on the west and the Paleocene Quottoon on the east (Figure 3). Gareau (1991a) divided stratified rocks of the belt into four principal units: metavolcanic rocks, metasedimentary rocks, quartzite and layered gneiss. The metavolcanic unit consists of mafic and intermediate composition metavolcanic rocks, interlayered with lesser felsic metavolcanic and metasedimentary rocks. Metavolcanic rocks are intruded by two large, elongate, mid-Devonian plutons called the Big Falls tonalite. Recent geochronology studies (Alldrick *et al.*, this volume) confirm Gareau's (1991a) interpretation that the main metavolcanic sequence in the belt is also of mid-Devonian age. The metavolcanic package and its coeval subvolcanic stocks are overlain by a regionally extensive package of metasedimentary rocks, consisting of a lower metapelitic unit and an upper quartzite unit. These strata are overlain in turn along the eastern margin of the Ecstall belt by a mafic gneiss (Figures 3 and 4). The protolith for this black and white banded gneiss is interpreted as a mafic volcanic package of Late Devonian age.

The geologic history of the Ecstall Greenstone Belt (Figure 4) is outlined in Alldrick *et al.* (this volume). At least four plutonic events post-date the middle to upper Devonian stratigraphic succession. An extensive suite of small, weakly deformed diorite stocks are scattered throughout the central Ecstall belt. One stock has yielded an Early Mississippian age, which may indicate the age for all these plugs. In addition to Paleozoic intrusions, two elongate plutonic bodies of Early Jurassic age, the Johnston Lake and the Foch Lake tonalites, intrude the eastern part of the belt (Figure 3). The two bounding plutons, the mid-Cretaceous Ecstall on the west and the Paleocene Quottoon on the east, have associated dikes, sills and small stocks which cut the Ecstall belt rocks.

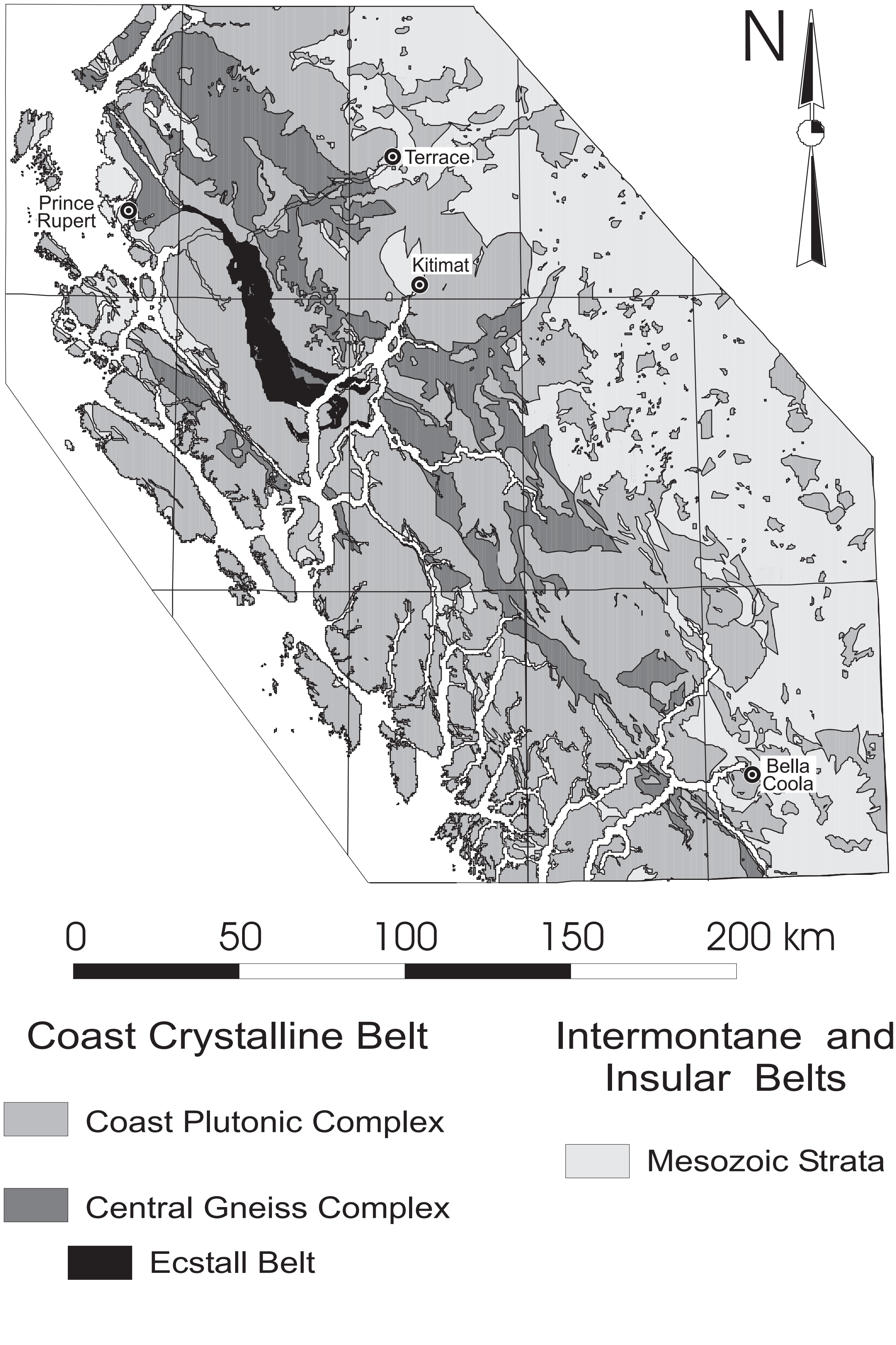

Figure 2. Geology of the mid-coast region of British Columbia, highlighting the location of the Ecstall metavolcanic belt within the Central Gneiss Complex and the Coast Plutonic Complex.

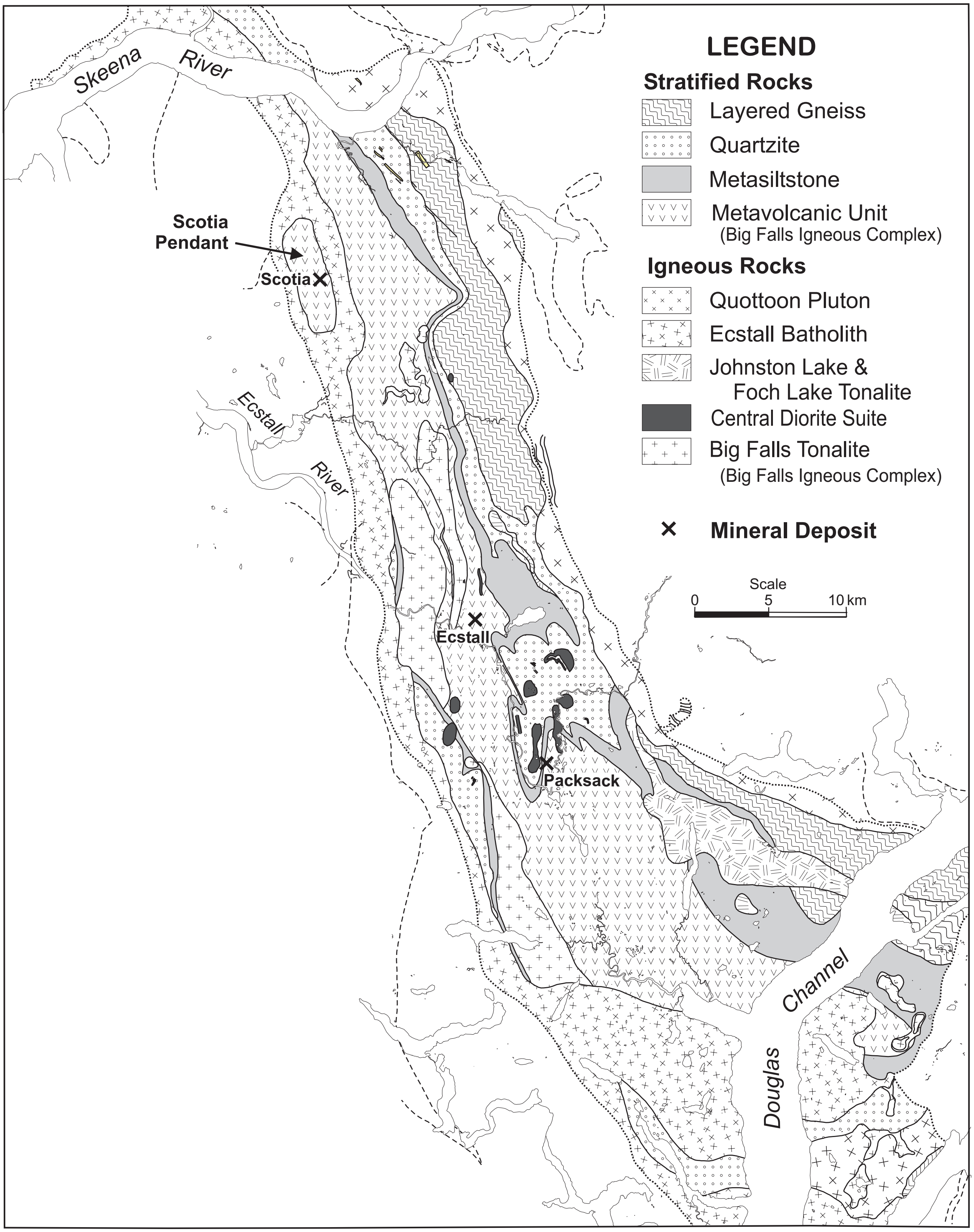

Figure 3. Simplified geology of the Ecstall belt (modified from Gareau, 1997) .

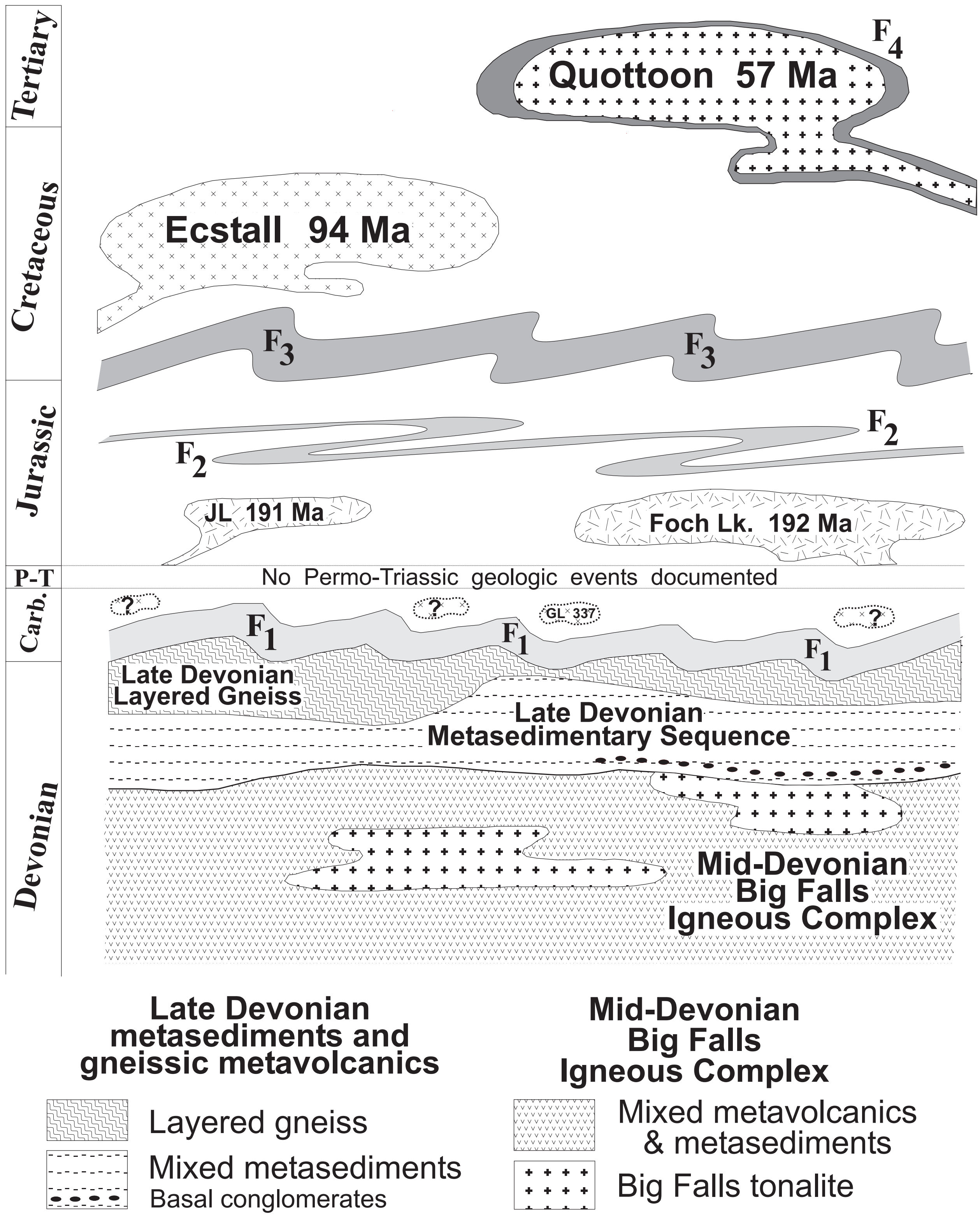

Figure 4. Schematic stratigraphy and geologic history of the Ecstall belt.

