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2011

doi:10.4095/288757

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It can also be downloaded free of charge from GeoPub (http://geopub.nrcan.gc.ca/).

Recommended citation:
Mercier-Langevin, P., Goutier, J., Ross, P.-S., McNicoll, V., Monecke, T., Dion, C., Dubé, B., Thurston, P., Bécu, V., Gibson, H., Hannington, M., and Galley, A., 2011. The Blake River Group of the Abitibi greenstone belt and its unique VMS and gold-rich VMS endowment; Geological Survey of Canada, Open File 6869, 61 p. doi:10.495/288757

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Judi Pennanen, water colour / aquarelle, 56 cm x 75 cm

28-30 May 2011

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Field Trip - Excursion 2B

FIELD TRIP 2B

THE BLAKE RIVER GROUP OF THE ABITIBI GREENSTONE BELT AND ITS UNIQUE VMS AND GOLD-RICH VMS ENDOWMENT

P. Mercier-Langevin[1], J. Goutier[2], P.-S. Ross[3], V. McNicoll[4], T. Monecke[5], C. Dion[6], B. Dubé[1], P. Thurston[7], V. Bécu[1], H. Gibson[7], M. Hannington[8], and A. Galley[4]

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Field Trip Guidebook Prepared for Ottawa 2011

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ACKNOWLEDGEMENTS

We thank the LaRonde Division of Agnico-Eagle Mines ltd., and Cogitore Resources Inc. for access to their mining properties and drill core. Support and scientific contribution from S. Lacroix, R. Marquis, J. Ayer, and J. Parker are sincerely acknowledged. Discussions with H. Poulsen, M. Legault, V. Pearson, B. Lafrance, W. Mueller and a large number of geologists from the industry and graduate students have helped shape some of the ideas presented here. New data and interpretations dicussed in this document result from the joint Targeted Geoscience Initiative Program of the Geological Survey of Canada and Plan Cuivre of the Ministère des Ressources naturelles et de la Faune du Québec, done in partnership with the Ontario Geological Survey, the industry and academia. The authors want to express their sincere appreciation to E. Ambrose for her help formatting this document. We also thank the Mineral Deposits Division of the Geological Association of Canada for supporting the Precambrian metallogeny: a Canadian Archean and Proterozoic perspective Symposia to which this field trip is attached. Tjis is Geological Survey of Canada contribution number 20110016, and Ministère des resources naturelles et de la Faune du Québec contribution number 8439-2011-2012-1.

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RECOMMENDED CITATION

Mercier-Langevin, P., Goutier, J., Ross, P.-S., McNicoll, V., Monecke, T., Dion, C., Dubé, B., Thurston, P., Bécu, V., Gibson, H., Hannington, M., Galley, A. 2011. The Blake River Group of the Abitibi greents one belt and its unique VMS and gold-rich VMS endowment; Geological Association of Canada – Mineralogical Association of Canada – Society of Economic Geologists – Society for Geology Applied to Mineral Deposits Joint Annual Meeting, Ottawa 2011, Guidebook to Field Trip 2B, 61 p.

To reference parts of the report, the following is recommended:

Mercier-Langevin, P., Dubé, B., Hannington, M., Galley, A., McNicoll, V., and Bécu, V. 2011. Day 3: The LaRonde Penna world-class gold-rich VMS deposit, Doyon-Bousquet-LaRonde mining camp – Geologic setting, alterations and mineralization; Geological Association of Canada – Mineralogical Association of Canada – Society of Economic Geologists – Society for Geology Applied to Mineral Deposits Joint Annual Meeting, Ottawa 2011, Guidebook to Field Trip 2B, p. 40-54.

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OBJECTIVES OF THE FIELD TRIP

Patrick Mercier-Langevin (GSC-Qc)[1], Jean Goutier (MRNF)[2], Vicki McNicoll (GSC-Ottawa)[3], Thomas Monecke (CSM)[4], Pierre-Simon Ross (INRS-ETE)[5], Benoît Dubé (GSC-Qc)[1]

The Plan Cuivre and the Targeted Geoscience Initiative Program (TGI-3) of the Ministère des Ressources naturelles et de la Faune (MRNF), and the Geological Survey of Canada (GSC), respectively, aimed at providing a better understanding of the Abitibi greenstone belt geology. Research and mapping were conducted in partnership with the Ontario Geological Survey. One of the principal objectives of this collaborative effort was to better understand the geology and evolution of the Blake River Group and its volcanogenic massive sulphide (VMS) deposits. This was primarily achieved by completing extensive mapping and high-precision U-Pb geochronology, detailed geochemical sampling and characterization, geophysics, and a number of thematic studies at various scales. Academia and the industry were largely involved in that geoscientific effort as well. The combined results provide an improved image of the Blake River Group geometry, evolution and mineral potential.

