Stratigraphic setting of the LZ5 and Ellison mineralized zones, LaRonde Zone 5 project, Doyon-Bousquet-LaRonde mining camp, Abitibi, Quebec

Émile Boily-Auclair[1]*, Patrick Mercier-Langevin[2], Pierre-Simon Ross[1], and David Pitre[3]

[1]Institut national de la Recherche scientifique – Centre Eau Terre Environnement, 490 rue de la Couronne, Québec, Quebec G1K 9A9

[2]Geological Survey of Canada, 490 rue de la Couronne, Québec, Quebec G1K 9A9

[3]Agnico Eagle Mines Limited, LaRonde Division, 10200, route de Preissac, Rouyn-Noranda, Quebec J0Y 1C0

*Corresponding author's e-mail: emile.boily-auclair@ete.inrs.ca

ABSTRACT

The LaRonde Zone 5 (LZ5) project and the neighbouring mineralized zones of the Ellison property are part of the Doyon-Bousquet-LaRonde mining camp in the southern part of the Abitibi greenstone belt. The mineralized zones of the LZ5 (zones 4, 4.1, and 5) and the Ellison property (zones A and B) are hosted in the Bousquet Formation of the Blake River Group. The host rocks are steeply south-dipping (80–90°) and south-facing, mafic to felsic volcanic and volcaniclastic units. The synvolcanic gold mineralization consists of deformed discordant networks of millimetre to centimetre thick pyrite±pyrrhotite±chalcopyrite veinlets (10–20 vol.%) and, to a lesser extent, very finely disseminated pyrite (1 vol.%) in altered volcanic and volcaniclastic rocks. Prior to this study, the LZ5 and Ellison mineralized zones were interpreted to be hosted in the Bousquet heterogeneous unit (Unit 4.4) in the uppermost part of the lower member of the Bousquet Formation. The current study shows that the mineralized zones are located higher in the stratigraphic sequence, i.e., in highly deformed and altered mafic to felsic volcanic and volcaniclastic units (tuff and lapilli tuff) at the base of the upper member of the Bousquet Formation. Consequently, the LZ5 mineralization, which is considered one of the oldest in the camp, coincides in time and space with a shift in the magmatic evolution of the Bousquet Formation from dominantly tholeiitic-transitional mafic-intermediate (lower member) to dominantly transitional-calc-alkaline intermediate-felsic (upper member). The revised position of the LZ5 ore zones to slightly higher in the stratigraphic sequence substantiates the camp-wide association between Au (±Cu-Zn-Ag) mineralization and intermediate to felsic transitional to calc-alkaline magmatism and further indicates that hydrothermal and petrogenetic processes are linked in major synvolcanic Au deposits in the Archean.

INTRODUCTION

The Doyon-Bousquet-LaRonde mining camp in the southern Abitibi greenstone belt, Quebec, represents one of the richest Canadian gold districts. It hosts world-class Au-rich volcanogenic massive sulphide deposits as well as intrusion-associated Au±Cu vein systems (Mercier-Langevin et al., 2017). These contrasting deposit styles are considered to be mostly coeval, and part of an Archean synvolcanic magmatic-hydrothermal system (Yergeau et al., 2015; Mercier-Langevin et al., 2017, and references therein). Many of those deposits have been studied in detail over the past two decades, but the past-producing Bousquet 1 mine, and its lowermost ore zones (Zone 4.1, Zone 4, and Zone 5) remain poorly documented. These ore zones of the former Bouquet 1 mine are located in the central part of the camp and mark the transition between intrusion-related-style systems to the west, and volcanogenic massive sulphide (VMS)-style systems to the east. They thus represent a critical area for the understanding of the metallogenic evolution of the camp. Renewed mining activity in this area gave access to new material and exposures and provided an opportunity to study zones 4, 4.1, and 5, which define the LZ5 project. These zones were formerly part of the Bousquet 1 mine, which produced 42 t Au, or 1.36 Moz, from 1978 to 1996 (Mercier-Langevin et al., 2017). The LZ5 is currently mined underground by Agnico Eagle Mines Limited from the LaRonde mine complex and resources are estimated at 17.5 Mt of ore at 2.0 g/t Au for a total resource of 35.9 t Au (1.15 Moz) (Agnico Eagle Mines Ltd., 2019a).

Several models have been proposed for the timing and origin of the Au mineralization at Bousquet 1 (now LZ5 project), including a synvolcanic origin for both the gold and the sulphides (e.g. Valliant et al., 1982; Stone, 1990; Mercier-Langevin et al., 2007c), and a synvolcanic sulphide system overprinted by a syn-

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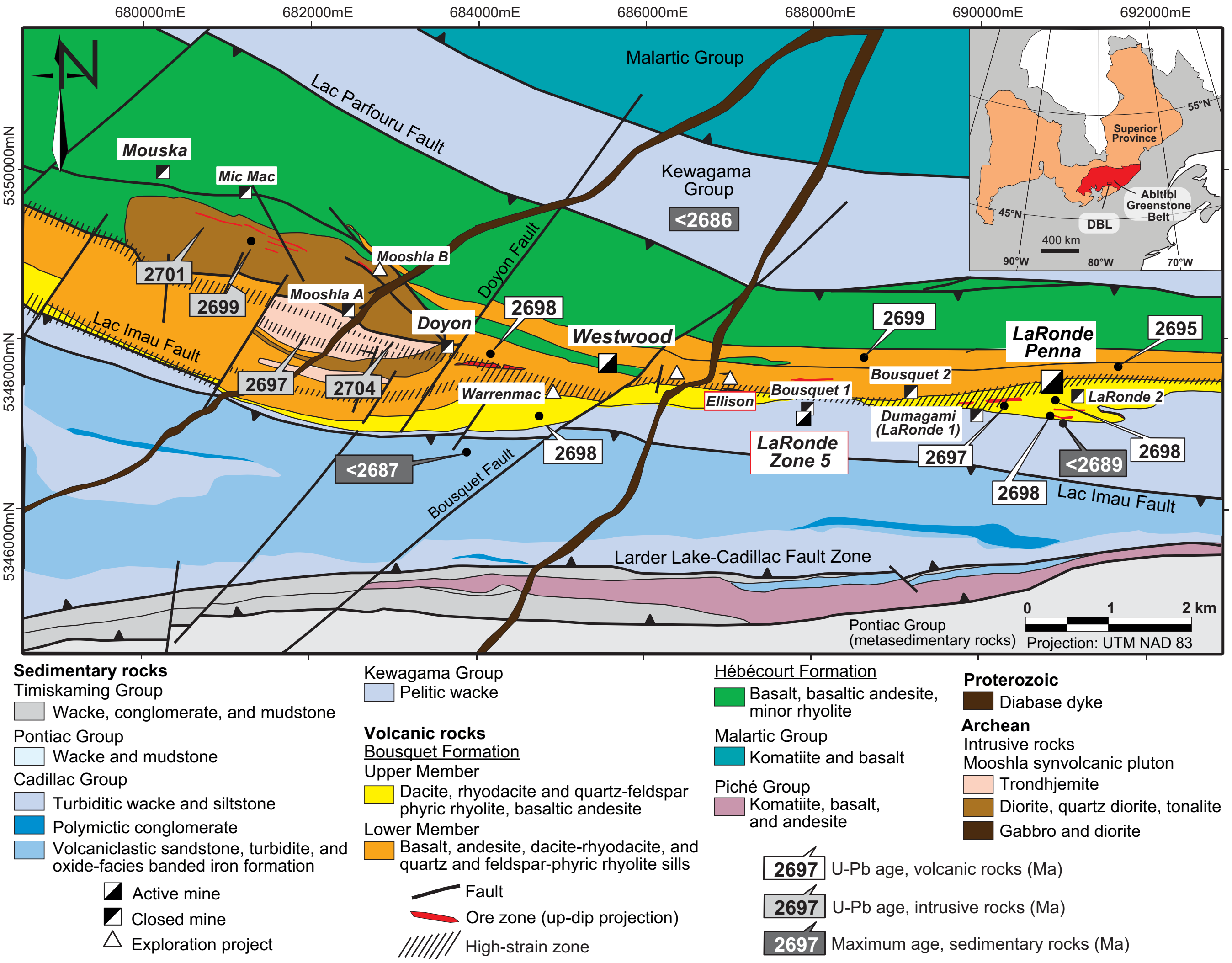


Figure 1. Geology of the Doyon-Bousquet-LaRonde mining camp (*from* Mercier-Langevin et al., 2017).

deformation gold episode (e.g. Tourigny et al., 1989). Even though recent work indicates a synvolcanic origin for the gold in the Doyon-Bousquet-Laronde (DBL) camp, doubts remain as to the exact timing of the auriferous mineralization at the LZ5 project, which shows characteristics that contrast with those of other deposits in the camp (Boily-Auclair et al., 2019). For example, the style of mineralization (pyrite±pyrrhotite±chalcopyrite±sphalerite veins and veinlets, and lesser disseminated and fragmental pyrite) strongly contrasts with the Au-rich massive and semi-massive sulphides, Au-rich sulphide vein stockworks and disseminations, intrusion-hosted sulphide-rich quartz veins, and orogenic sulphide-rich Au-Cu vein systems that have been documented in the DBL camp.

This report establishes the stratigraphic position of the mineralized zones at the LZ5 project and neighbouring Ellison property and examines the possible controls on ore style and distribution. Ongoing research at the LZ5 project and on the Ellison property aims to establish the relative timing of events, compare mineralization with the other ore styles of the camp, and contribute to the metallogenic models for Archean gold deposits in the southern Superior Province.

DOYON-BOUSQUET-LARONDE MINING CAMP

The Doyon-Bousquet-LaRonde mining camp represents one of the largest gold and base metal districts in Canada, with a total estimated gold budget of 865 t Au, (28.8 Moz; past production, estimated reserves, and resources: Mercier-Langevin et al., 2017). The stratigraphy of the DBL mining camp consists of a succession of volcanic and volcaniclastic rocks of the Hébécourt and Bousquet formations of the Blake River Group. The succession is homoclinal, dips steeply (~75–90º), and faces south (Fig. 1).