Stratified Rocks

The regional stratigraphic components have been well established by Gareau (1991a,b,c and 1997) and are reviewed in Gareau and Woodsworth (2000) and Alldrick *et al.*, (this volume), however, the sense of stratigraphic tops is not resolved. The sense of `tops' used in this report is based on 1. the conspicuous absence of the extensive Big Falls tonalite intrusion within the widespread and locally adjacent stratigraphic units of metasiltstone and quartzite (e.g. Gareau, 1997) which suggests that the intrusion pre-dates the sedimentary rocks, and on 2. the abundant "granitoid" (tonalite) clasts within conglomeratic members of the metasiltstone unit (Gareau, 1991a and Gareau and Woodsworth, 2000, Figure 7b).

UNIT 1 - METAVOLCANIC ROCKS (BIG FALLS IGNEOUS COMPLEX)

The base of the stratigraphic sequence is the metavolcanic unit which consists mafic to intermediate to felsic metavolcanic and derived metasedimentary rocks. The unit has been isoclinally folded (Gareau, 1991a, p.46), consequently apparent stratigraphic thicknesses, which range from 1 to 10 kilometres, are at least double their original value. This sequence is the largest unit defined by Gareau (1997), and extends the entire length of the belt, averaging four kilometres in thickness. Metavolcanic rocks are in gradational contact with the Big Falls tonalite (map unit A) and have sharp, but interlayered contacts with metasedimentary rock units. Metavolcanic rocks of the Ecstall belt host all but 3 of the 38 mineral occurrences (Figure 5).

The metavolcanic unit is heterogeneous. Biotite schist, hornblende-biotite schist and semi-schist comprise 70% of the unit. Interlayered with these lithologies are lenses of pyrite-quartz-sericite schist up to 100 metres thick, as well as amphibolite, quartzite, metasiltstone and calcareous muscovite-biotite schist layers. These smaller lenses may extend along strike for several kilometres.

Manojlovic and Fournier (1987) studied volcanic rock chemistry on the Scotia property. They concluded that most rocks are subalkalic, ranging in composition from basalt to rhyolite. The majority of mafic to intermediate rocks were tholeiitic, felsic rocks were dominantly calc-alkalic.

U-Pb zircon ages for a felsic metavolcanic member of this unit, for a quartz diorite sill at the Ecstall deposit, and for the Big Falls tonalite, are identical within error limits (Alldrick *et al.*, this volume). These contemporaneous rocks are components of a Middle Devonian age intrusive-extrusive complex consisting of a suite of subvolcanic, synvolcanic stocks and sills; coeval, comagmatic volcanic rocks; and associated sedimentary rocks. These comagmatic rocks and their locally derived, intercalated sedimentary rocks are informally referred to as the Big Falls Igneous Complex (Figure 4) to denote the rocks most important for the formation and preservation of volcanogenic massive sulphide deposits within the belt.

Unit 1a - Mafic Metavolcanics

Mafic metavolcanic rocks are preserved as strongly deformed pillow lavas and fragmental basalts, and as intensely foliated mafic schists or amphibolites. Subtle fragmental textures are preserved in some amphibolite outcrops. Hornblende-biotite schist is a black to greenish black recessive rock that is fissile and commonly highly weathered. It is the thickest of the metavolcanic units, averaging several hundred meters in thickness, and displays gradational boundaries with surrounding metavolcanic and metasedimentary lithologies. Also present within the mafic metavolcanics are lenses of resistant, homogeneous, black to rusty-coloured, garnet-hornblende amphibolite interlayered on a 5 to 20 metre scale.

Compositional layering is typically non-existent, or is very weak and defined by discontinuous millimetre-thick laminae. The rock contains more than 50% medium-grained biotite and 10% to 20% hornblende. Granular, fine to medium-grained plagioclase comprises up to 20% of the rock and is typically polygonal. Disseminated pyrite locally constitutes up to 5% of the rock and accessory skeletal garnet porphyroclasts are preserved. Euhedral titanite, that makes up to 10% of some thin sections, is a common mineral associated with sulphide grains. Titanite occurs as well defined layers, as radial masses cored by pyrite, or as interstitial clusters or individual grains. Epidote-hornblende knots or pods are common within this unit; when present these knots make up 5% to 15% of the rock. The schist locally displays discontinuous, orange, medium-grained, calcareous lenses that are highly recessive.

The abundance of hornblende and biotite and the lack of quartz is consistent with a mafic volcanic protolith. The lithologic heterogeneity observed in the unit suggests a highly dynamic depositional environment. Discontinuous carbonate lenses appear to be primary and are indicative of a subaqueous environment.

Unit 1b - Intermediate Metavolcanics

Gareau (1991a) concluded that hornblende-diopside-biotite-quartz-plagioclase semi-schist is the dominant lithology in the northern part of the Ecstall belt. Semi-schist is fine to medium-grained, granular, well indurated and weathers dark grey to black. This quartz-plagioclase rock has medium-grained biotite partings spaced 1 to 5 centimetres apart. Plagioclase and diopside microlithons have 5% to 10% interstitial biotite. Titanite occurs as euhedral interstitial grains making up less than 2% of the rock. Fine to medium-grained prismatic hornblende, ranging from 5% to 10% by volume, is concentrated along biotite parting surfaces.

The presence of biotite semi-schist members within the mafic metavolcanic schists marks a decrease in mafic minerals, and an increase in quartz from near zero to 10% to 20%. This mineral assemblage suggests that the protolith was a metamorphosed intermediate volcanic rock, or a volcaniclastic sedimentary rock.

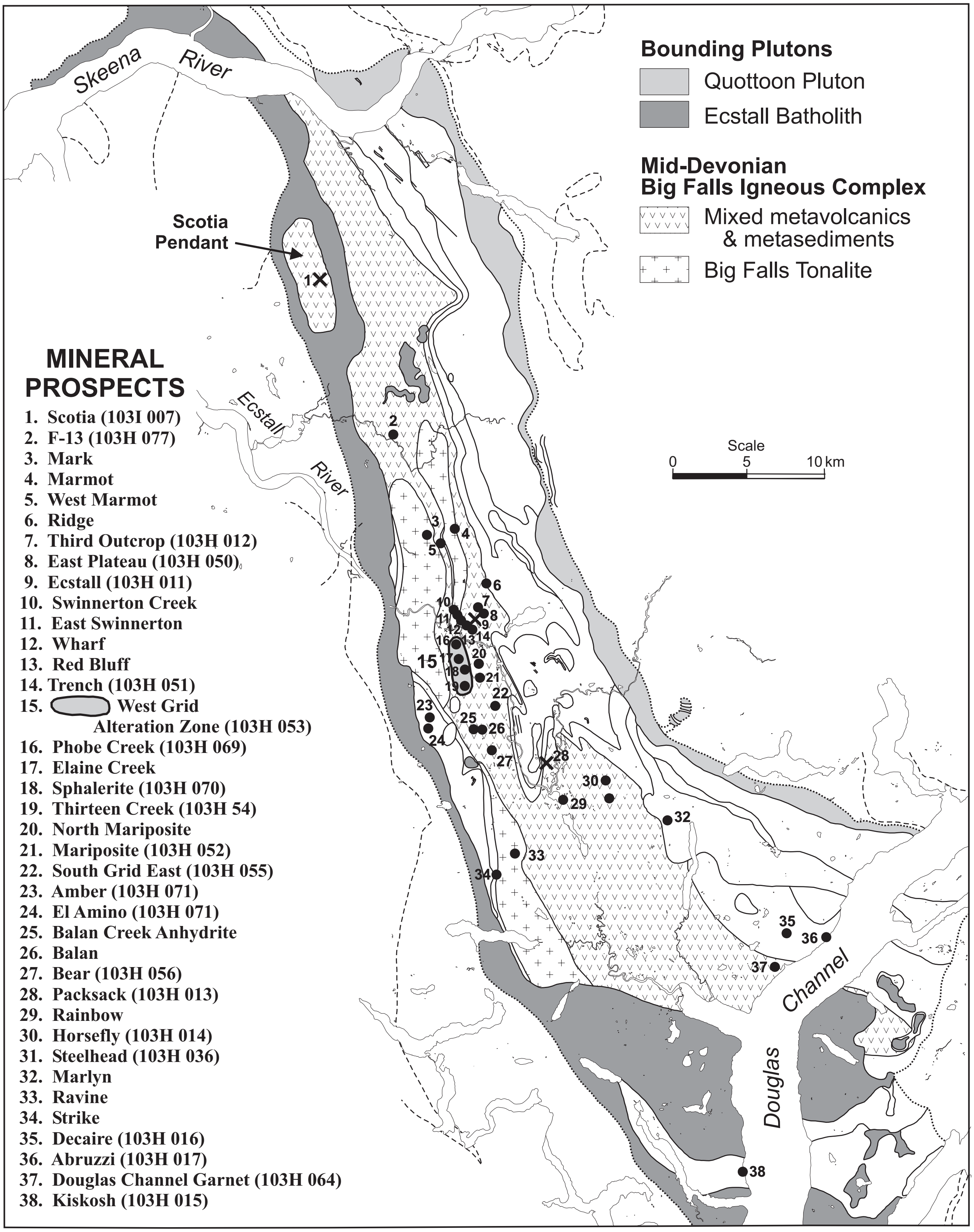

Figure 5. Mineral occurrences of the Ecstall belt (geology outlines modified from Gareau, 1997).

Unit 1c - Felsic Metavolcanics

These heterogeneous units are composed of pyritic quartz-sericite (muscovite) schist interlayered with 10 to 20 metre thick bands of muscovite-bearing quartzite and hornblende-biotite schist. Local thin units (1 to 5 metres) of thinly laminated (1 to 2 centimetres) quartz-rich rock that grades into the quartz-sericite schist are likely metamorphosed chert. Contacts with adjacent lithologies are typically sharp but may be gradational over half a metre to a metre.

Quartz-muscovite schist is a medium to coarse-grained rock with significant sulphides, containing on average 5% to 15% pyrite. These rocks also locally display relict clastic or fragmental volcanic textures. Primary compositional layering, on a 1 to 10 centimetre scale, is defined by alternating quartz and phyllosilicate layers. Pyrite seams or layers, up to 4 millimetres thick, are concordant with compositional layering and characterize the lithology. Subhedral garnet, with an average diameter of 5 millimetres, is commonly associated with the sulphides, as is biotite. Chlorite can be seen in handsample surrounding the garnet porphyroblasts. Quartz-rich metasediments associated with the felsic metavolcanic rocks are similar in composition to quartzites described below in Unit 2.

Pyritic quartz-sericite schists are interpreted as metamorphosed felsic volcanic flows, tuffs and fragmental rocks associated with subaqueous extrusion.