The Blake River Group (BRG), with its ~375 Mt including production, reserves and resources, contains almost half of the entire Abitibi greenstone belt VMS tonnage (Table 1). The Rouyn-Noranda mining district represents one of Canada's most important mining districts. Over the past 85 years, the discovery and mining of over 20 economic VMS deposits in the district has been key for economic expansion and regional development of northern Québec (Roberts, 1956). Despite the fact that production in the district essentially came to a halt in 1993 with the closure of the Ansil mine, Rouyn-Noranda remains a major mining centre as Xstrata Copper Canada continues to operate the Horne smelter complex initially built to process ore from the Horne mine. The city of Rouyn-Noranda also serves a number of currently active mines in the region, including those of the Doyon-Bousquet-LaRonde mining camp, located approximately 45 km to the east of the city. Recent research conducted in the BRG (TGI-3, Plan Cuivre and other initiatives from universities and industry) shows, among other key new findings, that VMS-forming events occurred about every million year and that Au-rich VMS deposits were formed during two distinct events, as it will be discussed during this field excursion.

The objectives of this field trip are to give an overview of the main units and volcanic architecture that characterize the Blake River Group units and the VMS-bearing sequences. A special emphasis is put on the world's two largest Au-rich VMS deposits-bearing sequences that are part of the Blake River Group (Fig. 1). Day 1 will focuss on the overall geological setting and evolution of the BRG, with some emphasis on VMS deposits of the central camp. Day 2 will be dedi-

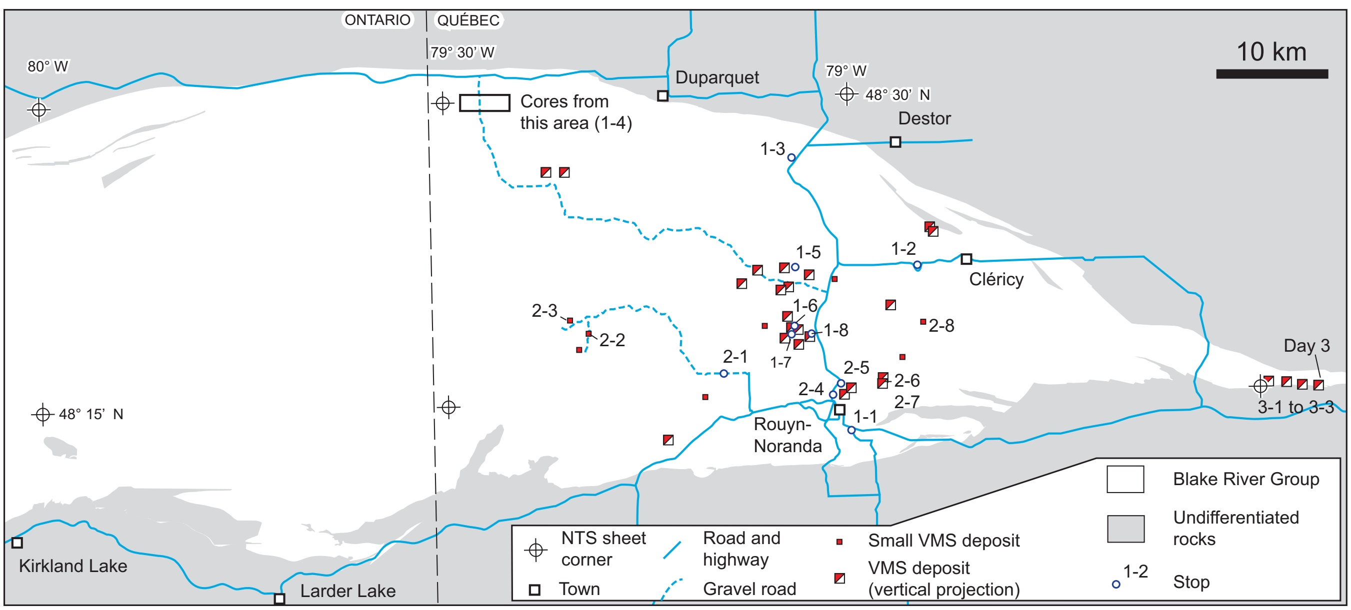

Figure 1. Schematic map of the Blake River Group showing the location of the field stops part of this excursion, and the location of the main VMS deposits of this area.