The Hébécourt Formation is the lowermost unit in the DBL camp and includes massive to pillowed mafic flows, including several variolitic layers of tholeiitic composition (Goutier, 1997; Fig. 1, 2). Conformably overlying the Hébécourt Formation is the Bousquet

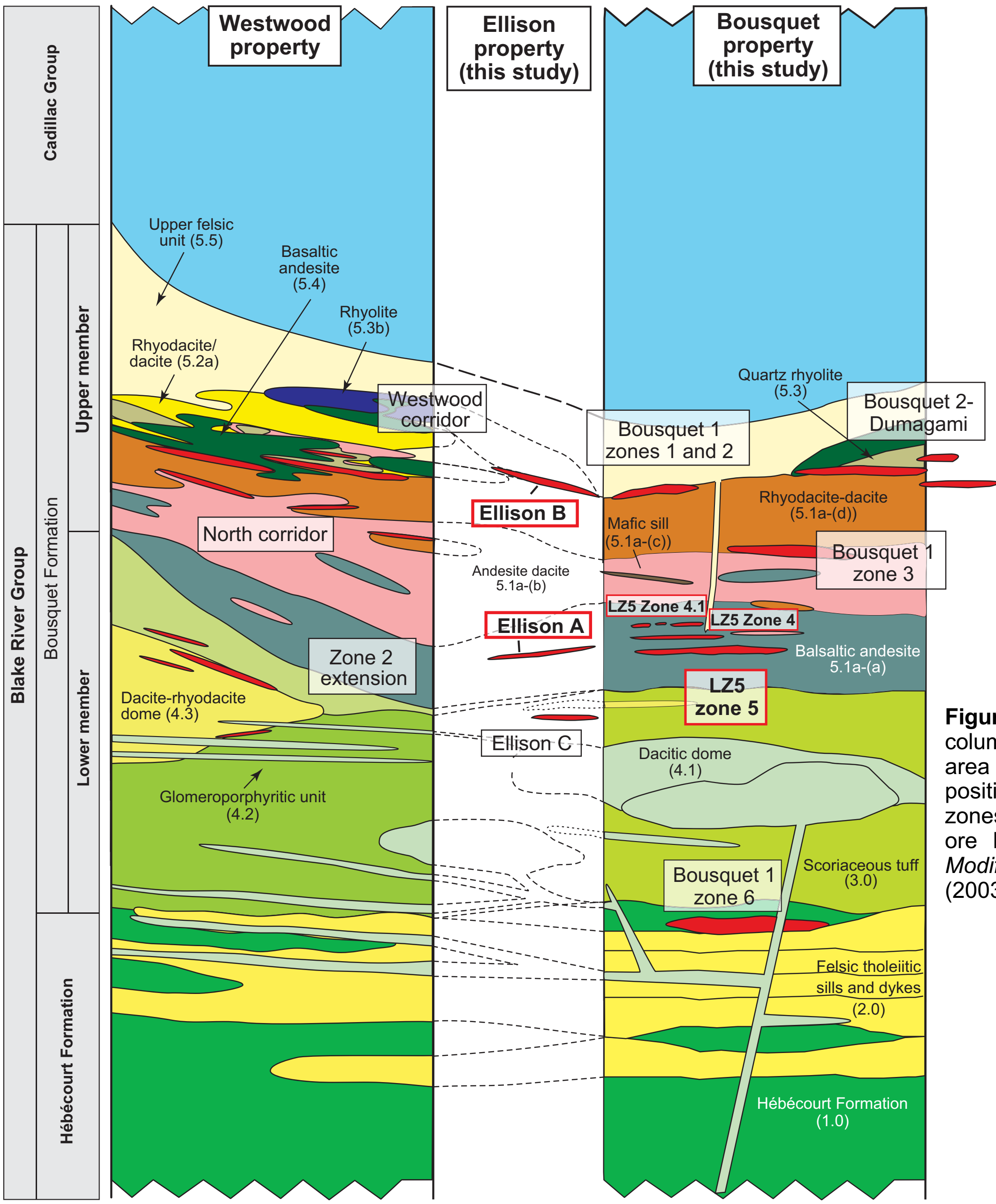


Figure 2. Simplified stratigraphic columns of the Bousquet-Ellison area showing the stratigraphic position of the main mineralized zones of the LZ5 project. The ore lenses are not to scale. *Modified from* Lafrance et al. (2003) and Yergeau (2015).

Formation (ca. 2699–2696 Ma), one of the youngest volcanic units of the Blake River Group (McNicoll et al., 2014). It is divided into two members: the lower member consists of volcanic to volcaniclastic, basaltic to andesitic rocks with minor felsic units; the upper member is andesitic to dacitic at the base and rhyolitic at the top (Fig. 2). The Bousquet Formation is tholeiitic at the base and calc-alkaline towards the top (Lafrance et al., 2003; Mercier-Langevin et al., 2007a).

The Hébécourt and Bousquet formations are structurally bounded to the north by the Kewagama Group sedimentary rocks (≤2684 ± 1 Ma: Davis, 2002) and to the south by the Cadillac Group sedimentary rocks (≤2687 ± 3 Ma: Davis, 2002; Lafrance et al., 2005). The contact between the Hébécourt Formation and the lower member of the Bousquet Formation is cut by the polyphase Mooshla intrusion (2698–2697 Ma: Lafrance et al., 2003; Galley and Lafrance, 2014; McNicoll et al., 2014; Fig. 1). The age of the Mooshla intrusion corroborates that it is temporally associated with the rocks of the Bousquet Formation, i.e., synvolcanic (Mercier-Langevin et al., 2007c; Galley and Lafrance, 2014). This intrusion is also thought to have contributed heat, hydrothermal fluids, and metals to the sulphide-quartz auriferous vein systems (Doyon and

Westwood Zone 2 Extension) and to the VMS deposits of the camp (Galley and Lafrance, 2014; Yergeau et al., 2015).

The rocks of the DBL mining camp were affected by at least three episodes of regional deformation (Mercier-Langevin et al., 2007c, and references therein). The geometry of the host rocks and ore zones is mainly controlled by the main phase of regional shortening (locally referred to as D_2). This is best defined by a steeply (~75–90º) south-dipping, east-trending foliation (S_2). This fabric corresponds to fabric S_3 at the regional scale (Monecke et al., 2017).

STRATIGRAPHY OF THE LZ5 PROJECT AND ELLISON PROPERTY

The LZ5 and Ellison mineralized zones are hosted in highly deformed, metamorphosed (greenschist facies) and altered volcanic and volcaniclastic units of the Bousquet Formation upper member. The effects of alteration, deformation, and metamorphism make it difficult to recognize primary textures and strongly hamper mapping solely based on macroscopic rock descriptions. Recent studies (e.g. Lafrance et al., 2003; Mercier-Langevin et al., 2007a,b, 2008, 2009; Yergeau et al., 2015) have shown that combining lithogeochemistry with careful surface, underground mapping, drill core descriptions, and microscopic observations make it possible to differentiate the units composing the upper and lower member of the Bousquet Formation with more confidence.

Since unaltered rocks are rare in the area, a protolith composition based on the average of samples considered the least altered has been used to estimate the primary composition of the host rock of the LZ5 and Ellison mineralized zones. The samples used were selected based on low loss of ignition values (LOI ≤6 wt%), and low S (<0.9 wt%) and CO_2 (<2.5 wt%) content, as well as specific ranges of alteration indices (i.e. Hashimoto alteration index (AI: Ishikawa et al., 1976) ≤60; advanced-argillic alteration index (AAAI: Williams and Davidson, 2004) ≤60; and chlorite-carbonate-pyrite index (CCPI: Large et al., 2001) ≤90). Results and observations presented in the following sections mostly come from the detailed study of core from 6 drillholes (S10-04, S11-44, BZ-1805136-1, 121-06-11, 121-06-16, and 121-06-20). These intersect the LZ5 and Ellison A and B ore zones and most of the footwall and hanging wall units.

LZ5 and Ellison Mineralized Zones

The LZ5 project is located halfway between two world-class Au deposits that are characterized by contrasting mineralization styles, i.e., the Bousquet 2-Dumagami Au-rich VMS deposit to the east, and the Westwood intrusion-related and Au-rich VMS deposit to the west (Fig. 1). The LZ5 and Ellison mineralized zones are hosted in a succession of mafic to felsic volcanic and volcaniclastic units (tuff and lapilli tuff±tuff breccia) forming part of the base of the upper member of the Bousquet Formation (*see* the following sections). The LZ5 consists of three distinct mineralized corridors, referred to as, from south to north, Zone 4.1, Zone 4, and Zone 5 (Fig. 2, 3). The Ellison zones are located a few hundred metres west of the LZ5 project and consist of three stacked mineralized corridors, referred to as zones A, B, and C (Fig. 2). The Ellison Zone B is located stratigraphically higher than the LZ5 mineralized corridors, whereas the Ellison Zone A is located approximately at the same stratigraphic position as the LZ5 mineralized corridors. The mineralized rocks at LZ5 and Ellison are generally moderately to intensely foliated, and locally sheared. The steeply south-dipping, east-trending regional S_2 schistosity (~80–90°) affects all rock units, which show evidence of flattening, stretching, boudinage, transposition, and folding (Boily-Auclair et al., 2019). The LZ5, as well as the Ellison Zone A mineralized corridors, were previously interpreted to be hosted within the heterogeneous Bousquet unit (unit 4.4) of the Bousquet Formation lower member. This unit consists of tuffs, lapilli tuffs, and massive, pillowed, and brecciated flows of mafic to intermediate composition (Yergeau, 2015).

Zone 5 is the main mineralized body at the LZ5 project. Gold grades are generally slightly higher and more consistent than in zones 4 and 4.1, which are considered as discontinuous satellite zones. Zone 5 is up to 30 m thick (Fig. 3) and extends over approximately 600 m along strike (east-west). Zone 5 extends from surface down to 1,100 m below surface (current resources envelope). The mineralized corridor gradually thins out both to the east and to the west to only a few metres thick, where it becomes subeconomic (Fig. 2). The mineralization consists of transposed discordant networks of millimetre to centimetre thick pyrite veinlets (10–20 vol.%; Fig. 4a) and, to a lesser extent, of very finely disseminated granoblastic pyrite, in clusters and/or as elongated/flattened centimetre to decimetre long fragments (≤10 vol.%; Fig. 4b–e). Pyrrhotite, chalcopyrite, and sphalerite are present in minor to trace amounts, in association with pyrite. Gold occurs as inclusions in granoblastic pyrite (Tourigny et al., 1989; Boily-Auclair et al., 2019). Zone 5 is hosted in massive mafic to intermediate rocks that are tentatively correlated to the Doyon dacite-rhyodacite unit (unit 5.1a) and possibly to the Westwood basaltic andesite unit (unit 5.4; Fig. 5a,b), as discussed below. The mineralization style of zones 4 and 4.1 is similar to that of Zone 5, although sulphides are slightly less abundant and gold grades are slightly lower on average than in Zone 5.The mineralized intervals of the Ellison zones