Unit 1d - Intercalated Metasedimentary Rocks

Minor metasedimentary members within the metavolcanic unit include metapelites, metasiltstones, granitoid-clast conglomerates, and rare chert or metaquartzite. South of Big Falls Creek, quartzite is interlayered with lenses of fine to very fine grained garnet-biotite-quartz schist. The gradational contact between the quartzite and schist is marked by quartz-rich rock with partings of medium-grained biotite and rare subhedral garnets ranging from 0.3 to 1.0 centimetres in diameter.

UNIT 2 - METASEDIMENTARY ROCKS

The Big Falls igneous complex is overlain by a regionally extensive package of metasedimentary rocks, consisting of a lower metasiltstone (metapelitic) unit and an upper quartzite unit.

Unit 2a - Metasiltstone

The volcanic succession is overlain regionally by a metasiltstone unit of medium to dark grey to black metapelite to metasiltstone to metaquartzite that is locally pyritic. This is the "metasedimentary unit" of Gareau (1991a) and the "metaclastic unit" of Gareau and Woodsworth (2000, p.27). The hornblende-biotite-quartz-feldspar-epidote rock has a mafic mineral content ranging from 20% to 70% (Gareau, 1991a). Rare intervals with fine disseminated magnetite grains have been noted. The thickness of this unit ranges from 100 metres near the Packsack deposit to over 5 kilometres along Douglas Channel; much of this increase is due to structural thickening near the axis of a regional scale fold in the Douglas Channel-Hawkesbury Island area. Gareau (1991a, p.10-13) describes contacts between the metasiltstone unit and the metavolcanics ranging from gradational to sharp.

This unit is significant in the regional stratigraphic construction because no dikes, sills or stocks correlated with the Big Falls magmatic complex have been identified within it, although younger intrusive rocks are common within this unit. Also, this unit includes repeated, extensive, granitoid clast conglomerate members (Gareau, 1991a). Clasts average 10 centimetres in diameter and typically make up 10% of the rock. Gareau (1991a) reports an exposure of conglomerate on the ridgecrest north of Johnston Lake that is 300 metres thick. Mafic mineral content of the granitoid clasts ranges from 20% to 70%, and K-feldspar is absent, indicating a tonalite composition.

Unit 2b - Quartzite

The black metapelite unit is overlain regionally by an extensive unit of quartzite (metasandstone). This white to light grey, well-laminated rock resembles thin-bedded sandstone, but the thin micaceous partings, rhythmic spaced at 5 to 10 centimetre intervals, are interpreted as a metamorphic effect. Minor associated lithologies include dark grey to black metapelite, black phyllite, dark grey metasiltstone and rare marble. Thickness of this unit ranges from 600 metres near Gareau Lake to more than 7 kilometres around the upper Ecstall River where the unit has been structurally thickened.

Gareau (1991a) describes the contact between this unit and the underlying metasiltstone unit as gradational over a 20 to 100 metre interval. Along the eastern margin of the Ecstall belt, the unit is in contact with a black and white layered gneiss, Gareau (1991a, p.14-15) describes the contact between these units as sharp to gradational over an interval of 500 metres.

Like the subjacent metasiltstone unit, this quartzite unit is an important component in the regional stratigraphic construction because no dikes, sills or stocks correlated with the Big Falls magmatic complex have been identified within it.

The quartzite unit consists predominantly of muscovite-bearing quartzite, but also includes minor units of metasiltsone. Quartzite contains greater than 95% quartz and is very well indurated, resistant, homogeneous, light to medium grey, and fine to very fine grained. The rock typically weathers light grey, but is rusty red when pyrite is present. The map unit is described as a "white to grey, locally pyritic quartzite, interlayered with lesser amounts of biotite-hornblende gneiss, fissile mica schist, black phyllite to meta-argillite, semi-pelite to pelite and marble… The unit locally contains lenses of matrix-supported conglomerate composed of stretched metatonalite and other granitoid cobbles with an aspect ratio of 10:2:1 or more. Finely laminated compositional layering is defined by light grey quartz-rich layers alternating with dark grey to black layers of quartz, biotite and graphite(?). Pyrite commonly occurs along partings as disseminations or semi-continuous laminae, not exceeding 5% of the rock." (Gareau, 1991a, p.14). The quartzite is a granoblastic rock; biotite is present in thin layers or partings less than 1 millimetre thick, or as minor interstitial grains. Accessory minerals are plagioclase, zoisite, cummingtonite, muscovite and carbonate. Gareau (1991a, p.14) concluded that these potassium and calcium-rich accessory minerals are consistent with a protolith of quartz arenite rather than chert.

UNIT 3 - LAYERED GNEISS

Gareau (1991a,b,c and 1997) defined a major stratigraphic unit of layered gneiss (Figure 3) along the eastern edge of the Ecstall belt, lying between the regionally extensive quartzites (map unit 2b) and the Quottoon pluton (map unit E). The metamorphic grade here is higher than the rest of the belt and lies within the upper amphibolite to granulite range (Gareau, 1991a).

The layered gneiss is interpreted as a metavolcanic rock (Gareau, 1991a). The protolith to this gneiss might be a repeated fold limb of the metavolcanic sequence of the Big Fall igneous complex (map unit 1), or a different, younger, mafic volcanic rock unit. Gareau and Woodsworth (2000) report a ~370 Ma U-Pb zircon age for this rock, which confirms that this unit is a younger volcanic package which stratigraphically overlies the quartzite unit (map unit 2b). The layered gneiss is the youngest (uppermost) stratigraphic unit preserved in the Ecstall Greenstone Belt (Alldrick *et al.*, this volume).

Intrusive Rocks

Five intrusive episodes are recorded in the rocks of the Ecstall belt (Figures 3 and 4). Two large, elongate, mid-Devonian plutons that are comagmatic with the host metavolcanic sequence and at least four plutonic suites post-date the mid to late Devonian stratigraphic succession. Small, weakly deformed diorite stocks are scattered throughout the central Ecstall belt. One stock has yielded an Early Mississippian age, which may indicate the age for all these plugs. In addition to Paleozoic intrusions, two elongate Early Jurassic plutons, the Johnston Lake and the Foch Lake tonalites, intrude the eastern part of the belt. Two bounding plutons, the mid-Cretaceous Ecstall on the west and the Paleocene Quottoon on the east, have associated dikes, sills and small stocks which cut the rocks of the Ecstall Greenstone Belt.

UNIT A - BIG FALLS TONALITE

Gareau (1997, *see* Figure 2) mapped out two large bodies of foliated tonalite, the Big Falls tonalite, which are enclosed mainly by the metavolcanic sequence of the Ecstall Greenstone Belt, and locally by the overlying metasiltstone unit. A sample from the eastern lens of this rock produced a U-Pb zircon age of 385 Ma, leading Gareau (1991a,b) to conclude that the tonalite bodies are coeval, synvolcanic, subvolcanic intrusions that fed the overlying volcanic pile. Recent global research into the geologic setting of VMS deposits has stressed the importance of subvolcanic plutons of tonalite/trondhjemite composition as the heat source which concentrates VMS deposits at the overlying paleosurface (Galley, 1996; Large *et al.*, 1996).

The Big Falls Tonalite is a Middle Devonian (385 Ma; Gareau, 1991a), foliated, medium to coarse-grained epidote-biotite-hornblende tonalite that crops out as two separate elongate plutons. The plutons have a maximum structural thickness of 3.5 kilometres. This homogeneous, resistant, light grey rock is in gradational contact with the surrounding metavolcanic unit. This contact zone is several hundred metres wide and characterized by decreasing grain size and increasing biotite content outward from the tonalite (Gareau, 1991a).

Textural variations range from weakly foliated to porphyroclastic to mylonitic. Gareau (1991a) reports gneissic zones tens of metres thick with 5 to 10 centimetre bands of alternating quartz-plagioclase and biotite-hornblende layers. Porphyroclastic tonalite consists of 0.5 to 1 centimetre diameter plagioclase porphyroclasts in a medium grey, fine to medium-grained matrix consisting of biotite, hornblende, quartz and plagioclase. Minor epidote pods and layers are common. Up to 2% garnet is locally present. A 20-metre-thick mylonite zone crops out south of Big Falls Creek. Within this zone, millimetre-scale plagioclase porphyroclasts are set in a very fine grained matrix.

The composition, homogeneity, and presence of clear, colourless, euhedral zircons led Gareau (1991a) to conclude that this is an intrusive rock. The gradational contacts, showing a progressive variation from medium to fine grain size, were interpreted as evidence of a large coeval subvolcanic pluton which fed the surrounding and overlying volcanic pile.

Childe (1997, p.225-228) analysed a sample of foliated quartz diorite sill that crops out just to the west of the North Lens of the Ecstall massive sulphide deposit (Alldrick *et al.*, this volume, and Schmidt, 1995). The U-Pb zircon age of 377 Ma provides a Late Devonian minimum age for the nearby, syngenetic sulphide deposit, and indicates that this sill is comagmatic with the two stocks of Big Falls tonalite.

UNIT B - THE CENTRAL DIORITE SUITE

An extensive suite of small, weakly deformed diorite stocks are scattered throughout the central Ecstall belt (Holyk *et al.*, 1958; Gareau, 1991c, 1997). One stock has yielded an Early Mississippian age, which may indicate the age for all these plugs. Gareau (1991a, p.21-22) describes a series of mafic and ultramafic stocks intruded through the central Ecstall belt, to which she ascribes a Jurassic or Cretaceous age. These rocks crop out in three main areas: as two stocks on Allaire Ridge, 10 kilometres south-southwest of Johnston Lake; as six small stocks scattered along Prospect Ridge, immediately west and uphill of the Packsack VMS deposit; and as a small body mapped on the peak of Red Gulch Mountain, 2.7 kilometres north-northeast of the Ecstall VMS deposit. These mafic rocks are dominantly diorites, but range in composition from quartz diorite to diorite to gabbro to hornblendite. The age of intrusion of all these rocks is unknown, although they must be younger that the quartzite host rock with a probable Late Devonian depositional age and older than the Early Cretaceous metamorphism. It is possible that these scattered clusters of weakly foliated mafic to ultramafic stocks are all comagmatic with the weakly foliated Gareau Lake diorite stock, described below, in which case they would have a mid-Mississippian age in the range of 337 Ma (Figure 4).

Unit B-1 - Gareau Lake Stock

Gareau (1991a, p.173-175) describes a small (<100 metres diameter) weakly foliated quartz diorite stock that intrudes the layered gneiss (map unit 3) on a ridgecrest 2 kilometres southeast of Gareau Lake. The rock is composed of 75% plagioclase, 10% quartz, 5% biotite and 3% hornblende with accessory titanite, apatite, zircon and opaque minerals. The U-Pb zircon age for this rock is 337 Ma (Gareau, 1991a). This date is consistent with intrusion into the 370 Ma layered gneiss host rock and indicates a mid-Mississippian magmatic episode of quartz diorite to diorite composition.

Unit B-2 - Allaire Ridge Mafic Complex

A large, irregular, mafic complex [JKum] is outlined on Gareau's map (1997) along the north-trending ridgecrest at the head of Allaire Creek, 5 kilometres to 9 kilometres south of the Ecstall deposit. Detailed mapping this season shows that this intrusion consists of two separate, but adjacent stocks that intrude metasedimentary rocks in the south and metavolcanic rocks in the north. The intrusive rock is resistant and underlies three prominent peaks along the ridgecrests. Two main phases are mapped: medium to coarse-grained diorite and very coarse grained hornblendite. At the 1242-metre peak at the northern edge of the northern stock, coarse-grained diorite is intruded in turn by tonalite of the Ecstall batholith, forming extensive intrusion breccias.

Diorite is medium to coarse-grained, and only weakly foliated. Massive hornblendite (hornblende gabbro) intrudes metasiltstone (map unit 2a) and quartzite (map unit 2b). The fresh rock is black and weathers rusty brown. Hornblendite is medium to very coarse grained, with hornblende (var. pargasite) crystals ranging up to 1.4 centimetres diameter. Metasediments within 1 to 2 metres of the intrusive contact are buckled, and screens of quartzite are incorporated near the margin of the intrusion. This intrusive phase was mapped across a 100 metre wide exposure along the ridgecrest, where it forms a prominent resistant spire. Gareau sampled this coarse-grained hornblendite for a K-Ar analysis, and interpreted the 115 Ma K-Ar age as a thermally reset date due to early to mid-Cretaceous regional metamorphism.