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Table 1. Blake River Group volcanogenic massive sulphide deposits tonnage and grade.

Deposit Number[(1)]		Camp[(2)]	Deposit name[(3)]	Tonnage Mt	Cu %	Zn %	Au g/t	Ag g/t	Sources
1		West	Magusi	1.68	3.3	5.13	1.84	65.9	Ress. indicated and inferred, First Metals, 2009 (website)
2	1	West	**Fabie (New Insco)**	0.46	2.53		0.02	1.23	Prod. 2008, Moorhead et al. (2009); prod. 1976-1977, 0.09 Mt to 2.8% Cu
3	2	West	**Aldermac (3, 4, 5)**	1.87	1.65		0.02	1.23	Prod. 1933-1943, Cattalani et al. (1995)
3		West	Aldermac (7 and 8)	1.04	1.5	4.13	0.3	31.2	Jones (1990)
4		NCC	West Ansil	1.13	3.35	0.29	0.82	7.45	Indicated and inferred resources, Alexis Minerals (website
5	3	NCC	**Ansil**	1.6	7.06	1.77	2.21	26.3	Prod. 1989-1993, Rive (1991, 1992); Verpaelst (1993, 1994)
6	4	NCC	**Vauze**	0.36	3.1	2.2	0.69	30.78	Prod. 1961-1965, Ministère des Richesses naturelles, 1963 to 1967
7	5	NCC	**Norbec**	4.6	2.61	3.88	0.65	43.8	Prod. 1964-1976, Cattalani et al. (1994)
8		NCC	Zone D						Satellite lens of Norbec, Cattalani et al. (1994)
9	6	NCC	**East Waite**	1.496	4.1	3.25	1.8	31.0	Prod. 1952-1961, Gibson et Watkinson (1990)
10	7	NCC	**Old Waite**	1.12	4.7	2.98	1.1	22.0	Prod. 1928-1930; 1937-1948, Gibson et Watkinson (1990)
11		SCC	Bedford Hill	0.229	1.45				McMurchy (1961). Stringer-type mineralization
12	8	SCC	**Amulet F**	0.27	3.4	8.6	0.3	46.3	Prod. 1930-1937; 1944-1962, Gibson and Watkinson (1990)
13	9	SCC	**Amulet C**	0.56	2.2	8.5	0.6	86.7	Prod. 1930-1953, Gibson and Watkinson (1990)
14	10	SCC	**Amulet Lower A**	4.69	5.1	5.2	1.43	44.1	Prod. 1937-1962, Gibson and Watkinson (1990)
14		SCC	Amulet Upper A	0.18	2.3	6.1	2.0	46.0	Prod. 1937-1962, Gibson and Watkinson (1990)
14		SCC	Amulet A-11	0.44	3.6	2.4	0.7	22.0	Prod. 1956-1962, Gibson and Watkinson (1990)
14		SCC	Bluff						Prod. Included in Amulet Lower A, Gibson and Watkinson (1990
14		SCC	Lake Dufault (zinc)	0.073	0.17	8.65	0.69	45.26	Knuckey et al. (1982)
15		SCC	D-266		4.0	5.9	1.524	49.94	Knuckey et al. (1982). (0.056 Mt included in Millenbach
16	11	SCC	**Millenbach**	3.48	3.42	4.28	0.91	46.25	Prod. 1971-1981, see references below[(4)]
16		SCC	# 14		3.75	6.6	0.818	63.49	Knuckey et al. (1982) (0.151 Mt included in Millenbach
17		SCC	# 23		2.15	6.49	0.508	53.33	Knuckey et al. (1982) (0.032 Mt included in Millenbach
18		SCC	D-68		3.82	5.02	1.975	61.79	Knuckey et al. (1982) (0.041 Mt included in Millenbach
19	12	SCC	**Corbet**	2.65	2.92	1.57	0.84	17.48	Prod. 1979-1986, MacIntosh, J.A. (1980); Rive (1981 to 1987)
20	13	South	**Quemont**	13.82	1.32	2.44	5.49	30.9	Prod. 1949-1971, Bancroft (1987)
20		South	Quemont	0.087	0.33	9.26	4.42	46.3	Prod. 2001, Verglas project, Perreault et al. (2002)
21	14	South	**Horne**	53.7	2.2	0.17	6.06	13.0	Prod. 1927-1976, Cattalini et al. (1993)
21		South	lenses (A to E; K)						Prod. included in Horne
21		South	lens F and zone tunnel						Prod. included in Horne, prod. 1994, 0.04 Mt 1.1 % Cu, 3.4 g/t Au[(5)]
21		South	lens G						Prod. included in Horne
21		*South*	lens H						Upper H et Lower H (main lenses of Horne deposit)
21		South	Zone No. 5	170.00	0.14	0.5			Prod. 1967-1976, 0.2 Mt (0.73 % Cu, 7.1 Au g/t), Kerr and Mason (1990)
22	15	South	**D'Eldona**	0.08	0.2	5.27	5.27	27.36	Prod. 1951-1952, Farnsworth (1953, 1954)
23	15	South	**Delbridge**	0.37	0.61	9.66	2.8	109.5	Prod. 1969-1971, Van de Walle (1971a, 1971b); MacIntosh (1973)
24		East	South Dufault	0.216	1.08				Spiegle (1990)
25	16	East	**West MacDonald**	0.936	0.0	3.03	0.05	1.37	Prod.1955-1959, see references below[(6)]
25	16	East	**Gallen**	2.6	0.12	4.94	1.12	33.57	Prod.1981-1985; 1997-2000, see references below[(7)]
26	17	NE	**Mobrun**	1.63	0.84	2.45	2.41	27.39	Prod. 1986-1992, Rive (1987 to 1992); Verpaelst (1993)
27	17	NE	**Bouchard-Hébert**	9.61	0.78	4.74	1.41	43.28	Prod. 1995-2005, see references below[(8)]
28		DBL	Warrenmac	0.31	0.2	4.54	6.9	5.48	Reserves, Mercier-Langevin et al. (2009b)
29		DBL	Westwood						VMS and vein-style mineralization (no resource estimate for the VMS
30	18	DBL	**Bousquet 2**	8.22	0.7		8.56		Prod. 1990-2002, Mercier-Langevin et al. (2009b)
30	19	DBL	**Dumagami**	7.33	0.7	0.07	6.84	19.5	Prod. 1988-1999, Mercier-Langevin et al. (2009b)
31	20	DBL	**LaRonde Penna**	78.50	0.3	1.9	3.70	39.7	Resources and prod. 2000- , This guidebook, section on Day 3
31		DBL	Zones 6 and 7						Included in LaRonde Penna
31		DBL	lens 20 North						Included in LaRonde Penna
31		DBL	lens 20 South						Included in LaRonde Penna
			Total tonnage	**375.30**					