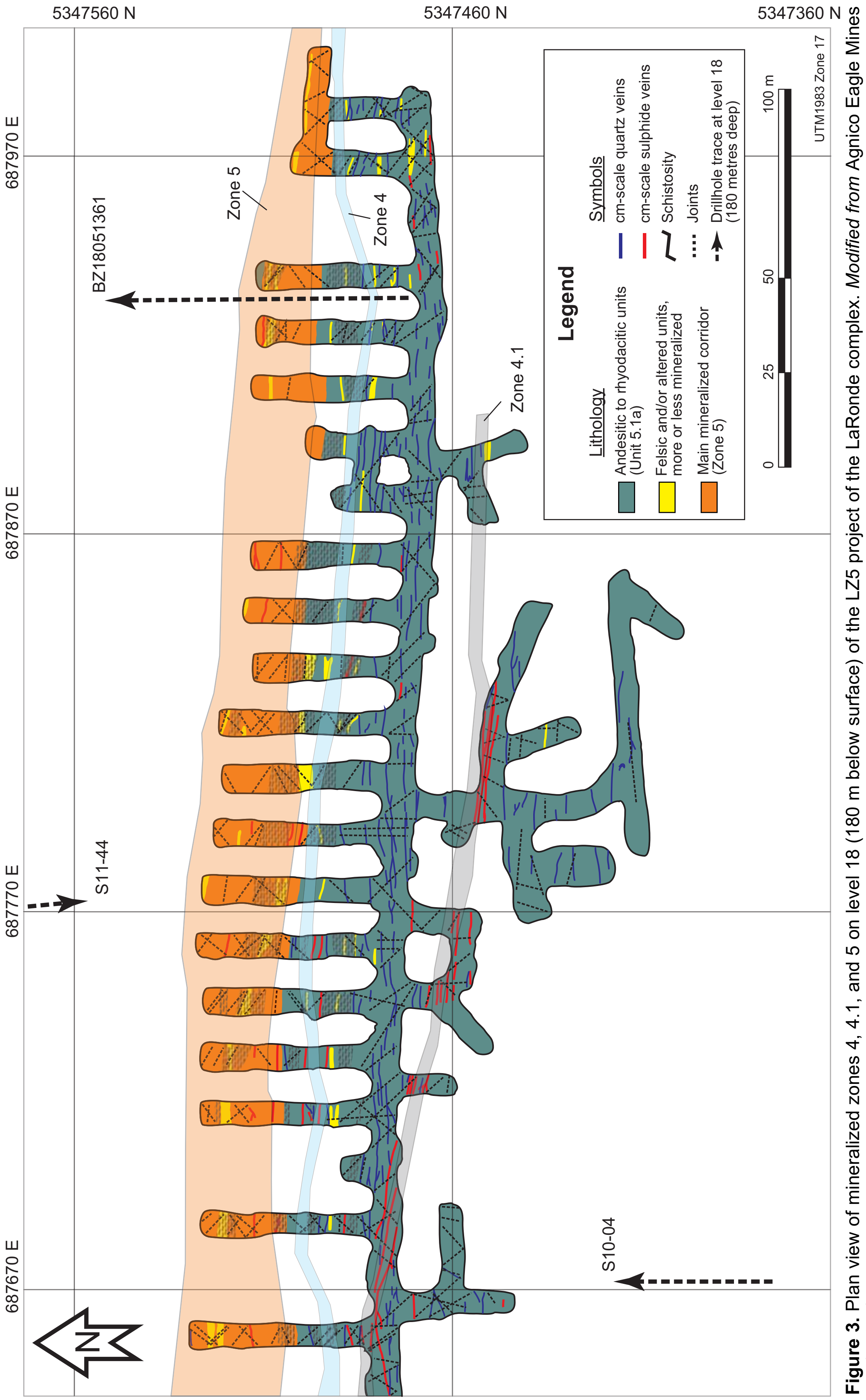


Figure 3. Plan view of mineralized zones 4, 4.1, and 5 on level 18 (180 m below surface) of the LZ5 project of the LaRonde complex. *Modified from* Agnico Eagle Mines Ltd (2019b).

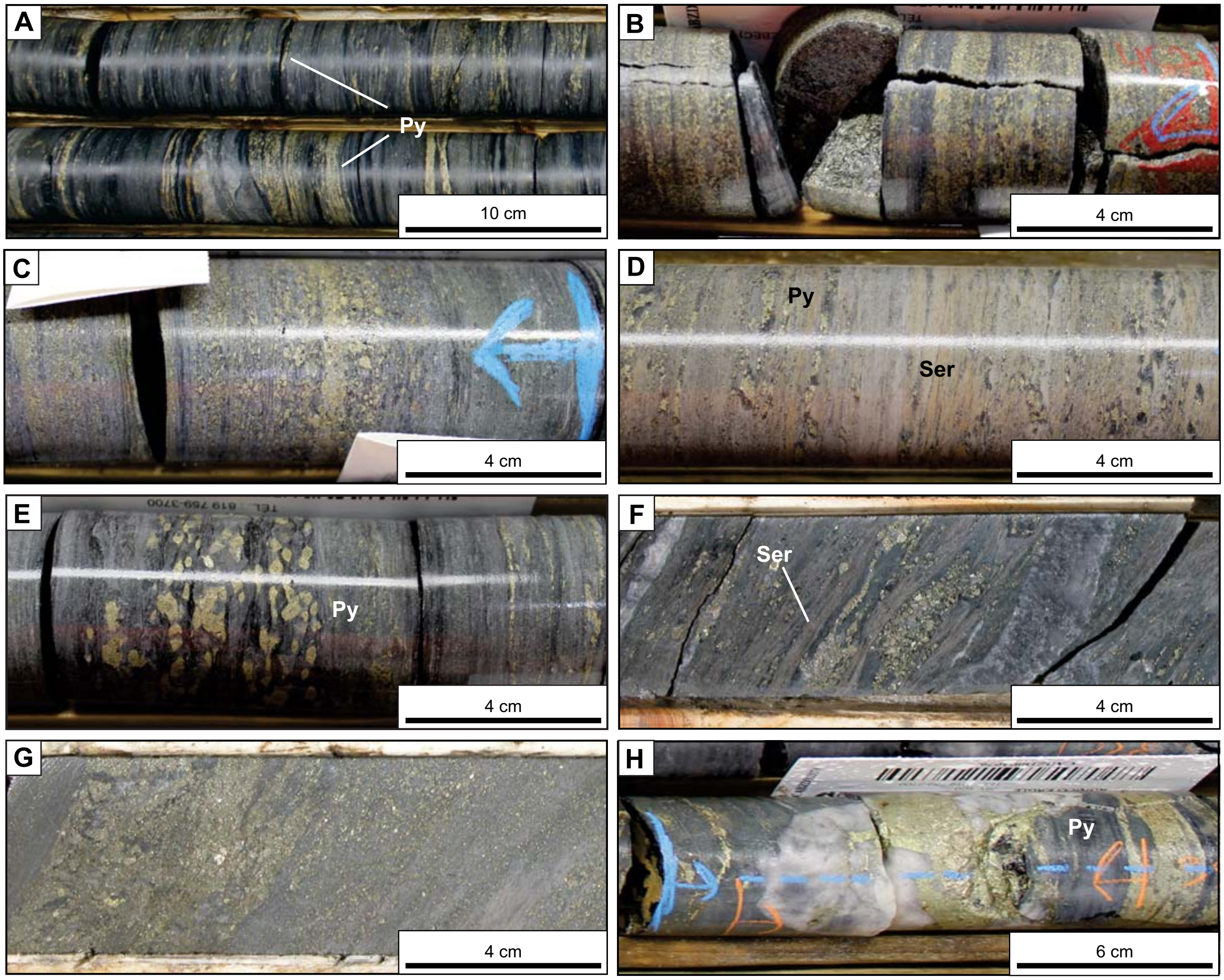


Figure 4. a) Massive and homogeneous andesitic rock (typical of Zone 5) with 10 to 12 vol.% millimetre-thick stringers of pyrite, subunit 5.1a-(b), drillhole BZ-0905119-1. **b)** Finely disseminated pyrite mineralization in an andesitic rock, north of Zone 5, unit 5.1a-(b), drillhole BZ-0905119-1. **c)** Banded andesitic unit located north of Zone 5. Finely disseminated sulphides and discontinuous millimetre-thick stringers, unit 5.1a-(a), drillhole BZ-0905116-1. **d)** Very fine-grained, strongly sericitized unit. The mineralization is finely disseminated in the matrix and in millimetre-thick fragments, Zone 4, unit 5.1a-(a), drillhole BZ-1805120-1. **e)** Millimetre-thick pyrite fragments in an intermediate rock, beginning of Zone 5, unit 5.1a-(b), drillhole BZ-0905119-1. **f)** Felsic lapilli tuff cut by centimetre-thick quartz veins as well as sulphide veinlets and fragments, Ellison Zone B, unit 5.3a-(b), drillhole 121-06-11. **g)** Disseminated to semi-massive granoblastic pyrite in an andesitic rock, Ellison Zone A, unit 5.1a-(a), drillhole 121-06-11. **h)** Quartz vein with a massive chalcopyrite cluster in a typical andesitic unit of Zone 5 (7.5 g/t Au), drillhole BZ-0905116-1. Abbreviations: Py = pyrite; Ser = sericite.

A and B consist of discordant networks of millimetre to centimetre thick pyrite veinlets (10–20 vol.%), disseminated pyrite, pyrite clusters, and elongated pyrite fragments (Fig. 4f). Whereas in zones 4, 4.1, and 5 of the LZ5, variable amounts of chalcopyrite, sphalerite, and pyrrhotite are present within the mineralized corridor of the Ellison property. Mineralized intervals of zones A and B show higher gold concentration (e.g. 6.4 g/t Au over 4 m, and 4.3 g/t Au over 8 m), but are thinner than those found at the LZ5 and are discontinuous. Silver grades are also higher at Ellison, which has Ag values as high as 80 g/t over short intervals (1.2 m long). In addition, semi-massive to massive bands of pyrite are present within the mineralized intervals (Fig. 4g). These bands have high gold grades (≤30 g/t over 1.5 m intervals), with relatively abundant chalcopyrite (Cu ≤0.1 wt%) and sphalerite (Zn ≤3.5 wt%). Ellison Zone A is hosted within Westwood basaltic andesite (subunit 5.1a-(a)) and Zone B is hosted within the Westwood porphyritic rhyolitic dome (subunit 5.3a-(b); Fig. 2).

Additionally, discordant, sulphide-rich, centimetre to decimetre thick quartz-carbonate veins are present within the LZ5 and Ellison mineralized zones, particularly in Zone 5 (Fig. 4h). Grades of up to 60 g/t are associated with some of these veins (Boily-Auclair et