Unit B-3 - Prospect Ridge Diorite

West and uphill from the Packsack prospect, six small diorite stocks have been mapped along the crest and flanks of Prospect Ridge by Padgham (1958), Holyk *et al.* (1958), Delancey and Newell (1973), Maxwell and Bradish (1987b), Payne (1990c) and Gareau (1991c and 1997).

Unit B-4 - Red Gulch Mountain Diorite

Holyk *et al.* (1958) and Gareau (1997) show a small hornblende diorite stock at the peak of Red Gulch Mountain, 2.7 kilometres north-northeast of the North Lens of the Ecstall deposit. This resistant igneous rock underlies the prominent peak.

UNIT C - FOCH LAKE STOCK AND JOHNSTON LAKE STOCK

Gareau (1991a) identified two large, elongate Early Jurassic age intrusions emplaced along the eastern margin of the Ecstall belt. These plutons are both weakly to strongly foliated tonalite, but one is medium-grained and equigranular while the other is plagioclase megacrystic. The northern, equigranular Johnston Lake pluton yielded U-Pb zircon ages of 193 Ma and 190 Ma (Gareau, 1991a). The southern, coarsely porphyritic, Foch Lake stock yielded a U-Pb zircon age of 192 Ma (Gareau, 1991a). These plutons suggest that the Ecstall belt strata were associated with Stikine Terrane before the Early Jurassic time (Gareau and Woodsworth, 2000, p.39-40).

UNIT D - ECSTALL PLUTON

The Ecstall pluton is the largest of a series of magmatic-epidote-bearing plutons (Zen and Hammarstrom, 1984; Zen, 1985) in the western Cordillera called the Ecstall Suite (Woodsworth *et al.*, 1992, p.518-519). Regionally, the Ecstall suite includes diorite, tonalite and granodiorite phases (Gareau, 1991a). Along the western margin of the map area (Figure 3), the early Late Cretaceous Ecstall pluton is biotite-hornblende diorite to quartz diorite to tonalite. Age determinations span 98 Ma to 64 Ma, with the six most recent analyses averaging 93.5 Ma (unpublished data from van der Heyden, 1991, cited in Gareau, 1991a, p.161-164).

The rock is massive to moderately foliated, medium to coarse-grained, and weathers to a black and white, granular-textured surface. Foliation is defined by preferentially oriented biotite and hornblende. The rock is commonly equigranular, but locally displays plagioclase porphyroclasts. Hornblende-biotite-epidote tonalite ranges from light to medium grey on fresh surfaces. Grain size typically ranges from medium to coarse-grained equigranular, but local very coarse grained phases were noted. Foliation is generally more intense near the pluton margins. Primary layering (flow-banding or cumulate layering) was noted in one location. The pluton is highly sheared in places; mylonitic and pyritic shear zones were mapped this season. Cobble to boulder size mafic xenoliths are locally abundant. Screens of metasedimentary rock up to 40 metres wide are typically incorporated near the margins.

A distinctive feature of the Ecstall pluton is the presence of magmatic epidote, which increases in abundance from the margins to the centre of the intrusion. Within 200 metres of the contact, no epidote is apparent; epidote becomes progressively more abundant moving into the pluton, appearing first in fractures, then as fine interstitial grains, finally as equigranular coarse grains making up to 5% of the rock volume. Prominent crystals and aggregates of magmatic epidote comprise 5% of the rock and are associated with knots of biotite. Dark grey to black mafic schlieren are common and parallel the foliation within the rock. Medium-grained, euhedral, transparent titanite is also present. Contacts are sharp and discordant to the foliation. The eastern contact of the pluton is also discordant to the regional trend of map units. No chilled margin or contact metamorphic aureole was noted.

Along the southwest edge of the Ecstall Greenstone Belt, a porphyritic phase of the Ecstall pluton, crops out as a satellite pluton, roughly 1 kilometre in diameter, and consists of dark grey massive diorite(?) with an aphanitic groundmass and feldspar phenocrysts 3 to 4 millimetres across. Swarms of narrow pegmatite dikes concentrated along the western margin of the Ecstall belt are also likely components of the Ecstall magmatic episode.

UNIT E - QUOTTOON PLUTON

The Quottoon pluton intrudes along the eastern margin of the Ecstall Greenstone Belt (Figure 3). It is a long narrow body that extends north through southeastern Alaska, where it is called the "foliated tonalite sill" (Brew and Ford, 1978; Gehrels *et al.*, 1991a). The Quottoon Pluton is a medium to coarse-grained hornblende quartz diorite to tonalite and is intensely foliated close to its contact with the gneissic rocks of the Ecstall belt. Age determinations from this extensive pluton span Late Cretaceous (80 Ma) to mid-Eocene (43 Ma) time (van der Heyden, 1989, p.158-160), with Gareau's (1991a, p.184-185) age of 57 Ma determined for a sample site closest to the present study area. This pluton is the focus of ongoing studies by the Keck Geology Consortium.

Gareau (1991a, p.182-184) reported a U-Pb zircon age of 59 Ma for an unfoliated pegmatite dike near the eastern edge of the belt, which indicates that the extensive swarm of pegmatite dikes that intrudes the eastern margin of the Ecstall belt is a component of the Quottoon magmatic episode.

Structure

The stratigraphic sequence has been isoclinally folded (Gareau, 1991a, p.46). Strata are exposed as a mirror-image sequence along the two margins of the belt (Gareau, 1997), although the layered gneiss (map unit 3) is missing along the western limb of the fold. The two plutons of Big Falls tonalite are likely repetitions of the same subvolcanic pluton duplicated by folding.

Rocks of the central Ecstall belt are highly deformed and characterized by north-striking, steeply dipping to vertical foliation defined by near-parallel compositional layering and cleavage. Detailed analyses of the structure of this belt are presented in Gareau (1991a) and Alldrick and Gallagher (2000). Coaxial, map-scale, upright, F_1 and F_2 isoclinal folds and upright to inclined F_3 open folds are identified (Alldrick and Gallagher, 2000). Mineral lineations and stretching lineations are steeply northwest to southeast plunging. The relative timing of thermal and dynamic metamorphic events deduced from analysis of textures, mineralogy and cross-cutting plutons are illustrated in Figure 4 and discussed in Alldrick *et al*., (this volume).

Metamorphism

Two metamorphic episodes have been documented; a peak regional prograde metamorphic event (M_1) and a much later regional retrograde metamorphic event (M_2). Gareau (1991a) demonstrated that peak metamorphic grades varied from lower amphibolite facies in the southwest part of the belt to granulite facies in the northeast part of the belt. In the central part of the Ecstall Belt, biotite, muscovite, garnet and kyanite are consistent with upper amphibolite facies metamorphism. No gneiss units were noted in the central part of the Ecstall belt, in sharp contrast to extensive gneiss units mapped further to the north (Alldrick and Gallagher, 2000) and the layered gneiss (map unit 3) mapped to the east (Gareau, 1997). Rocks are generally moderately to highly deformed, but local areas of relatively undeformed rocks are preserved. A 400-metre-long unit of pillow lava and adjacent pillow breccia were mapped south of Thirteen Creek cirque; Hassard *et al.* (Figure 6 in 1987b) report a similar exposure of pillow lava in the canyon of Red Gulch Creek, 1050 metres upstream from the north end of the North Lens, and Schmidt (1996a) reports graded beds, accretionary lapilli and bomb sags in outcrops near the Steelhead prospect.

Gareau (1991a) attributed a series of mid-Cretaceous K-Ar dates on hornblende from metavolcanic rocks, and metasedimentary rocks to thermal resetting by an early to mid-Cretaceous regional-scale metamorphic event. Still younger thermal resetting of the westernmost and easternmost samples in the transect were caused by the thermal envelopes of the Ecstall (94 Ma) and Quottoon (57 Ma) plutons respectively. A Paleocene metamorphic event is attributed to emplacement of the Quottoon pluton, which created metamorphic zircons and titanites. The metamorphic ages coincide well with U-Pb zircon ages of 57 Ma and 61 Ma that Gareau (1991a) obtained from a samples of the Quottoon pluton and a related dike.

MINERAL DEPOSITS OF THE ECSTALL BELT

The 36 sulphide mineral prospects and 2 industrial mineral occurrences in the Ecstall Greenstone Belt (Figure 5) are described below, drawing extensively on information from files provided by Atna Resources Inc., Bishop Resources Ltd. and Ecstall Mining Corporation. Reserves for three deposits are summarised in Table 2.

1. Scotia (103I 007)

The Scotia deposit was discovered in 1958 by Texasgulf Ltd. geologists during a regional exploration program (Delancey, 1978). The property has been explored intermittently until 1999. The Scotia massive sulphide deposit lies within the Scotia pendant, a 3.5 kilometre by 7.5 kilometre roof pendant of metavolcanics and metasediments within the Ecstall batholith (Figure 3). The roof pendant is separated from the Ecstall Greenstone Belt by a 1.0 to 1.5 kilometre wide band of medium to coarse-grained Ecstall diorite, but the Scotia pendant is likely composed entirely of the same mid-Devonian metavolcanic unit that forms the basal metavolcanic sequence of the Ecstall belt.

The location of the Scotia deposit within a roof pendant of the Ecstall batholith has isolated the sulphide deposit and its host strata from the early to mid-Cretaceous and Paleogene deformation that affected rocks throughout the main part of the Ecstall belt. Scotia pendant rocks do not show the pronounced vertical mineral lineations, vertical fold axes and vertically stretched clasts that characterize the rest of the belt (Alldrick and Gallagher, 2000; Schmidt, 1995a; Gareau 1991a). Consequently the deposit has a form and attitude unlike any other sulphide occurrence in the region.

The deposit crops out in a southeast-facing cliff at 825 to 850 metres elevation. The Main Zone is a rod-like mass that trends 340º into the ridge, but plunges down at 9º toward 160º. At surface the deposit has a pod-like core of massive mineralization almost 10 metres in diameter. Bands, pods and stringers trending 20º up-dip to the east-northeast and 20º to 30º down-dip to the west-southwest (Birkeland *et al.*,1998). The up-dip extensions tend to pinch out abruptly or continue as thin but high-grade sphalerite sheets up to 30 cm thick that decrease in size and intensity to the east. The down-dip extensions to the west usually grade into increasingly iron sulphide-rich disseminated mineralization. Low-grade zinc mineralization has been intersected in these lenses more than 100 metres down-dip from the Main Zone.

TABLE 2
RESERVES FOR SULPHIDE DEPOSITS IN THE ECSTALL BELT

PROPERTY	SIZE (mT)	Cu %	Pb %	Zn %	Ag g/T	Au g/T
Scotia	1,240,000	0.1	0.4	3.8	13.0	0.25
Ecstall	6,878,539	0.65		2.45	17.0	0.5
Packsack	2,700,000	0.5	0.01	0.2	34.0	0.3
TOTAL	10,818,539	0.5	0.05	2.1	20.8	0.4

The deposit has been explored by prospecting and by geological, geochemical and geophysical programs over the last 41 years. Five drilling programs have been completed, totaling 4,340 metres in 42 holes. A geological resource of 1.34 million tonnes grading 3.8% Zn, 0.4% Pb, 13 g/t Ag and 250 ppb Au has been calculated by Lindinger (*in* Birkeland, Lindinger and Sinnot, 1998), which includes a drill-indicated and probable resource within the Main Zone of 232,000 tonnes grading 12.0% Zn, 1.2% Pb, 0.2% Cu, 23 g/t Ag and 550 ppb Au. The Scotia deposit remains open up-plunge to the north-northwest and down-dip to the west-southwest.

The Scotia deposit has higher zinc, lead and gold contents and lower copper content than the other deposits in the Ecstall belt (Ecstall and Packsack). The Scotia deposit is also furthest from the coeval, mid-Devonian Big Falls tonalite. These patterns are similar to the zoning patterns and intrusive relationships described for distal VMS deposits of the Mount Read VMS belt of western Tasmania by Large *et al.* (1996).

Host rocks are a highly metamorphosed volcanic sequence intruded by a series of diorite and pegmatite dikes. Volcanic rocks range in composition from tholeiitic basalt and andesite to calc-alkaline dacite to rhyolite (Manojlovic and Fournier, 1987). Metamorphism reached upper amphibolite facies and most rocks are preserved as gneissic units, schists or semi-schists. Protoliths are identified as basalt, andesite, dacite and rhyolite, plus minor siltstone, chert, chert breccia, “exhalite” and quartz porphyry units (Birkeland *et al.*, 1998). Fragmental textures can still be recognised in well-weathered outcrops of mafic volcanic rocks, now preserved as fine-grained amphibolite.

The Scotia deposit is the southwesternmost exposure of significant sulphides (> 2% pyrite) within the Scotia pendant. This season, several north-northwest striking horizons of pyritic quartz-sericite schist were mapped along the ridges to the north and east of the deposit. Some of these units have been previously sampled along the ridgecrests, but these prospective pyritic quartz-sericite schist units have not yet been investigated along the intervening slopes, valleys and creek drainages.

2. F-13 (103H 077)

The F-13 showing is exposed alongside a logging road on the north bank of Big Falls Creek. The roadcut transects a 300 metre thick section of rusty, weakly pyritic quartz-sericite schist that is interpreted as the metamorphic equivalent of a felsic tuff. Adjacent strata are hornblende-biotite-plagioclase schists that are interpreted as intermediate to mafic tuffs. Within the quartz-sericite schist unit, a 50-metre-thick strongly gossanous zone hosts increased (5% to 8%) disseminated pyrite, and four semi-massive and massive sulphide bands between 0.4 to 2.0 m thick. A 0.7-metre-thick band of semi-massive to massive sulphides is composed of granular pyrite with minor black sphalerite and trace chalcopyrite. A chip sample collected by the writer through this zone assayed 0.14% Cu, 166 ppm Zn and 17 ppb Au .

The exploration history of this prospect helps indicate the level of exploration coverage through the Ecstall belt. The showing as discovered on Friday, August 13, 1999 during follow-up of regional stream sediment and moss-mat survey anomalies. The prospect was located in an eight-year-old logging roadcut where it is exposed as a 50-metre-long highly gossanous band, now heavily overgrown by roadside brush. While this sequence of events demonstrates the effectiveness of stream sediment geochemistry, it also shows that logging roads in the area have not been routinely prospected.

3. Mark

The Mark prospect is 7 kilometres north-northwest of the Ecstall deposit. The showing crops out in a cirque at the head of an unnamed creek that drains northward into Big Falls Creek. This minor showing of pyritic quartz-sericite-chlorite schist is 50 metres thick and can be traced for 800 metres along strike (Graf, 1981c, p.19-20). Malachite was noted in all outcrops. The best assay values are 0.14% Cu, 0.01% Pb, 0.02% Zn, 0.06 opt Ag and 0.002 opt Au (Graf, 1981c).

4. Marmot

Marmot is exposed on a ridgecrest and on the adjacent south-facing slope, 7 kilometres north of the Ecstall deposit and along the linear trend of Red Gulch. In detail, the Marmot showing lines up along strike with the quartz-sericite schist horizon that hosts the Third Outcrop prospect (7).The Marmot prospect consists of rusty-weathering pyritic quartz-sericite schist; host rocks are chlorite schists (Graf, 1981c, p.20). Soil and stream sediment samples collected in the area of this occurrence are moderately anomalous in copper, lead and zinc. The best assay obtained for the showing was 0.006% Cu, 0.01% Pb, 0.02% Zn, 0.01 opt Ag and 0.002 opt Au (Graf, 1981c).

5. West Marmot

West Marmot crops out 2 kilometres southwest of the Marmot prospect, along the same high ridgecrest. No rock descriptions or assays are reported for this large rusty scree zone.

6. Ridge

The Northern Pyrites Limited prospecting map (Mason, 1937c) shows a short, narrow, north-northwest-trending gossanous alteration zone on the ridgecrest 500 metres east of the peak of Red Gulch Mountain.

7. Third Outcrop (103H 012)

This prospect lies 900 metres north-northeast of the northern end of the North Lens of the Ecstall deposit (9). The showing was discovered during the exploration program of 1919 (MacDonald, 1920, p.3) by searching for the source rocks of an iron-oxide cemented talus pile that had come to rest in Red Gulch Creek. The prospect crops out 60 metres east and uphill of Red Gulch Creek, exposed in a minor west-draining creek gully. A lens of massive pyrite, 30 metres long and 1.5 to 2.0 metres thick, is hosted in pyritic quartz-sericite schist (Hassard *et al.*, 1987b, p. 24-26 and Figure 6). A 1952 drill program completed 13 short holes; best assays obtained were 0.63% Cu and 2.3% Zn over 5.18 metres. The immediate hangingwall (east side) rock is a 30-centimetre-thick chert unit. The northward continuation of this zone crops out 150 metres to the north-northwest in Red Gulch Creek as a 10 centimetre-wide band of massive pyrite. The host pyritic quartz-sericite schist unit has been traced for another 1.4 kilometres to the north-northwest where it crops out as the Ridge prospect (6) along the crest of Red Gulch Ridge. The northward projection of this quartz-sericite schist horizon beyond Red Gulch Ridge coincides with the Marmot prospect (4).

8. East Plateau (103H 050)

This prospect crops out 930 metres northeast of the north end of the North Lens of the Ecstall deposit, at an elevation of 665 metres (Hassard *et al.*, 1987b, p.28 and Figure 6). Exposed in a west-southwest-draining creek, a one metre wide sericitic shear zone strikes sub-parallel to the Ecstall massive sulphide lenses and hosts 5% pyrite and trace disseminated sphalerite. A single grab sample assayed 0.184% Zn and 0.032% Cu (Hassard *et al.*, op. cit.). Host rocks to the pyrite-sericite schist are variable quartz-chlorite schists.

9. Ecstall (103H 011)

Seasoned gold prospector Charles Todd discovered the Ecstall massive sulphide deposit in 1890 (Flewin, 1924, p.209). His financial partner was J.N. MacKay, chief factor for the Hudson's Bay Company at Port Simpson. While no credit is given to local natives, Todd was the Indian Agent for northern British Columbia at the time of this discovery, and was likely guided to this remote, heavily overgrown site. One sample of Ecstall sulphides reached the Geological Survey of Canada laboratory in Ottawa in 1891 and is described by G.C. Hoffman (1892, p.67R) as:

"12. PYRITE. A crystalline, granular, massive, iron-pyrites, through which is disseminated a trifling amount of blende, occurs at the head of Eckstall Inlet, south of Port Essington, Skeena River, British Columbia, where it is said to constitute a vein fifteen feet wide, nearly vertical, running in a north-easterly direction from the shore and traceable for nearly a mile. It has been examined by Mr. Johnston and found to contain a trace of gold and 0.350 of an ounce of silver to the ton of 2,000 lbs., likewise a trace of copper and a little zinc, but no nickel or cobalt."

Todd decided not to stake the Ecstall showing, presumably reflecting his interest in gold prospects.

The Ecstall deposit remained open for 10 years and was finally staked for the first time in April, 1900 by prospector Henry Prevost for William Edgar Oliver of Victoria. The four initial claims, Bell-Helen, Bluestone, Red Bluff and Red Gulch were sold to John Bryden that same year (Flewin, 1901, p.788-789), and the claims were crown-granted in 1902. Table 3 summarizes the exploration history at the Ecstall deposit.

The geology at the Ecstall deposit has been described in reports by Schmidt (1995a), Hassard *et al.* (1987b), Douglas (1953), Bacon (1952), Holyk (1952a) and MacDonald (1918, 1927) and is illustrated in maps by Schmidt (Figure 4 in 1995a), Hassard *et al.* (Figure 6 in 1987b), Bacon (1952, p.A83) and Holyk (1952b,c).

The Ecstall deposit is best exposed in a spectacular outcrop in the floor of a narrow canyon (Figure 6). The floodwaters of Red Gulch Creek have exposed a continuous outcrop of faintly laminated, medium to coarse-grained pyrite over a 25 metre by 90 metre area on the east side of the creek, 1.5 kilometres upstream from the Ecstall River. This is the northernmost outcrop of the deposit which consists of two en echelon sulphide lenses, the North Lens and South Lens. These two lenses are exposed discontinuously for 570 metres along the banks of Red Gulch Creek. The two deposits strike north, dip 80º E and plunge 70º to the south. The North Lens is considerably larger and reaches a maximum width of 37 metres near its northern end. The North Lens has been completely delineated by drilling, but the South Lens remains open to the south and to depth at its southern end.

Both lenses are composed of medium to coarse-grained granular pyrite with trace to minor sphalerite and chalcopyrite, and rare galena and pyrrhotite. The sulphides are cemented by about 5% calcite-quartz-sericite gangue. This less resistant gangue material preferentially weathers out, freeing the sulphide grains. Consequently, outcrops of the Ecstall deposit massive sulphides have not formed major gossans; sections of the North Lens exposed along the creek are blanketed by bright pyrite sand banks and similar accumulations of pyrite sand have been built up by back eddies all the way down Red Gulch Creek.

The two massive sulphide lenses are enveloped by a one to two metre thick zone of quartz-muscovite/sericite schist. Schmidt (1995a, p.9) documented that footwall strata west of the South Lens and hangingwall strata east of the North Lens are mirror-image sequences consisting of quartz-muscovite schist, quartz-muscovite-biotite gneiss, quartz-chlorite schist and a unit of interlayered muscovite and chlorite schists. He concluded that the two main lenses of the Ecstall deposit lie in opposite limbs of a tightly-folded antiform. Douglas (1953a) noted that the lenses diverge at depth. The fold axis is near-horizontal and located above the present erosion surface. A distinctive sill-like body of foliated hornblende-quartz-feldspar quartz-diorite rock intrudes the hanging wall strata; Childe (1997, p.222-227) obtained a U-Pb age of 377 +9/-4 Ma from this rock, within analytical error of Gareau's U-Pb age of 385 +/- 4 Ma for the Big Falls tonalite, suggesting that the two foliated intrusions are comagmatic.

Base-metal sulphides show zonal distributions within the deposit. Sphalerite content increases in a narrow zone along the eastern (hangingwall) contact of the North Lens. Chalcopyrite is significantly enriched along the footwall of the North Lens. The upper section of the South Lens (that is, elevations greater than 35 metres below sea level) has copper grades 3 times greater than the deeper section of the lens, but zinc content is constant throughout (Table 4).