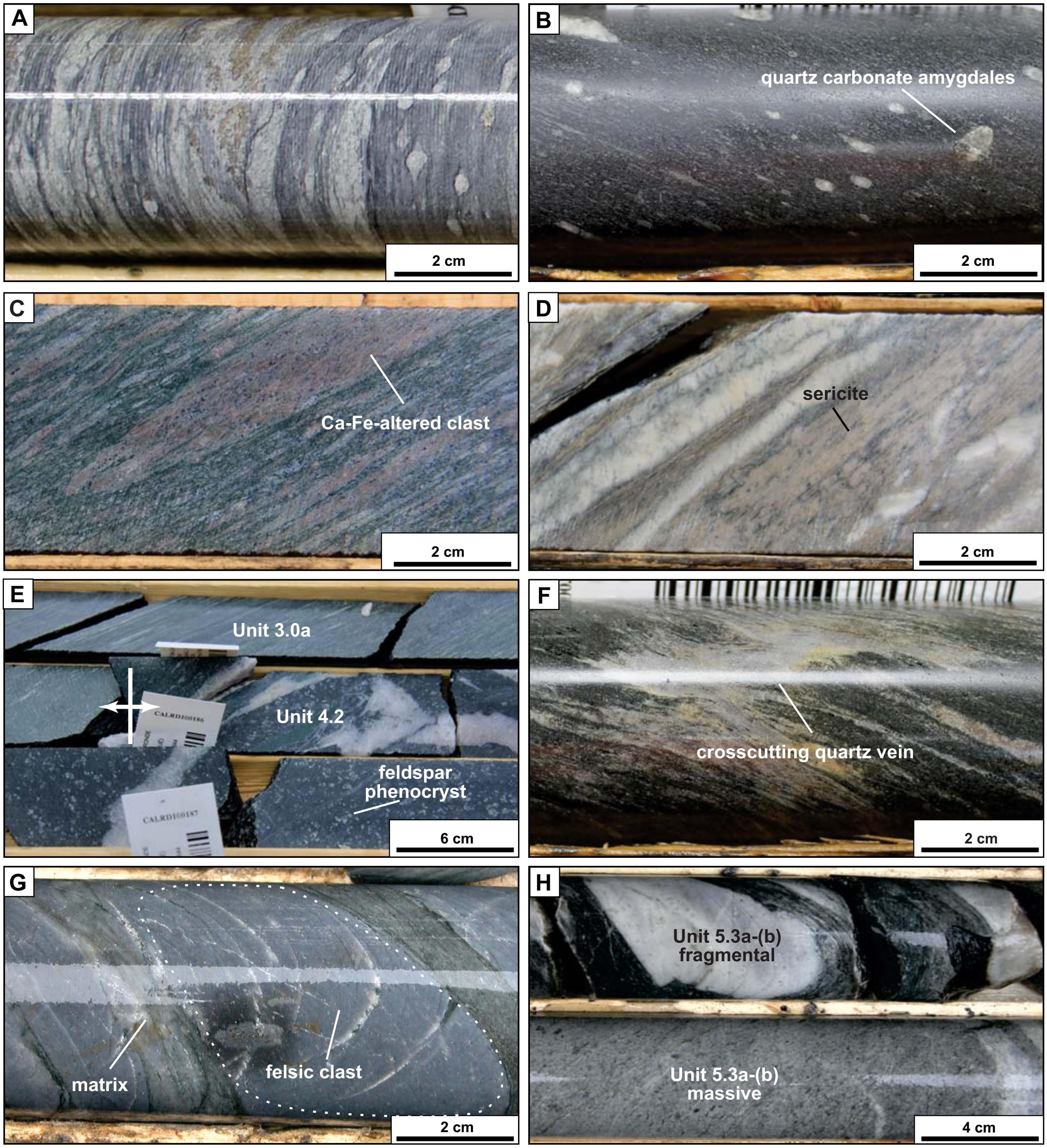


Figure 5. a) Typical fragmental intermediate rock of unit 5.1a-(a), drillhole BZ-18-05-136-1. **b)** Typical amygdaloidal massive rock of unit 5.1a-(b), drillhole S10-04. **c)** Lapilli tuff with altered chlorite matrix and altered Fe-carbonate fragments, unit 3.0a, drillhole S11-44. **d)** Altered rhyodacitic breccia with massive sericite and apparent flattened fragment, unit 4.1, drillhole S11-44. **e)** Crosscutting dyke or sill into a lapilli tuff unit. Note the presence of feldspar phenocrysts and thin quartz vein network, unit 4.2 and 3.0a, drillhole S11-44. **f)** Mafic sill or dyke cut by a quartz vein network in the footwall of Zone 5, unit 5.1a-(c), drillhole S10-04. **g)** Felsic block in a sericitized and chloritized matrix, unit 5.3a-(b), drillhole 121-06-16. **h)** Felsic lapilli tuff and quartz-feldspar porphyritic felsic rock, units 5.3a-(b) and 5.5, drillhole 121-06-11.

al., 2019). Silver and base metal grades are also low at LZ5 compared with the other deposits of the camp.

Footwall and Host Units of the LZ5 and Ellison Mineralized Zones

The LZ5 mineralized corridors are hosted in mafic to felsic rocks of transitional to calc-alkaline magmatic affinity (Fig. 6a,b,c). The base of the sequence consists of volcaniclastic subalkaline basalt and andesite of the Bousquet scoriaceous tuff (unit 3.0) intercalated with thin (≤10 m) but relatively continuous intermediate to felsic sills or dykes of the Bousquet dacitic dome (unit 4.1), the Doyon glomeroporphyritic unit (unit 4.2), and the Doyon felsic unit (unit 4.3).

The Bousquet scoriaceous tuff (unit 3.0) forms the base of the lower member of the Bousquet Formation (Fig. 2). It consists of mafic to intermediate lapilli tuff and/or tuff breccia that are commonly polymictic and locally sorted and normally graded (Yergeau, 2015; Fig. 5c). This unit has been divided into two subunits based on composition: 1) a mafic subunit (subunit 3.0a) and 2) an andesitic subunit (subunit 3.0b) (Yergeau, 2015). Both subunits are present at LZ5 (Fig. 6a,b). Subunit 3.0a also has a more tholeiitic magmatic affinity than subunit 3.0b (Fig. 6c). Samples of subunit 3.0a are the only ones to plot in the tholeiitic field of the Ross and Bédard (2009) diagram (Fig. 6c). The least altered samples of subunit 3.0a are characterized by low SiO_2 content (50.8 wt% on average), high TiO_2 content (1 wt% on average), and a very low $Zr/(TiO_2*10,000)$ ratio (0.003 on average: Fig. 6e, 7). The least altered samples also show low Zr (34.5 ppm on average) and low Y concentrations (11.6 ppm on average), which that contrasts with the other mafic units of the Bousquet Formation (Fig. 6d, 7). Subunit 3.0b is characterized by higher SiO_2 content (58.4 wt% on average), similar TiO_2 content (1.1 wt% on average). and higher $Zr/(TiO_2*10,000)$ ratio (0.0085 on average) with higher Zr and Y contents (94 ppm and 29.3 ppm on average, respectively: Fig. 6d,e, 7). Both subunits show similar chondrite-normalized multi-element patterns that are characterized by a small negative Nb-Ta anomaly, slightly negative light rare-earth elements (LREE), and flat to slightly U-shaped heavy rare-earth elements (HREE), although unit 3.0b shows a slight negative Ti anomaly (Fig. 8a).

The Bousquet dacitic dome (unit 4.1) was mapped north of the former Bousquet 1 mine (Lafrance et al., 2003; Fig. 2), but sills of similar composition are present a few kilometres to the west, at the Westwood mine (Mercier-Langevin et al., 2009). This unit is also present in the LZ5 footwall (Fig. 5d). The least altered rocks of the Bousquet dacitic dome have a high SiO_2 concentration of 69.5 wt% on average, a low TiO_2 concentration of 0.54 wt% on average, and a high $Zr/(TiO_2*10,000)$ ratio (0.05 on average; Fig. 6e, 7). Zirconium and Y values are high at 271 and 45.6 ppm (Fig. 6d, 7).

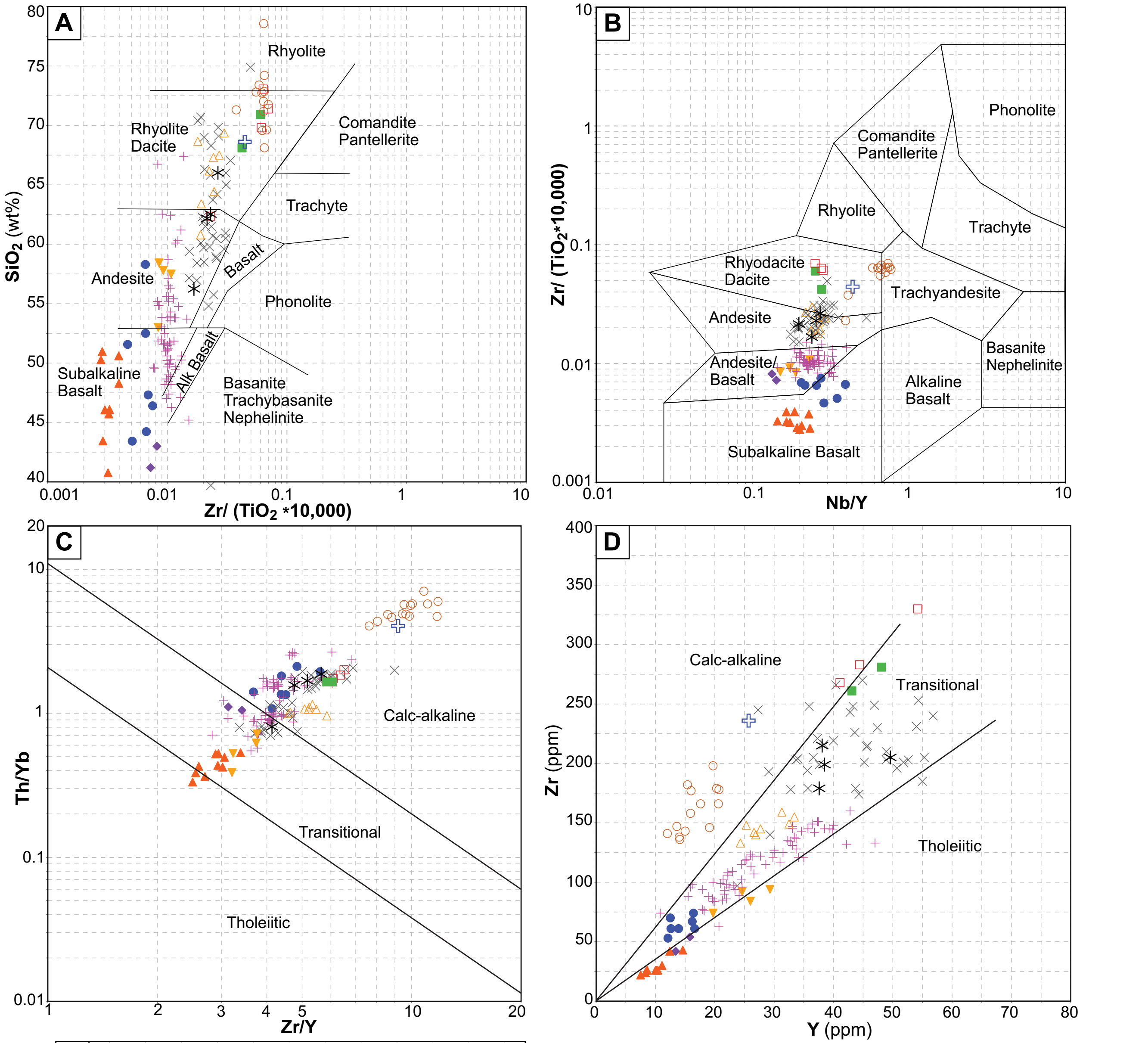
The Doyon glomeroporphyritic unit (unit 4.2) is compositionally similar to the Bousquet dacitic dome, but it contains abundant feldspar phenocrysts and glomerophenocrysts, whereas the Bousquet dacitic dome is generally very fine grained (Yergeau, 2015; Fig. 5e). This unit forms lobe-hyaloclastite deposits in the Doyon mine area but consists of thin sills and dykes in the Westwood mine area (Yergeau, 2015). Fresh samples from unit 4.2 are characterized by an average SiO_2 content of 61.7 wt%, an average TiO_2 content of 0.93 wt%, and an average $Zr/(TiO_2*10,000)$ ratio of 0.02 (Fig. 6e, 7). The Zr and Y contents of this unit are also relatively high at 200 and 41 ppm on average, respectively (Fig. 6d, 7).