In plan, the outline of the North Lens resembles a tadpole; the northern end of the deposit is consistently the thickest part at all levels. In long section the North Lens has the outline of an heraldic shield. The maximum di-

TABLE 3
HISTORY OF EXPLORATION AND DEVELOPMENT AT THE ECSTALL DEPOSIT

Year	Work Done	Company	DDH Holes	Surface Length (ft)	Surface Length (m)	Underground Length (ft)	Underground Length (m)
1901		BC Pyrites Co.	1	68	20.7		
1901	Bulk Sample	BC Pyrites Co.					
1916	Drilling	Hinman	3	734	223.7		
1918	Drilling	Granby	14	3,647	1,111.6		
1919	Drilling	Granby	17	6,446	1,964.7		
1923	Drilling	Granby	?	?	?		
1937-40	Drilling	TGS	40			5964	1,817.8
1952	Drilling	TGS	23	1,378	420.0	8880	2,706.6
1966	Bulk Sample	TGS					
TOTALS			98		3,740.8		4,524.5

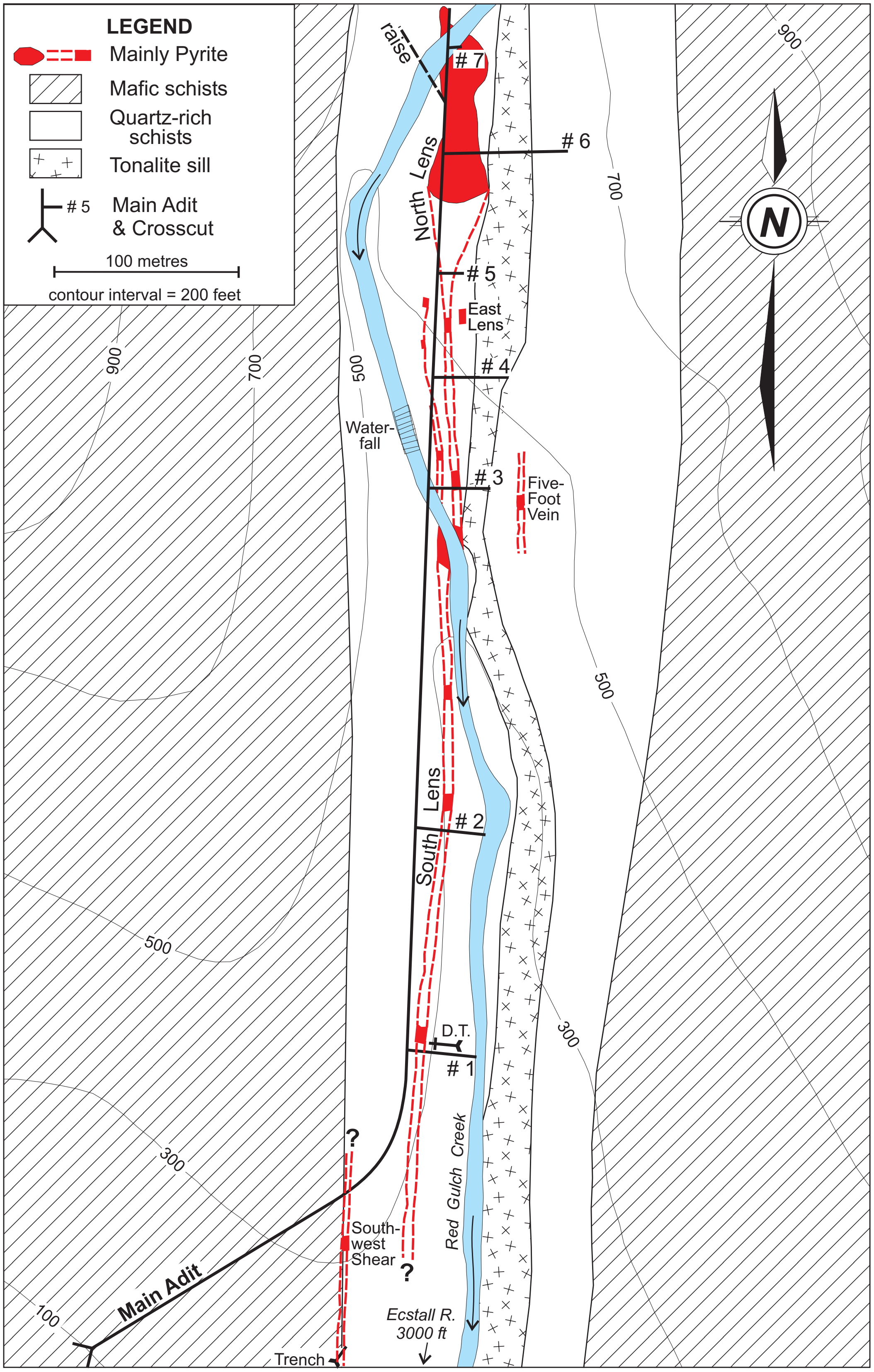

Figure 6. Geology of the Ecstall deposit (modified from Bacon, 1952).

TABLE 4
RESERVES AT THE ECSTALL DEPOSIT

Zone	Tons	Tonnes	% Cu	% Zn	% Pb	opt Ag	opt Au	Source
North Lens	3,400,000	3,084,140	0.80	2.00		0.5	0.015	Mason, 1961
North Lens	3,800,000	3,446,980	0.86	2.20	0.2	0.74	0.02	Gray, 1961
North Lens	3,030,000	2,748,513	0.80	2.00				Douglas, 1952
North Lens	3,240,000	2,939,004						Guernsey, 1936
North Lens	4,036,875	3,661,849	1.24			0.6	0.03	MacDonald, 1918
North Lens	3,843,475	3,486,416	0.86	2.20		0.74	0.02	MacDonald, 1920, 1927
North Lens Footwall	450,000	408,195	2.00			0.52	0.028	Gray, 1961
North Lens Footwall	339,100	307,598	1.91			0.5	0.028	Mason, 1940
North Lens Footwall	425,000	385,518	1.85			0.52	0.028	Mason, 1940
North Lens Footwall	623,200	565,305	1.89			0.8	0.03	MacDonald, 1920
North Lens Footwall	350,000	317,485	2.00			0.5	0.02	Peatfield, 1980
North Lens Footwall	412,500	374,179	2.79			1.2	0.05	MacDonald, 1918
South Lens	4,183,000	3,794,399	0.45	3.00		0.8	0.013	Mason, 1961
South Lens	4,756,000	4,314,168	0.44	2.95				Douglas, 1952
South Lens	3,900,000	3,537,690						Guernsey, 1936
South Lens	900,000	816,390	1.24			0.6	0.03	MacDonald, 1918
South Lens	1,000,000	907,100	0.50	2.90		0.6	0.01	MacDonald, 1920, 1927
Ecstall Deposit	4,843,475	4,393,516	0.79	2.30		0.71	0.02	MacDonald, 1920, 1927
Ecstall Deposit	7,140,000	6,476,694						Guernsey, 1936
Ecstall Deposit	7,786,000	7,062,681						Douglas, 1952
Ecstall Deposit	7,583,000	6,878,539	0.65	2.45				Mason, 1961
Ecstall Deposit	8,024,834	7,279,327	0.55	2.75		0.5	0.015	Tipple, 1958
Deposit: High Grade	4,883,000	4,429,369	0.85	2.20				Mason, 1940
Deposit: Lower Grade	2,700,000	2,449,170	0.30	2.90				Mason, 1940

mensions of this sulphide body are 333 metres long by 150 metres deep by 37 metres wide. The deposit has been drilled off, although potential still exists for separate lenses nearby. The western, footwall section of the North Lens includes a copper-rich zone of 385,000 tonnes grading 1.85% Cu, 18 g/t Ag and 1.0 g/t Au (Mason, 1940f and Table 4). A thin zinc-rich band has been identified along the eastern contact at the northern end of the lens. In 1940, five channel samples across the entire North Lens were collected from underground and analysed for 9 elements at the Texas Gulf Sulphur Company laboratory (Mason, 1940c); selenium analyses ranged from 40 ppm to 100 ppm. In the present study, four surface samples of North Lens sulphides were analysed for 39 elements; selenium concentrations ranged from 31 ppm to 108 ppm.

The South Lens is a thin sulphide slab. This lens thickens slightly below its surface exposure and the grade increases, then drops off again at depths below 35 metres below sea level. At its maximum, the South Lens measures 533.4 metres along strike and has a maximum thickness of 15.25 metres. It has been intersected in drilling at 293 metres below sea level, and no holes test the zone below this depth. In long section the South Lens resembles a parallelogram with one horizontal edge (along surface) and two roughly parallel edges plunging southward at 70 degrees. The South Lens remains open to depth at its southern end and to the south. The geological resource for the South Lens is 3.8 million tonnes at 0.44% Cu and 2.95% Zn (Douglas, 1952).

Two sulphide lenses lie just to the east and uphill of the North Lens. Both are small, but significant, because they indicate potential for additonal sulphide lenses to the east of the North Lens, perhaps stepped off in an en echelon pattern. Sixty-five metres north-northeast of the main waterfall in Red Gulch Creek, the East Lens crops out just 7 metres east of the North Lens, separated from it by a unit of black argillite (Figure 4 in Schmidt, 1995). Early geology maps depict the East Lens as one sulphide body, but Schmidt shows that the East Lens consists of two adjacent thin massive pyrite layers exposed in the canyon of a small creek that drains southwestward into Red Gulch Creek. The Five Foot Vein (Douglas, 1953, p.20-21) is another massive pyrite lens that lies east of the North Lens, 80 metres southeast of the main waterfall in Red Gulch Creek. It crops out at 160 metres elevation, in a small creek that drains into Red Gulch Creek at the southern end of the North Lens (Figure 4 in Schmidt, 1995a). A grab sample collected by Schmidt (sample US-E94-013 on Figure 5 in Schmidt, 1995a) assayed 1.38% Cu, 0.27% Zn, 54.5 g/t Ag and 280 ppb Au.

One massive sulphide lens has been identified on the west side of the deposit. The Southwest Shear (Douglas, 1953, p.21 and p.28) crops out uphill and to the west of the South Lens, 120 metres south-southwest of the portal of the Dunsmuir Tunnel, as a 25-centimetre-wide band of massive pyrite, hosted in quartz-sericite schist. Directly south, just north of the old mining camp and 140 metres east of the Main Adit portal, this horizon is exposed again in a large open cut near the base of the hill (Figure 6 in Hassard *et al.*, 1987b), where it is termed the Trench prospect (14). The sulphide layer is 10 centimetres wide in this location, again hosted in quartz-sericite schist, and a sample assayed 330 ppm Cu, 1200 ppm Zn, 46 ppm Pb, 4.5 ppm Ag and 70 ppb Au (Hassard *et al.*, 1987b, p.26). This same zone was intersected in the Main Adit, mid-way between the portal and the No. 1 crosscut, and was also intersected in underground drillholes 60 and 60a, drilled southward from the east end of the No.1

crosscut (Douglas, 1953). The Southwest Shear / Trench prospect is significant because it indicates good potential for a lens of massive sulphide mineralization en echelon to the southwest of the South Lens.

Further to the north and south of the Ecstall deposit, good potential for additional massive sulphide deposits along the Ecstall horizon is indicated by the Third Outcrop (7) and Marmot (4) prospects to the north, and by the North Mariposite (20) and Mariposite (21) prospects to the south.

The Ecstall deposit has been evaluated at different times as a possible source of pyrite (for sulphuric acid production), for copper and for zinc; consequently several reserve calculations have been completed (Table 4). The global resource for the deposit is 7,279,327 tonnes at 0.55% Cu, 2.75% Zn, 17 g/t Ag and 0.5 g/t Au (Tipple, 1958).

Nine diamond drill programs have been completed at the Ecstall deposit (Table 3). A total of 8265 metres of drilling have been completed in 98 surface and underground holes. The Ecstall deposit has been accessed from underground at five locations. In 1901, three short adits and a three-metre-deep shaft were completed (Flewin, 1902) . The Dunsmuir Tunnel, a 21-metre crosscut tunnel, was collared at 90 metres elevation, just below the southernmost outcrop of the South Lens. Track for a tramway was laid for 1006 metres from Dunsmuir tunnel to the wharf constructed on the north side of the Ecstall River. This adit allowed bulk sampling of the South Lens from two short (7 metres each) drifts blasted to the north and south of the main tunnel along the massive sulphide lens. During this same period, two short adits were collared at 145 and 155 metres elevation on the southern part of the North Lens, 20 metres east of the big waterfall in Red Gulch Creek (see Figure 4 in Schmidt, 1995a) and another short adit was collared into the base of the hillside at the campsite. The location of the 3-metre-deep shaft is unknown. The Main Adit system was developed between 1938 and 1940, collared at 37 metres elevation on the alluvial fan to the southwest of the deposit, west of the point where Red Gulch Creek emerges from its canyon. The underground workings total 1250 metres in length, consisting of a main drift (847 metres) along the footwall of the deposits, seven crosscuts (totaling 220 metres) off the main drift, one raise to surface (183 metres) at the north end of the drift, and three short exploration levels (drill stations) off this raise.

10. Swinnerton Creek

The Northern Pyrites Limited prospecting map (Mason, 1937c) shows a narrow, north-trending gossanous alteration zone 80 to 100 metres up the east bank of Swinnerton Creek, and 200 metres northeast of the mouth of Swinnerton Creek.

11. East Swinnerton

The Northern Pyrites Limited prospecting map (Mason, 1937c) shows a narrow, north-trending gossanous alteration zone 300 metres east of the mouth of Swinnerton Creek and parallel to and en echelon with the Swinnerton Creek showing (10).

12. Wharf

The Northern Pyrites Limited prospecting map (Mason, 1937c) shows a large, (300 metres wide, 650 metres long) gossanous alteration zone on the slopes just north of the Ecstall mine wharf (and one kilometre due west of the Ecstall North Lens). This zone trends east-northeast from a point 150 metres north of the Ecstall River to a point 800 metres from the river.

13. Red Bluff

The Northern Pyrites Limited prospecting map (Mason, 1937c) shows a short, narrow, north-trending gossanous alteration zone exposed in the east bank of Red Bluff Creek, 550 metres southwest of the large waterfall on Red Gulch Creek. This coincides exactly with the Red Bluff alteration zone mapped by Falconbridge (Figure 6 in Hassard *et al.*,1987b and p.26) and confirms the reliability of the earlier map. Falconbridge geologists describe the showing as a 10 centimetre wide band of massive pyrite in a 10 metre wide quartz-sericite schist unit, within a sequence of felsic to intermediate lapilli tuffs. A single sample (AB20730) of the massive sulphides assayed 2 ppm Cu, 51 ppm Zn and 40 ppb Au (Hassard *et al.*, op.cit.)

14. Trench (103H 051)

The Trench prospect crops out immediately southwest of the Ecstall South Lens (9). The showing is exposed by a large open cut near the base of the hill immediately north of the old mining camp, and 140 metres east of the Main Adit portal (Figure 6 in Hassard *et al.*, 1987b). In the exploration trench, quartz-sericite schist hosts a north-trending, 10 centimetre thick sulphide bed. A sample assayed 330 ppm Cu, 1200 ppm Zn, 46 ppm Pb, 4.5 ppm Ag and 70 ppb Au (Hassard *et al.*, 1987b, p.26).

This same thin massive sulphide bed crops out again uphill, directly to the north of this trench where it was termed the Southwest Shear (Douglas, 1953, p.21 and 28). This showing was investigated by a cluster of small prospecting pits to the west of the South Lens, 120 metres south-southwest of the portal of the Dunsmuir Tunnel, along the claim boundary between the Bluestone and the Red Gulch mineral claims. No assays are reported from these pits and outcrops. This same sulphide zone was intersected again in the Main Adit; mid-way between the portal and the No. 1 Crosscut is a 25 centimetre wide band of massive pyrite hosted in quartz-sericite schist (Douglas, 1953, Map Sheet 1). The Southwest Shear was also intersected in underground drillholes 60 and 60a, which were drilled southward from the east end of the

No.1 Crosscut (Douglas, 1953, p.21). The Trench / Southwest Shear prospect is significant because it indicates good potential for an en echelon lens of mineralization to the southwest of the South Lens.

15. West Grid Alteration Zone (103H 053)

The West Grid alteration zone encompasses a large area, including the whole of the basin of Thirteen Creek cirque, and extending as far north as Phobe Creek (Figure 5) (Figure 7 in Hassard *et al.*, 1987b and p.26-27). The entire West Grid area is also characterized by a broad alteration zone that extends from Phobe Creek to Thirteen Creek. Alteration consists of strong chloritization, sericitization and silicification over an area of 2.7 km^2 (Hassard *et al.*, 1987b, p. 21-22 and Figure 7). The alteration zone include four separate sulphide prospects: Phobe Creek (16), Elaine Creek (17), Sphalerite (18) and Thirteen Creek (19). Associated with the alteration is a unit of quartz-sericite schist up to 150 metres thick and characterized by chalcopyrite-malachite mineralization and anomalous copper-gold values up to 1.5% Cu and 310 ppb Au (Hassard *et al.*, 1987b). At Elaine Creek, the footwall (west side) chlorite schist is cut by numerous pyrite stringers which assay up to 0.87% Cu (Hassard *et al.*, 1987b). Several large boulders containing polymetallic sulphides have been identified scattered over the floor of the cirque, but the source of this float has not been located.

16. Phobe Creek (103H 069)

The Phobe Creek prospect was located during prospecting work in the early part of the century (Holyk *et al.*, 1958) This showing lies within the West Grid alteration zone (15) and is exposed along the banks of Phobe Creek at elevations ranging from 250 metres to 300 metres. Stringer and disseminated chalcopyrite occurrences are hosted in quartz-sericite-kyanite schist. This mineralization is similar in style and grade to the showings in Elaine Creek (17).

The disseminated chalcopyrite zone contains 5% disseminated chalcopyrite across a 6.5 metre wide band within the quartz-sericite-kyanite schist. A 7 metre composite chip sample across this mineralized band averaged 0.69% Cu, 66 ppm Zn, 2.22 ppm Ag and 251 ppb Au (Hassard *et al.*, 1987c, p.20-21 and Figure 7). The disseminated chalcopyrite zone is not well exposed and remains open along strike and to the west.

Stringers of chalcopyrite are scattered throughout the quartz-sericite-kyanite schist and adjacent mixed gneiss unit along Phobe Creek. Individual veinlets range from 1 to 3 centimetres wide and can be traced for a few metres. The best assays from grab samples are 6.56% Cu, 2041 ppm Zn, 19.1 ppm Ag, and 880 ppb Au (Hassard *et al.*, 1987c).

17. Elaine Creek

The Elaine Creek prospect lies within in the central area of the West Grid Alteration Zone (15) and consists of four separate showings well-exposed along the three main branches of Elaine Creek, and on the high ground mid-way between South Elaine Creek and Thirteen Creek. The Elaine Creek showings are very similar to the Phobe Creek (16) showings, and consist of chalcopyrite stringers and disseminated to blebby chalcopyrite, hosted by the quartz-sericite-kyanite schist unit (Hassard *et al.*, 1987c, p.19-20 and Figure 8). The numerous chalcopyrite veinlets are 1 to 3 centimetres wide and can be traced for a few metres. Grab samples from all four showings were averaged for each zone, and the best assays from these averaged samples ranged up to 3.04% Cu, 913 ppm Zn, 11.7 ppm Ag, and 1525 ppb Au (Hassard *et al.*, 1987c). The assays show a consistent pattern of increasing gold northward over the 800 metre distance between these showings.

18. Sphalerite (103H 070)

The Sphalerite showing lies within the West Grid Alteration Zone (15) and crops out at 465 metres elevation, 250 metres north of Thirteen Creek (Hassard *et al.*, 1987b, p.19 and Figure 8). A 4 centimetre thick layer of banded sphalerite is exposed in one small outcrop over a 2.2 metre strike length along the contact between quartz-chlorite-biotite schist and a marble unit. The immediate host rock is green, medium-grained calc-silicate rock. A grab sample assayed 6.0% Zn, 579 ppm Cu, 28 ppm Pb, 1.5 ppm Ag, 15 ppb Au and 746 ppm Cd (Hassard *et al.*, 1987b).

19. Thirteen Creek (103H 54)

The Thirteen Creek prospect lies within the West Grid Alteration Zone (15) and crops out on cliffs on the south side on the Thirteen Creek cirque at 640 metres elevation. The showing is a 30 centimetre wide chert bed which hosts pods of massive pyrite-chalcopyrite (Hassard *et al.*, 1987b, p.26 and Figure 7). The chert unit has been traced for 100 metres along strike. A grab sample assayed 8.05% Cu, 0.53% Zn, 350 g/t Ag and 2.4 g/t Au (Hassard *et al.*, 1987b).

20. North Mariposite

The North Mariposite prospect is the northward continuation of the Mariposite prospect (21) and hosts up to 50% pyrite in six separate units of bright green, pyritic, fuchsite-rich, quartz-sericite schist (Hassard *et al.*, 1987a, p.27-28 and Figures 7 and 8). One strongly pyritic sample, collected 1.2 kilometres north of Mariposite Lake, assayed 0.22% Zn. The quartz-sericite schist units of the Mariposite schist belt are exposed discontinuously for 3.5 kilometres between Allaire Creek and Thirteen Creek and are typically anomalous in zinc. In the area of the North Mariposite prospect, the formations display their thickest intervals, highest pyrite concentrations and best base metal grades.

21. Mariposite (103H 052)

The Mariposite showing trends south from Mariposite Lake, along Mariposite Creek to Allaire Creek, a distance of 1.75 kilometres. The prospect consists of a thick unit of bright green, pyritic quartz-mica semischist within a steeply dipping unit of charcoal to black, weakly pyritic metasiltsone. The thickness of individual units ranges up to 120 metres, and six separate units have been identified within the stratigraphic succession. Pyrite content of the quartz-mica schist typically ranges from 1% to 5%, but local concentrations up to 50% pyrite are exposed at the adjacent North Mariposite prospect (20). The bright green mica has been identified as the chromium-rich muscovite, fuchsite, by SEM-EDX analysis (McLeod, 1984a). This mica varies in abundance from 1% to 20% of the rock and averages 5%. Fuchsite is concentrated along foliation planes and is preferentially displayed along fracture surfaces. The probable protolith to this silica-rich schist has been identified as felsic tuff or a pyritic tuffaceous chert (exhalite).

The unit has been sampled in several shallow prospecting trenches. One drill hole, 86-MAR-1, completed by Falconbridge in 1986 at the Mariposite prospect intersected one unit of quartz-mica schist with a true thickness of 16 metres. Best assays from core samples are 290 ppm Cu, 1200 ppm Zn, 440 ppm Pb, 5.5 ppm Ag and 110 ppb Au (Hassard *et al.*, 1987a, p.27-28 and Figures 7 and 8). In comparison, drilling at the North Mariposite prospect intersected 6 intervals of quartz-sericite schist; however, the geologic setting differs at the Mariposite prospect where the western margin of the volcano-sedimentary succession is intruded by a large body of foliated diorite (variably mapped as amphibolite or pyroxenite).

22. South Grid East (103H 055)

The South Grid East quartz-sericite schist lies stratigraphically 350 metres east of the Mariposite quartz-sericite schist belt (20, 21 and 33), and crops out to the south of Allaire Creek. This unit is 20 to 90 metres thick, strikes 172º, dips 85ºE, and extends for 1.7 kilometres along strike from Allaire Creek to Balan Creek (Hassard *et al.*, 1987b, p.28 and Figure 8). Pyrite content ranges up to 30%. A grab sample assayed 0.12% Cu and 0.024% Zn (Hassard *et al.*, 1987b).

23. Amber (103H 071) and 24. El Amino (103H 071)

The El Amino (Frizzell) and the Amber prospects are hosted in metasedimentary rocks and are described in a separate report by Scott (this volume).

25. Balan Creek Anhydrite

The Falconbridge (1987c) geology map shows an anhydrite occurrence exposed at a bend of Balan Creek, 75 metres upstream from the Balan (26) showing.

26. Balan

The Falconbridge (1987c) geology map shows that the east-draining glacial valley of Balan Creek cuts through three horizons of pyritic quartz-sericite schist. These are 1. the Balan showing, 2. the continuation of the North Mariposite (20), Mariposite (21) and Ravine (33) prospects, and 3. the southern continuation of the South Grid East prospect (22).

27. Bear (103H 056)

The Bear prospect includes a series of parallel pyritic quartz-sericite schist horizons which lie along strike to the south of the South Grid East prospect (22). The felsic pyritic schist horizons range from a few centimetres to 25 metres thick and locally host massive to semi-massive sulphides (Maxwell and Bradish, 1987a, p.13). Country rocks are greywackes, well laminated siltstones, banded quartzite and argillite.

28. Packsack (103H 013)

The Packsack deposit crops out in five small exposures in two parallel east-draining creeks, at 230 metres elevation on the east slope of Prospect Ridge. The deposit was discovered by W. Padgham in September, 1957, as a single 4.5 metre wide massive sulphide band in Gunnysack Creek. Follow-up work revealed another four sulphide horizons distributed over a 25 metre interval along Packsack Creek, 150 metres to the south of Gunnysack Creek (Schmidt, 1996a,b).