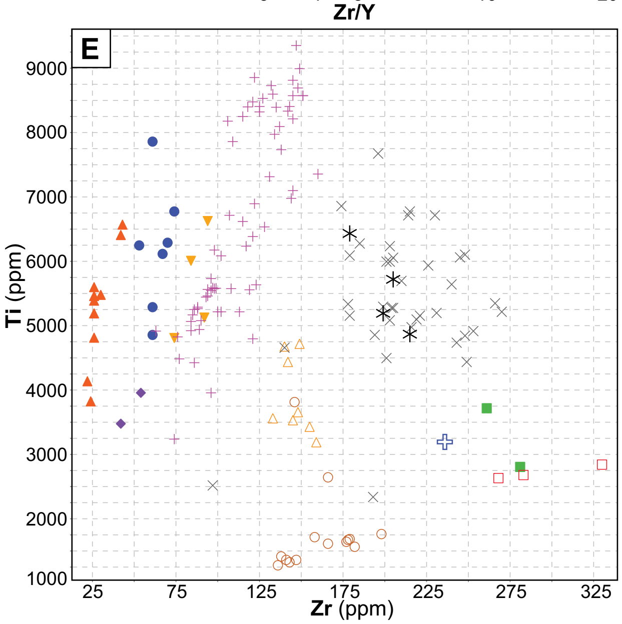
The Doyon felsic unit (unit 4.3) is only very locally present in the LZ5 footwall succession. At Westwood, it comprises massive and coherent felsic rocks that do not show particular primary textures (Yergeau, 2015). At LZ5, this unit forms thin dacitic to rhyodacitic dykes or sills of calc-alkaline magmatic affinity (Fig. 6a,b,c). The only analyzed sample from this unit shows a high SiO_2 content (68.6 wt%), a low TiO_2 content (0.53 wt%), and a relatively high $Zr/(TiO_2*10,000)$ ratio (0.04: Fig. 6e, 7). Zirconium (236 ppm) and Y (25.7 ppm) are relatively high for this unit (Fig. 6d, 7).

The Bousquet dacitic dome, the Doyon glomeroporphyritic unit, and the Doyon felsic unit are also characterized by relatively pronounced Nb-Ta anomalies, steep LREE patterns and flat to slightly U-shaped HREE patterns with a strong negative Ti anomaly (Fig. 8b). These patterns are typical of transitional to calc-alkaline felsic units of the Bousquet Formation (cf. Mercier-Langevin et al., 2007b).

The upper part of the footwall sequence consists mainly of massive to fragmental felsic to mafic rocks of the Doyon dacite-rhyodacite unit (unit 5.1a) intercalated with thin discontinuous sills or breccia deposits of the Westwood basaltic sills (unit 5.4a). The Doyon dacite-rhyodacite has been divided into 4 subunits based on texture and composition: the Westwood basaltic andesite (subunit 5.1a-(a)), the Westwood andesite-dacite (subunit 5.1a-(b)), the Westwood mafic sills (subunit 5.1a-(c)), and the Westwood dacite-rhyodacite (subunit 5.1a-(d)) (Mercier-Langevin et al., 2009; Yergeau, 2015; Fig. 5a,b,f).

The Westwood basaltic andesite (subunit 5.1a-(a)) is composed of aphanitic to fine-grained, volcanic and volcaniclastic rocks of mafic composition that appear dark green to greyish green and contain between 5 and 15 vol.% feldspar phenocrysts (Yergeau, 2015) (Fig. 5a). Their composition varies between subalkaline





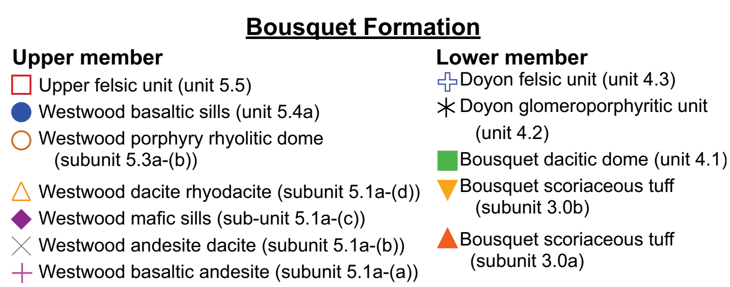


Figure 6. Geochemical diagrams of the volcanic, volcaniclastic, and intrusive rocks of the Bousquet Formation upper and lower member from the LaRonde Zone 5 project and on the Ellison property, sampled in drillholes S10-04, S11-44, BZ-1805136-1, 121-06-11, 121-06-16, and 121-06-20 (*see* Fig. 3 for the location of drillholes S10-04, S11-44, and BZ18-05-136-1). **a and b)** Winchester and Floyd (1977) volcanic rock classification diagrams. **c)** Ross and Bédard (2009) magmatic affinity diagram. **d)** Barrett and Maclean (1994) magmatic affinity diagram. **e)** Ti/Zr diagram, which can be used to differentiate the units of the LaRonde Zone 5 project and the Ellison property.

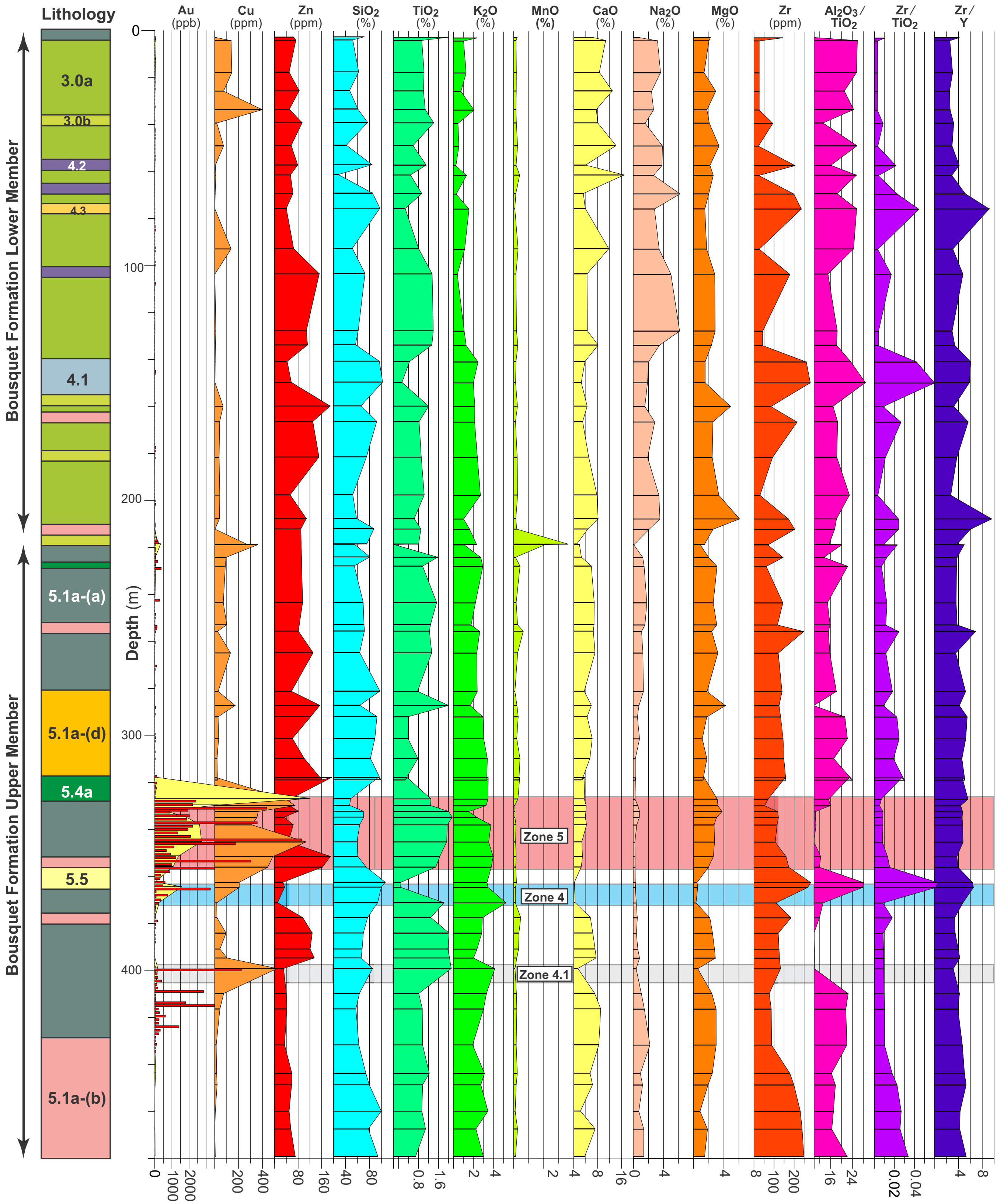


Figure 7. Geochemical profile of drillhole S11-44. Locations of samples and geochemical data are shown by short horizontal lines across each profile. Red bars in the Au column represent assays obtained from Agnico Eagle Mines Ltd.

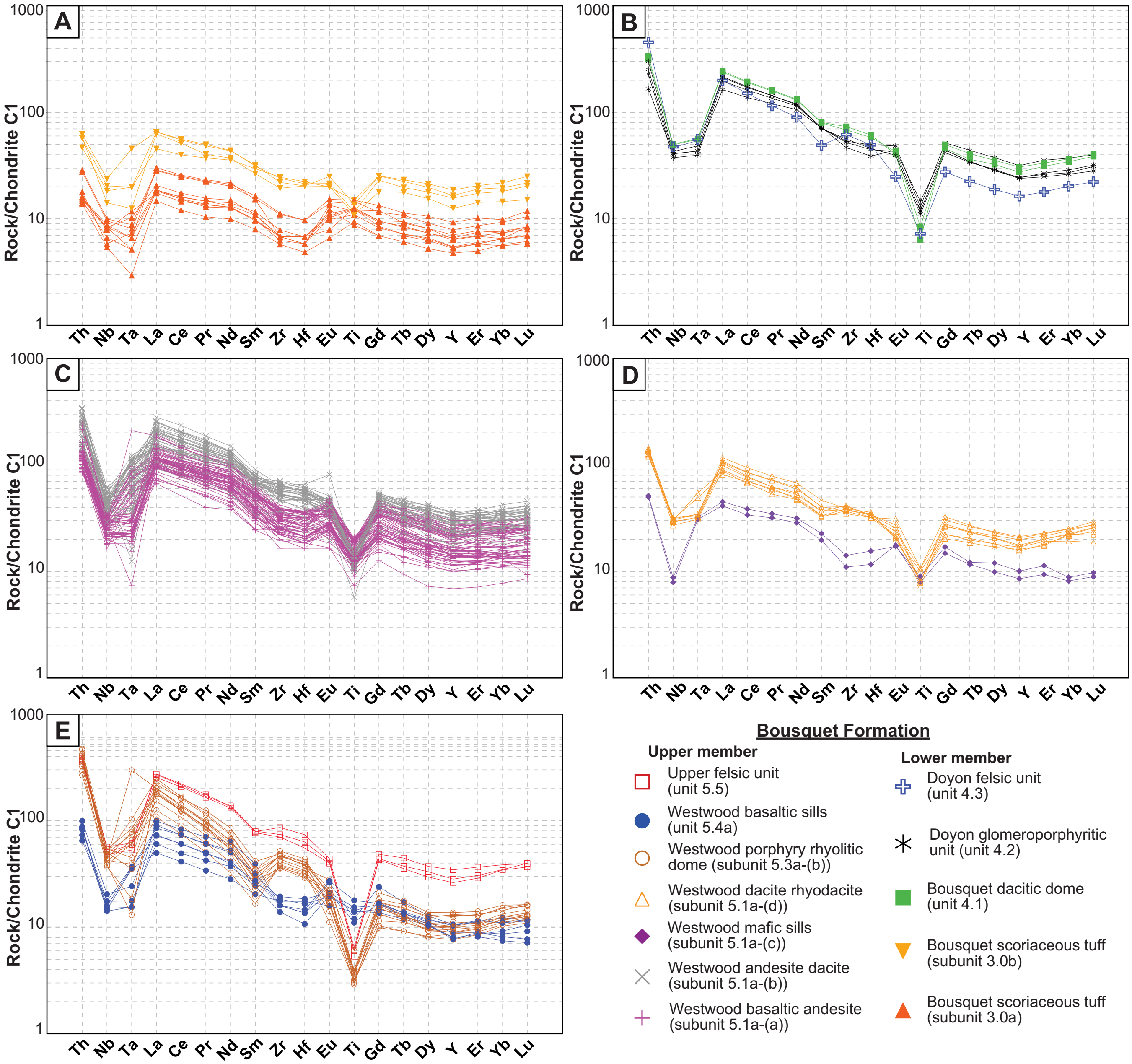


Figure 8. C1 chondrite-normalized (McDonough and Sun, 1995) multi-element patterns of **a)** units 3.0a and 3.0b; **b)** units 4.1, 4.2, and 4.3; **c)** units 5.1a-(a) and 5.1a-(b); **d)** units 5.1a-(c) and 5.1a-(d); and **e)** units 5.3a-(b), 5.4a, and 5.5.

basalt and andesite (Fig. 6a,b). Fresh samples are characterized by a SiO_2 content averaging 55.1 wt%, a TiO_2 content averaging 1.02 wt%, and a $Zr/(TiO_2{*}10{,}000)$ ratio averaging 0.01 (Fig. 6e, 7).

The Westwood andesite-dacite (subunit 5.1a-(b)) is composed mainly of massive volcanic rocks of intermediate to felsic composition, with a minor component of volcaniclastic rocks (Fig. 6a,b). This unit is also characterized by a high percentage of amygdules (up to 10 vol.%: Fig. 5b). Least altered samples from subunit 5.1a-(b) are characterized by higher SiO_2 content (63.5 wt% on average), lower TiO_2 content (0.9 wt% on average), and a higher $Zr/(TiO_2{*}10{,}000)$ ratio (0.02 on average: Fig. 6e, 7). This subunit is also characterized by high Zr and Y contents (207 ppm and 40 ppm, respectively: Fig. 6d, 7).

Rocks from the Westwood mafic sills (subunit 5.1a-(c)) consist of thin and discontinuous mafic dykes and slightly discordant sills. This unit is generally intersected by irregular networks of quartz veins that do not extend into the bounding units (Fig. 5f). This unit is of very limited extent and is generally strongly altered. All analyzed samples show evidence of major alteration (e.g. 10–12 wt% loss-on-ignition values). The composition of the protolith is difficult to establish, but appears to be mafic (Fig. 6e, 7).

The Westwood dacite-rhyodacite (subunit 5.1a-(d)) forms metric to decametric volcanic domes, cryptodomes, and lobes that are spatially and genetically associated with a significant succession of tuff, lapilli tuff, and tuff breccia (Yergeau, 2015). Least altered samples from this subunit are characterized by a high SiO_2 content of 68 wt% on average, a relatively low TiO_2 content of 0.7 wt%, and a $Zr/(TiO_2*10{,}000)$ ratio of 0.02 (Fig. 6e, 7). On a Winchester and Floyd (1977) volcanic rock classification diagram, the samples of the Westwood dacite-rhyodacite subunit plot between the field for andesite and rhyodacite/dacite (Fig. 6a,b).

The multi-element patterns of samples from the Westwood basaltic andesite and the Westwood andesite-dacite are characterized by strong enrichment in high field strength elements (HFSE) and LREE, pronounced negative anomalies in Nb and Ta, negative anomalies in Ti, and relatively flat heavy REE (HREE) patterns (Fig. 8c). The Westwood mafic sills are characterized by chondrite-normalized multi-element plots showing slight enrichment in HFSE and LREE, flat to negative HREE pattern, and a negative Nb anomaly (Fig. 8d). The Westwood mafic sills also show a weak positive Eu anomaly and a weak negative Ti anomaly (Fig. 8d). The Westwood dacite-rhyodacite shows strong enrichment in HFSE and LREE, pronounced negative anomalies in Nb and Ta, a negative anomaly in Ti, and relatively flat to U-shaped HREE patterns (Fig. 8d).

The Westwood basaltic sills (unit 5.4a) almost exclusively consist of massive basaltic intrusive rocks that do not have distinctive volcanic textures (Yergeau, 2015). The sills and dykes have variable thicknesses and occur at different stratigraphic positions (Yergeau, 2015). Westwood basaltic sill samples have high loss-on-ignition values. Consequently, a protolith composition based on a selection of least altered samples could not be obtained. Samples from this unit show, on average, a SiO_2 concentration of 51.6 wt%, a TiO_2 concentration of 1.3 wt%, and a $Zr/(TiO_2*10{,}000)$ ratio of 0.004 (Fig. 6e, 7). This unit is also characterized by negative Nb and Ta anomalies, slight LREE enrichment, a negative HREE pattern, as well as a weak positive Eu anomaly and a weak negative Ti anomaly (Fig. 8e).

The Ellison Zone B is located stratigraphically higher than the LZ5 zones 4, 4.1, and 5, whereas the Ellison Zone A is at a similar stratigraphic position as Zone 4 and could, therefore, represent the western extension of that zone on the Ellison property. The Ellison Zone A is hosted within the Westwood basaltic andesite (subunits 5.1a-(a)) and the Ellison Zone B is hosted within more deformed and altered rocks of the Westwood porphyritic rhyolite dome (subunit 5.3a-(b)). The footwall at Ellison consists almost exclusively of intermediate volcaniclastic rocks of the Doyon dacite-rhyodacite (subunit 5.1a-(d)), intercalated with a thin layer of felsic volcaniclastic rocks geochemically correlated to the upper felsic unit (unit 5.5).

The upper felsic unit is the uppermost unit of the Bousquet Formation and consists of massive to fragmental microporphyritic rhyodacitic to rhyolitic rocks. Least altered samples from this unit at LZ5 and Ellison show, on average, high SiO_2 content (66.8 wt%) and low TiO_2 (0.43 wt%) content, and a $Zr/(TiO_2*10{,}000)$ ratio of 0.03 (Fig. 6e, 9). The upper felsic unit is classified as calc-alkaline rhyodacitic to rhyolitic rocks using the Winchester and Floyd (1977) classification diagrams and the Ross and Bédard (2009) magmatic affinity diagram (Fig. 6a,b,c). On a chondrite-normalized multi-element plot, this unit shows strong enrichment in Th and LREE, flat HREE, strong negative Nb-Ta and Ti anomalies, and weak positive Zr-Hf anomalies (Fig. 8e).

Hanging-wall Units of the LZ5 and Ellison Mineralized Zones

The two main units comprising the Bousquet Formation upper member are present in the immediate hanging wall of the LZ5 mineralized corridors (Fig. 2, 7), i.e., the Westwood basaltic andesite (subunit 5.1a-(a)) and the Westwood andesite-dacite (subunit 5.1a-(b)). The hanging wall sequence of the Ellison zones A and B is composed of felsic volcaniclastic rocks of the Westwood porphyritic rhyolite dome (Fig. 5g,h, 6a,b) intercalated with felsic volcanic rocks of the upper felsic unit (Fig. 5h, 6a,b). The Westwood porphyritic rhyolite dome consists of felsic lapilli tuff and/or tuff breccia that has a distinct geochemical signature (Yergeau, 2015). On the Ellison property, least altered samples from the Westwood porphyritic rhyolite dome (Fig. 5h) have high SiO_2 content (73.5 wt% on average), very low TiO_2 content (0.25 wt%), and a high $Zr/(TiO_2*10{,}000)$ ratio (0.68: Fig. 6e). It is also characterized by a distinctively high Nb/Y ratio (0.73: Fig. 6b). This subunit is geochemically similar to the Westwood quartz porphyritic rhyolite (subunit 5.3a) but is visually distinct due to the absence of blue quartz phenocrysts (Yergeau, 2015). The Westwood porphyritic rhyolite dome consists of calc-alkaline rhyodacitic to rhyolitic rocks according to the Winchester and Floyd (1977) volcanic rock classification diagrams and the Ross and Bédard (2009) magmatic affinity diagram (Fig. 6a,b,c). This unit is characterized by chondrite-normalized multi-element plots showing strong enrichment in Th and LREE, flat HREE, strong negative Nb-Ta and Ti anomalies, and weak positive Zr-Hf anomalies (Fig. 8e).

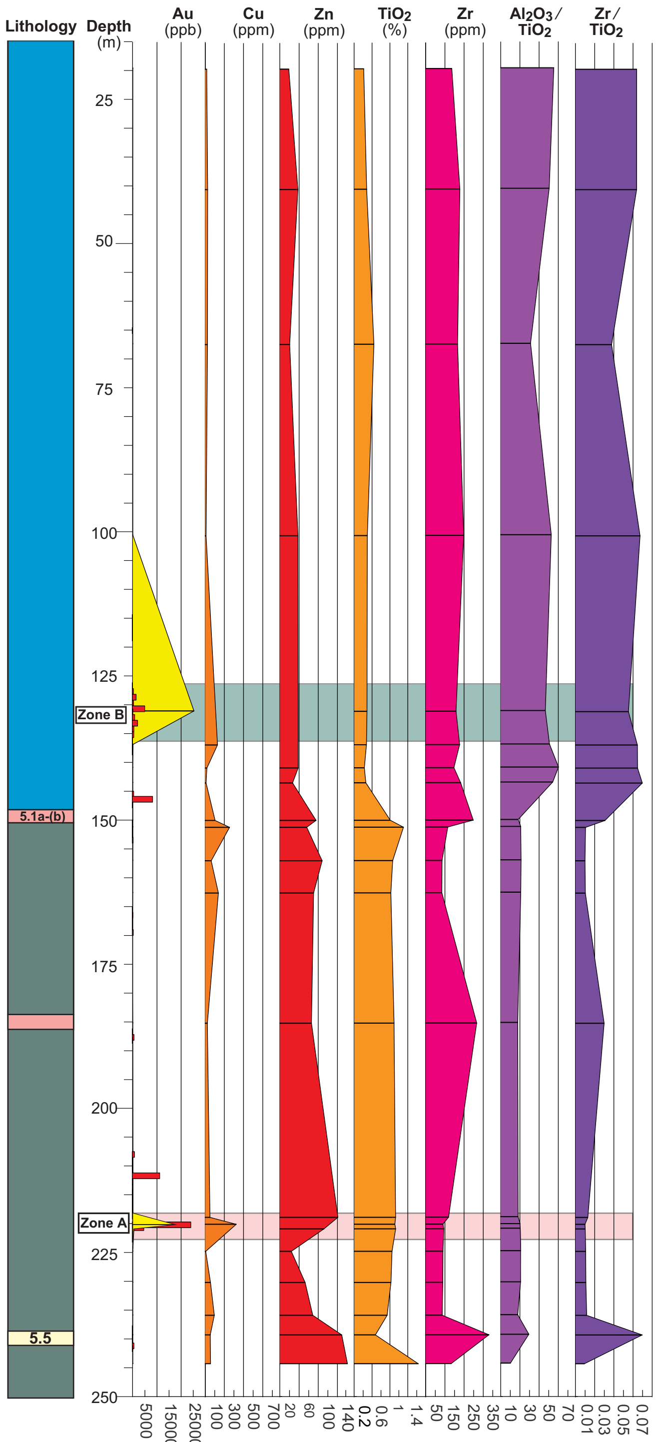


Figure 9. Geochemical profile of drillhole 121-06-11. Locations of samples and geochemical data are shown by short horizontal lines. Red bars in the Au column represent assays obtained from Agnico Eagle Mines Ltd.