The Packsack property has been repeatedly explored by prospecting and by geological, geochemical and geophysical programs over 40 years. The deposit was drilled in 1960 (11 holes) and again in 1990 (3 holes). Exploration trenches are conspicuous by their absence, but the sulphide deposit has been well-delineated by drill intersections and by EM surveys. Thirteen of the 14 drillholes intersected massive and semi-massive pyrite, and the deposit remains open to the north, south and at depth. Drilling has outlined two adjacent massive sulphide horizons, the Main and Hangingwall Zones, that range in true thickness from 2 to 8 metres. Both extend along strike for at least 500 metres. The geological resource at Packsack is 2.7 million tonnes at 0.5% Cu, 3.0% Zn, 0.01% Pb, 34 g/t Ag and 0.34 g/t Au (Graf, 1981c, p.23).

The sulphide lenses are hosted in pyritic quartz-sericite schist units that are interbedded with basaltic and andesitic tuffs and massive flows (Payne, 1990a). The pyritic quartz-sericite schists are interpreted and felsic ash tuffs and fragmental tuffs.

29. Rainbow

The Rainbow showing is located 250 metres east of Lower Ecstall Lake. The small outcrop knoll in this swampy area consists of north-trending, interlayered felsic and intermediate metavolcanics and two units of pyritic quartz-sericite schist. Noranda (1986c) evaluated the pyritic schist with two large east-trending exploration trenches. The highest assays obtained from 16 trench samples are 400 ppm Cu, 10 ppm Pb, 3100 ppm Zn and 1.8 ppm Ag (Noranda, 1986c). A sample of quartz vein exposed in the southwestern trench assayed 3.9 ppm Au.

30. Horsefly (103H 014)

The Horsefly prospect is located 4.5 km southeast of the Packsack deposit (28), high on the eastern slope above the upper reaches of the Ecstall River. The showing crops out at 685 metres elevation in three adjacent creeks over a distance of 100 metres, and the mineralized horizon is also exposed in a cliff-face 300 metres further to the south. Horsefly lies 1 kilometre north of, and along strike with, the Steelhead showing (31).

The prospect was discovered the Texas Gulf Sulphur Company Ltd. in 1960 during a regional exploration program following on from the discovery of the Packsack and Scotia deposits. Subsequently, the property was explored by a joint venture group in 1981, by Noranda Exploration in 1986, and by Atna Resources Ltd. in 1995. Five holes, totaling 652 metres, were drilled on the showing in October, 1995. The claims are owned by Ecstall Mining Corporation Ltd.

Local stratigraphy is a complex succession of mafic to intermediate to felsic volcaniclastic rocks and flows, and minor intercalated sedimentary units (Schmidt,1996a, p. 6-7). The showing consists of a 1 metre thick lens of massive pyrite with minor sphalerite, chalcopyrite and pyrrhotite hosted in a pyritic quartz-sericite schist unit that is 10 metres thick (Graf, 1981c, p.24). Siliceous argillite units adjacent to the host quartz-sericite schist are weakly pyritic and anomalous in zinc and lead. The best assay obtained from the discovery outcrops is 1.16% Cu, 0.13% Pb, 4.6% Zn, 39 g/t Ag and 0.5 g/t Au (Graf, 1981c). The drilling program outlined a blind, buried, 20 metre thick zone of disseminated and semi-massive sulphides, which is separate from the outcropping Horsefly prospect (Schmidt, 1996a, p.13). This zone is located 100 metres southeast of the Horsefly showing. It has been traced by drilling for 90 metres along strike and remains open in all directions. The best assay obtained from drill core was 2.75 metres of 1.69% copper; however, grades up to 5.6% copper, 1.65% Zn, 900 ppm Pb 30 ppm Ag and 860 ppb Au were obtained over narrower intervals of core (Schmidt, 1996a).

31. Steelhead (103H 036)

Located 1 kilometre south of the Horsefly (30) prospect, the Steelhead showing was discovered in 1986 during follow-up of Noranda Exploration's airborne EM survey. Investigation of the area around a series of strong ABEM anomalies outlined 3 pyritic quartz-sericite schist units hosting from 1% to 30% pyrite. In detail, these units consist of pyritic rhyolite, quartz-sericite schist and breccias (Schmidt, 1996a, p.8). Mineralization occurs as pods or patches of pyrite and pyrrhotite, with associated chalcopyrite and sphalerite. Some mineralization occurs in fragments within the breccias. As at the Horsefly prospect, the black siliceous argillite horizons in the Steelhead area are also mineralized with disseminated pyrite, pyrrhotite and rare chalcopyrite. Local geology consists of a succession of mafic to intermediate to felsic volcaniclastic rocks and flows, and minor intercalated sedimentary units (Schmidt, 1996a, p.6-7). Schmidt also reports (op. cit.) that fragmental rocks on the east side of the Steelhead grid have well-preserved primary textures - abundant lapilli and crystal fragments and rare bomb sags are evident. Numerous exposures of graded beds were also noted but textures were not clear enough to ascertain tops.

The best assays obtained from a series of grab samples were 1.65% Cu, 3.8% Zn, 5.8 g/t Ag and 120 ppb Au (Schmidt, 1996a). Three holes, totaling 424 metres, were drilled at Steelhead by Atna Resources Ltd. in September, 1995; the best intersection assayed 0.027% Cu, 1,276 ppm Pb, 362 ppm Zn, 13.8 ppm Ag and 24 ppb Au over 4.9 metres in an argillite unit hosting disseminated pyrrhotite and trace chalcopyrite (Schmidt, 1996a).

32. Marlyn

This showing lies 2.2 kilometres east of the Horsefly prospect (30), on the east-facing slope of Horsefly ridge. Rusty pyritic quartz-sericite schist assayed 0.005% Cu, 0.01% Pb, 0.05% Zn, 0.05 opt Ag and 0.002 opt Au (Graf, 1981c). Silt samples collected along the trend of this pyritic unit showed erratic, weakly anomalous copper and zinc values.

33. Ravine

A large semi-continuous gossanous zone trends north-northeast along this creek for 3.5 kilometres (Graf, 1981c). This marks the southern end of a prominent, narrow topographic depression that can be trace northward through exposures in Balan Creek to the Mariposite (21) and North Mariposite (20) zones.

34. Strike

This showing lies 6 kilometres west-southwest of Ecstall Lake. Two pyritic quartz-sericite schist units (up to 20 metres thick) and one pyritic argillite unit (50 metres thick) crop out in the area (Graf, 1981c, p.24-25). Only pyrite was noted in hand samples. The best assay from these exposures was 0.17% Cu, 0.27% Pb, 2.83% Zn, 1.13 opt Ag and 0.01 opt Au (Graf, 1981c). Stream sediment samples are moderately anomalous in copper and zinc over a distance of several thousand metres to the north of the showing.

35. Decaire (103H 016)

The Decaire lead-zinc prospect is located 1.5 kilometres north of Douglas Channel and 6 kilometres northeast of Kitkiata Inlet. The occurrence crops out on the easty side of the north fork of Koskeesh Creek at an elevation of 170 metres. This showing is a quartz vein which hosts minor cross-fractures of sphalerite, pyrite and minor galena. The quartz vein ranges from 2 to 4 metres wide over a 20 metre strike length, but the fracture-controlled sulphide mineralization is described as “very sparse” (Mandy, 1930, p.66). Two small prospecting pits were blasted in 1929. Early reports describe the quartz vein as hosted by silicified, foliated granite where the latter is cut by a lamprophyre dike; Gareau (1997) shows the occurrence within an area of extensive metasedimentary rocks.

36. Abruzzi (103H 017)

The Abruzzi showing is located along the north shore of Douglas Channel, 7.5 kilometres northeast of Kitkiata Inlet. This occurrence is hosted by a 10 metre wide zone of chlorite-altered mafic garnet-biotite-hornblende schist within a large lens of the mafic schist that is incorporated in granite (Mandy, 1929, p.70); Gareau (1997) shows this locality as an area of extensive metasedimentary rocks. The alteration zone, and the enclosing schist, strike 150º and dip 80º west. Mineralization consists of sparsely disseminated pyrrhotite and chalcopyrite, with local massive patches. Stringers of massive chalcopyrite, 0.5 to 4 centimetres wide are scattered across the chlorite-altered zone; the largest chalcopyrite vein is 23 centimetres wide and extends for 3 metres length. The mineralization has been explored along the shore by a shallow shaft and two open cuts, 10 metres apart. A 2.4-metre chip sample across the southern open cut assayed 1.4% Cu, 0.30 opt Ag and trace Au (Mandy, 1930, p.66).

37. Douglas Channel Garnet (103H 064)

Along this ridgecrest on the north side of Douglas Channel, biotite-garnet schists host up to 15% coarse garnet ranging up to 2.0 centimetres diameter.

38. Kiskosh (103H 015)

GSC map 278A (1933) plots a copper showing on the west shoreline of Douglas Channel, midway between Kiskosh Inlet and Kitkiata Inlet. This map also indicates that the showing is associated with schistose rocks, suggesting that the showing is likely hosted by the heterolithic “quartzite” unit of Gareau (1997). The most likely location for this showing is thus two kilometres north of the mouth of Kiskosh Inlet; that is, 2.5 kilometres south of the location shown on Gareau (1997).

EXPLORATION POTENTIAL

The three largest massive sulphide deposits in the belt (Table 2) are important indicators for the overall exploration potential in this belt. In the next two paragraphs, the size and grade of these 3 deposits are compared to typical grades and tonnages for this type of mineral deposit.

In a study of 878 volcanogenic massive sulphide deposits worldwide (Table 3 in Barrie and Hannington, 1997), the average size for VMS deposits associated with bimodal volcanic succession and hosted by felsic volcanic units is 5.2 million tonnes. The three deposits in the Ecstall belt are of this order of magnitude. Significantly, all three deposits crop out, and all have been eroded. Therefore the original VMS deposits at Scotia, Packsack and Ecstall must all have been substantially larger when deposited than they are today.

The grades of the Ecstall belt deposits should be carefully considered in assessing future exploration potential. A comprehensive tabulation (Table 2 in Leistel *et al.*, 1998) of the grades and tonnage of all the massive sulphide deposits in the Iberian Pyrite Belt shows that the median copper grade is 0.9% Cu, the median zinc grade is 2.0% Zn and the median deposit size is 2.75 million tonnes. These are similar to the average grade and size of the Ecstall Belt VMS deposits. The deposits of the Iberian Pyrite Belt have been in production for 5000 years. However, the richest deposit of the belt, the blind, deeply buried, Neves Corvo deposit, was discovered just 23 years ago, demonstrating the elusiveness - and the rewards - of high grade VMS orebodies within a volcanic belt characterized by lower grade deposits.

The 36 sulphide showings along the Ecstall Greenstone Belt (Figure 5) all crop out, suggesting that the potential for blind, buried deposits is high. The recent drill intersection of a blind, buried sulphide prospect adjacent to the Horsefly showing is proof of this potential.

DISCUSSION AND CONCLUSIONS

The Ecstall Greenstone Belt is a Middle to Late Devonian volcanosedimentary succession with a complex post-depositional history. The belt hosts 36 sulphide mineral prospects, primarily Kuroko-type polymetallic volcanogenic massive sulphide deposits. Deposits and prospects are hosted by felsic volcanic units within the differentiated mid-Devonian volcanosedimentary succession. Decades of industry mapping programs have traced out many favourable felsic units, as well as exhalative horizons and extensive stockwork-style mineralized zones.

Deposits are most abundant in the central section of the belt (Figure 5), but this may be an artifact of the concentration of prospecting efforts around the mining camp at the Ecstall deposit. Preliminary results of a new regional stream sediment geochemistry program (Jackaman *et al.*, this volume) suggest that base metal potential is evenly distributed along the 80 kilometre length of the belt.

The volcanic arc that evolved into the Ecstall Greenstone Belt developed close to a continental margin, similar to the setting envisaged for the extensive volcanosedimentary successions of the Yukon-Tanana and Nisling terranes.

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Fieldwork by geologist Brad Scott contributed to the success of the 2000 field season. Peter Delancey at Atna Resources Inc., Chris Graf at Ecstall Mining Corporation and Arne Birkeland of Arnex Resources Ltd. each arranged to share their comprehensive corporate files covering a century of exploration work in this region, and discussed ideas and areas deserving research. Mike Fournier, BCGS, prepared the figures with care.

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