DISCUSSION

Stratigraphic Setting of the LZ5 and Ellison Mineralized Zones

The LZ5 and the Ellison Zone A mineralized corridors where previously interpreted to be hosted within the Bousquet heterogeneous unit (unit 4.4) of the Bousquet Formation lower member, making them one of the lowermost ore zones in the DBL camp. Only the intrusion-associated vein systems of the Doyon and Westwood Zone 2 Extension deposits are currently considered to be hosted within the lower member of the Bousquet formation, associated with subvolcanic felsic units equivalent to the overlying upper member units (Yergeau et al., 2015). This study, however, indicates that the LZ5 mineralized corridors occur at the base of the upper member of the Bousquet Formation (Doyon dacite-rhyodacite; unit 5.1a; Fig. 2). The Bousquet heterogeneous unit has not been recognized in the stratigraphy of the LZ5 Project nor on the Ellison property. The uppermost part of the lower member of the Bousquet Formation could be missing in this part of the camp. This is in agreement with Yergeau (2015), who indicates that the Bousquet heterogeneous unit gradually thins east of the Westwood deposit. Also, the Doyon glomeroporphyritic unit (unit 4.2) and the Doyon felsic unit (unit 4.3) have not previously been recognized/mapped on the Bousquet property, despite their relationships with the formation of the intrusion-associated quartz-sulphide veins at Doyon and the Westwood mine (Yergeau, 2015). The Doyon glomeroporphyritic unit is present at surface in the Doyon mine area as a lobe-hyaloclastite complex, and as sills and dykes in the Westwood mine area. The Doyon felsic unit is present at Westwood, where it may thin out just east of the deposit (Yergeau, 2015). Anomalous Au values in the footwall of the LZ5 could represent the distal expression of the Zone 2 Extension of the Westwood deposit. These anomalous values are hosted within the Bousquet scoriaceous tuff (unit 3.0), at the base of the Westwood basaltic andesite (unit 5.1a-(a)) (Fig. 7).

The zones 4, 4.1, and 5 of the LZ5 project are hosted within the same unit as the Ellison Zone A, and approximately at the same stratigraphic position as the Westwood North Corridor ore zones, i.e., principally within the Doyon dacite-rhyodacite (unit 5.1a) (Fig. 2). This indicates that the LZ5 and the Ellison Zone A mineralized corridors are also spatially associated with the transition zone between the tholeiitic volcanism of the Bousquet Formation lower member and the calc-alkaline volcanism of the upper member. The transitional to calc-alkaline, intermediate to felsic volcanic and intrusive units of the upper member are an important metallotect in the area.

In terms of style, the LZ5 and the Ellison Zone A mineralized corridors are similar to some ore zones at the Westwood deposit. The Westwood North Corridor is characterized by replacement zones, disseminated sulphides, and centimetre to decimetre-thick veins of massive to semi-massive sulphides that are concordant to subconcordant. The Westwood North Corridor is hosted at the base of the upper member of the Bousquet

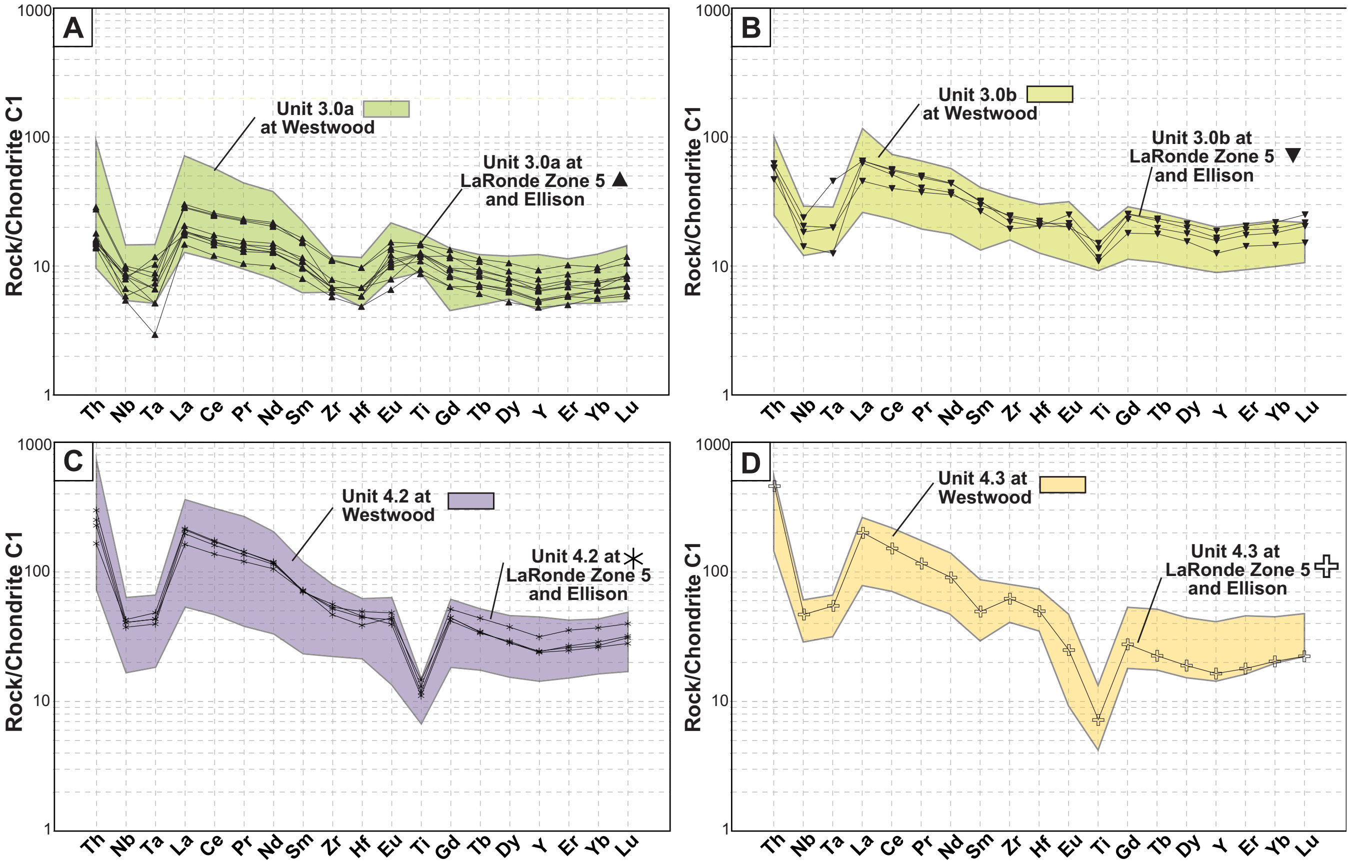


Figure 10. Geochemical comparison of the main units of the Bousquet Formation Upper and Lower members from the LaRonde Zone 5 project, and the Ellison property (samples from drillholes S10-04, S11-44, BZ-1805136-1, 121-06-11, 121-06-16, and 121-06-20) from the Westwood Property (Fig. 2, 3). The data from the Westwood deposits are from Yergeau (2015). The values are normalized to C1 chondrite from McDonough and Sun (1995). **a)** Comparative profile for unit 3.0a (Bousquet scoriaceous tuff). **b)** Comparative profile for unit 3.0b (Bousquet scoriaceous tuff). **c)** Comparative profile for unit 4.2 (Doyon glomeroporphyritic unit). **d)** Comparative profile for unit 4.3 (Doyon felsic unit). Figure is continued on the next page.

Formation in the Doyon dacite-rhyodacite (unit 5.1a) (Yergeau, 2015). These similarities and the stratigraphic position of the mineralization indicate that the LZ5, Ellison property, and Westwood North Corridor ore zones are time-stratigraphic equivalents. Ongoing work will help complete a thorough comparison between the Westwood deposit and LZ5-Ellison Zone A mineralized zones.

The footwall of the LZ5 mineralization consists of tholeiitic to transitional mafic rocks of the Bousquet scoriaceous tuff (unit 3.0), the lowermost unit of the Bousquet Formation. As at Westwood, unit 3.0 at LZ5 is intercalated with thin calc-alkaline intermediate to felsic sills or dykes that are part of units 4.2 and 4.3 (Doyon glomeroporphyritic unit and Doyon felsic unit, respectively). At the Westwood Zone 2 Extension, these two units are key factors in the formation of the Au-rich quartz-sulphide vein system (Yergeau, 2015), and suggest a potential for similar mineralization in the LZ5 area. The Bousquet dacitic dome (unit 4.1) does not occur at Westwood but is present within the Bousquet scoriaceous tuff on the Bousquet property and may also have influenced the development and location of the LZ5 ore zones.

At LZ5, the Doyon dacite-rhyodacite (subunits 5.1a-(a), 5.1a-(b), 5.1a-(c), and 5.1a-(d)), which constitute the immediate footwall succession to the Zone 5, are intercalated with thin discontinuous sills of the Westwood basaltic units (unit 5.4a). These units have compositions similar to those at the Westwood property (Fig. 10e,f,g,h, 11a). The Westwood basaltic sills are considered a marker unit in the immediate footwall and/or hanging wall of the Westwood Corridor and North Corridor ore zones. It also locally hosts some of the mineralization (Yergeau, 2015). In areas where the Westwood basaltic sills are not present, such as east of the Bousquet fault, mineralization is generally non-economic or absent. These observations suggest that there is a direct link between the presence of the Westwood basaltic sills and the fertility of the Westwood Corridor and the North Corridor (Yergeau, 2015), as recognized at the LaRonde Penna deposit (Dubé et al., 2007; Mercier-Langevin et al., 2007b). The Westwood basaltic sills are present in both the

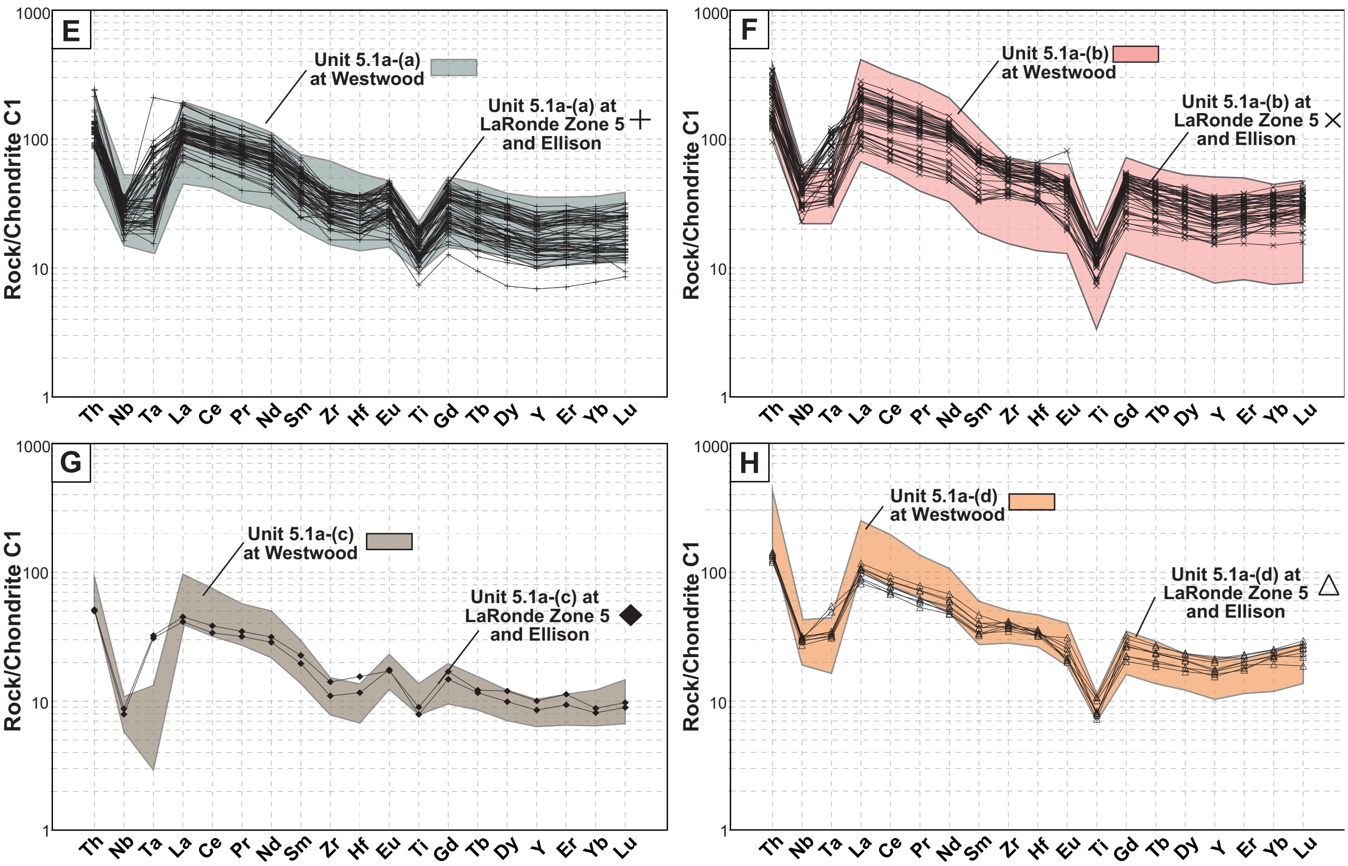


Figure 10 continued from the previous page. Geochemical comparison of the main units of the Bousquet Formation Upper and Lower members from the LaRonde Zone 5 project, and the Ellison property (samples from drillholes S10-04, S11-44, BZ-1805136-1, 121-06-11, 121-06-16, and 121-06-20) from the Westwood Property (Fig. 2, 3). The data from the Westwood deposits are from Yergeau (2015). The values are normalized to C1 chondrite from McDonough and Sun (1995). **e)** Comparative profile for unit 5.1a-(a) (Westwood basaltic andesite). **f)** Comparative profile for unit 5.1a-(b) (Westwood andesite-dacite). **g)** Comparative profile for unit 5.1a-(c) (Westwood mafic sills). **h)** Comparative profile for unit 5.1a-(d) (Westwood dacite rhyodacite).

footwall and hanging wall to the Zone 5 and could therefore also serve as an indicator for mineralization at the LZ5 project and on the Ellison property.

The immediate hanging wall to the LZ5 and Ellison mineralized corridors also consists of the Doyon dacite-rhyodacite (unit 5.1a). The hanging wall units of the LZ5 have not been studied since none of the available drill cores or underground development intersect this part of the stratigraphy. However, the units composing the LZ5 hanging wall are presumably similar to those found in the hanging wall of the Ellison Zone B. The Ellison Zone B hanging wall rocks consist of dacite, rhyodacite, and rhyolite of calc-alkaline magmatic affinity attributed to the Westwood porphyritic rhyolite dome (subunit 5.3a-(b)) and the upper felsic unit (unit 5.5). The chondrite-normalized multi-element patterns of the Westwood porphyritic rhyolite dome and the upper felsic unit present at Ellison are very similar to those present in the Westwood mine area (Fig. 11b,c). The Doyon rhyodacite-rhyolite (units 5.2a) and the Westwood quartz porphyritic rhyolite (unit 5.3a), which respectively forms the footwall and hanging wall of the 20 North massive sulphide lens at the LaRonde Penna mine, as well as the footwall of the Bousquet 2-Dumagami deposit mineralization (Fig. 2), are not present at LZ5 and Ellison. Both the LaRonde rhyodacite-rhyolite (unit 5.2) and the LaRonde quartz-rhyolite (unit 5.3) are considered as critical elements for the formation and location of the giant LaRonde Penna 20 North lens and the Bousquet-2-Dumagami exceptionally Au-rich VMS deposit. Their absence at LZ5 may explain the differences of mineralization style between the two areas, i.e., sulphide veins, stockworks, and disseminations versus Au-rich massive sulphide lenses.

CONCLUSION

The interim results of this ongoing study demonstrate that the LZ5 Project and Ellison property mineralized zones are located higher in the Bousquet Formation stratigraphy than previously interpreted. The mineralized corridors are hosted in the Bousquet Formation upper member rather than in the units of the lower member. The LZ5 zones 4, 4.1, and 5, as well as the

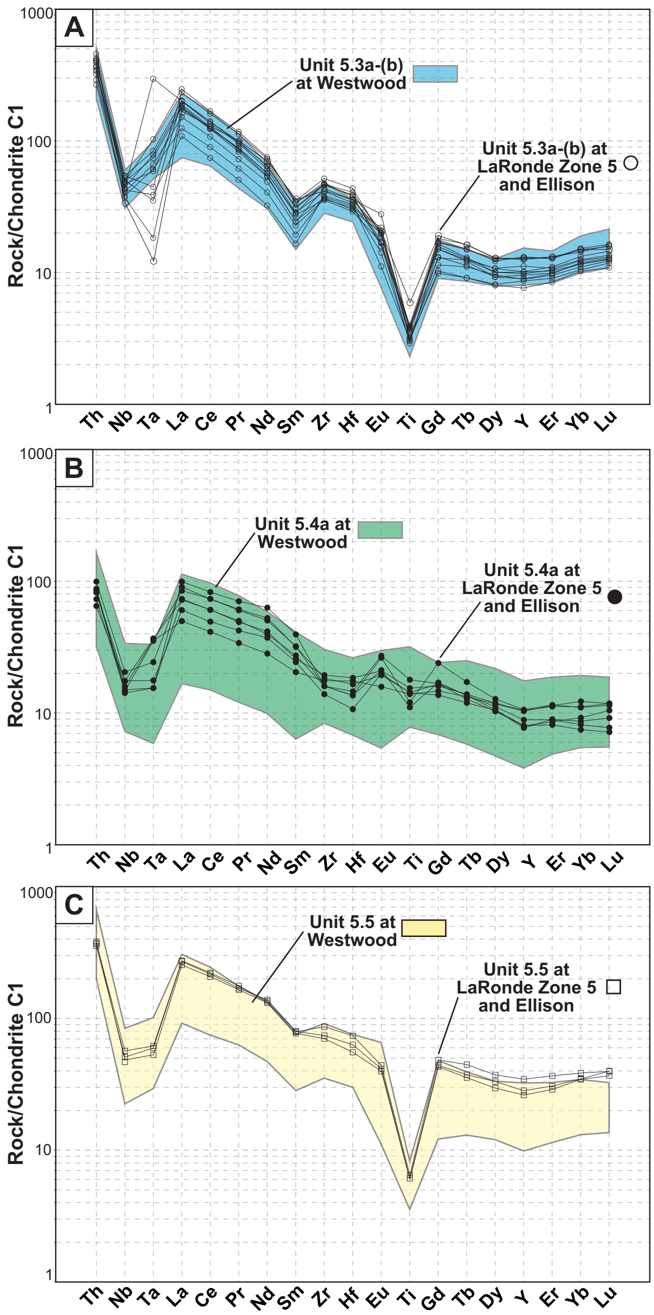


Figure 11. Geochemical comparison of the main units of the Bousquet Formation upper and lower members at the LZ5 Project and from the Ellison property with those found on the Westwood property (Fig. 2, 3). The data from the Westwood deposit are from Yergeau (2015). The values are normalized to C1 chondrite from McDonough and Sun (1995). **a)** Comparative profiles for unit 5.3a-(b) (Westwood porphyry rhyolitic dome). **b)** Comparative profiles for unit 5.4a (Westwood basal-tic sills). **c)** Comparative profiles for unit 5.5 (Upper felsic unit).

Ellison Zone A mineralized horizons are hosted within the Doyon dacite-rhyodacite (unit 5.1a) and associated subunits, whereas the Ellison Zone B is hosted slightly higher in the stratigraphy, within the Westwood porphyritic rhyolite dome (subunit 5.3a-(b)). This implies that the LZ5 ore is younger than unit 5.1a, which marks the onset of volcanism and magmatic activity associated with the upper member of the Bousquet Formation, i.e., the change from tholeiitic to transitional mafic to intermediate volcanism to transitional to calc-alkaline intermediate to felsic volcanic and magmatic activity. This change in the magmatic regime and the association with the ore-forming hydrothermal activity has been noted at camp scale but did not apply in the LZ5 area (former Bousquet 1 mine area) because of a previously erroneous interpretation about the exact stratigraphic position of the mineralized zones. This study provides further evidence for a direct association between magmatic evolution and Au-bearing, synvolcanic hydrothermal activity in the DBL mining camp. This study also strengthens the stratigraphic correlation with the Westwood deposit North Corridor ore zones. The LZ5 and Ellison Zone A are located at the same stratigraphic position as the Westwood mine North Corridor ore zones that similarly consist of strongly folded, partly transposed and boudinaged sulphide-rich veins and semi-massive sulphide bands. More work is needed to complete the characterization of the LZ5 and Ellison ore zones and to establish their significance in the metallogenic evolution of the DBL mining camp. This study represents a first step in the better understanding of the LaRonde Zone 5 project and Ellison property sulphide veins, stockworks, and disseminations, which represent an unusual style of Archean Au mineralization.

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