(1) First column refers to deposits numbers in figure 1-4b, second column is for deposits that were, or that are still in operation

(2) See figure 1-4b for camps location. DBL = Doyon-Bousquet-LaRonde camp, NCC = northern central camp, NE = northeast camp, SCC = southern central camp.

(3) Deposit names in bold = Past or current producers

(4) Millenbach: Van de Walle (1971b); MacIntosh (1973 to 1980); Rive (1981, 1982)

(5) Gaudreau and Goutier (1995)

(6) West MacDonald : Farnsworth, D.A. (1957, 1958); Courtemanche, G., and Duchesne, G. (1959); Inspecteurs des Mines (1960, 1961)

(7) Gallen: Rive (1982 to 1986); Gaudreau et al. (1998 to 2001); Perreault et al. (2002)

(8) Bouchard-Hébert: Gaudreau (1996); Lacroix et al. (1997); Gaudreau et al. (1998 to 2001); Perreault et al. (2002 to 2006)

cated to the observation of contrasting styles of VMS deposits west and east of the synvolcanic Flavrian Pluton, whereas Day 3 will be dedicated to the LaRonde Penna world-class Au-rich VMS deposit .

This field trip is an integral part of the GAC-MAC-SEG-SGA 2011 *Precambrian metallogeny: A Canadian Archean and Proterozoic perspective* symposia. This is a modified and updated version of a field trip that was first given in 2009 (Goutier et al., 2009a,b; Mercier-Langevin et al., 2009a; Monecke et al., 2009).

Some of the data presented and interpretations proposed here have not been formally published yet and remain preliminary. In particular, the stratigraphic subdivision of volcanic rocks in the Rouyn-Noranda mining district is still under debate and may need to be refined in the coming months. Development of a unified stratigraphic nomenclature is complicated by the degree of deformation and difficulties in correlating stratigraphic entities across fault blocks. Additional issues arise from the fact that previous mapping within the Rouyn-Noranda mining district has been conducted at different scales with different objectives and that maps allowing detailed subdivision of the stratigraphy are only available for parts of the district. In the last few

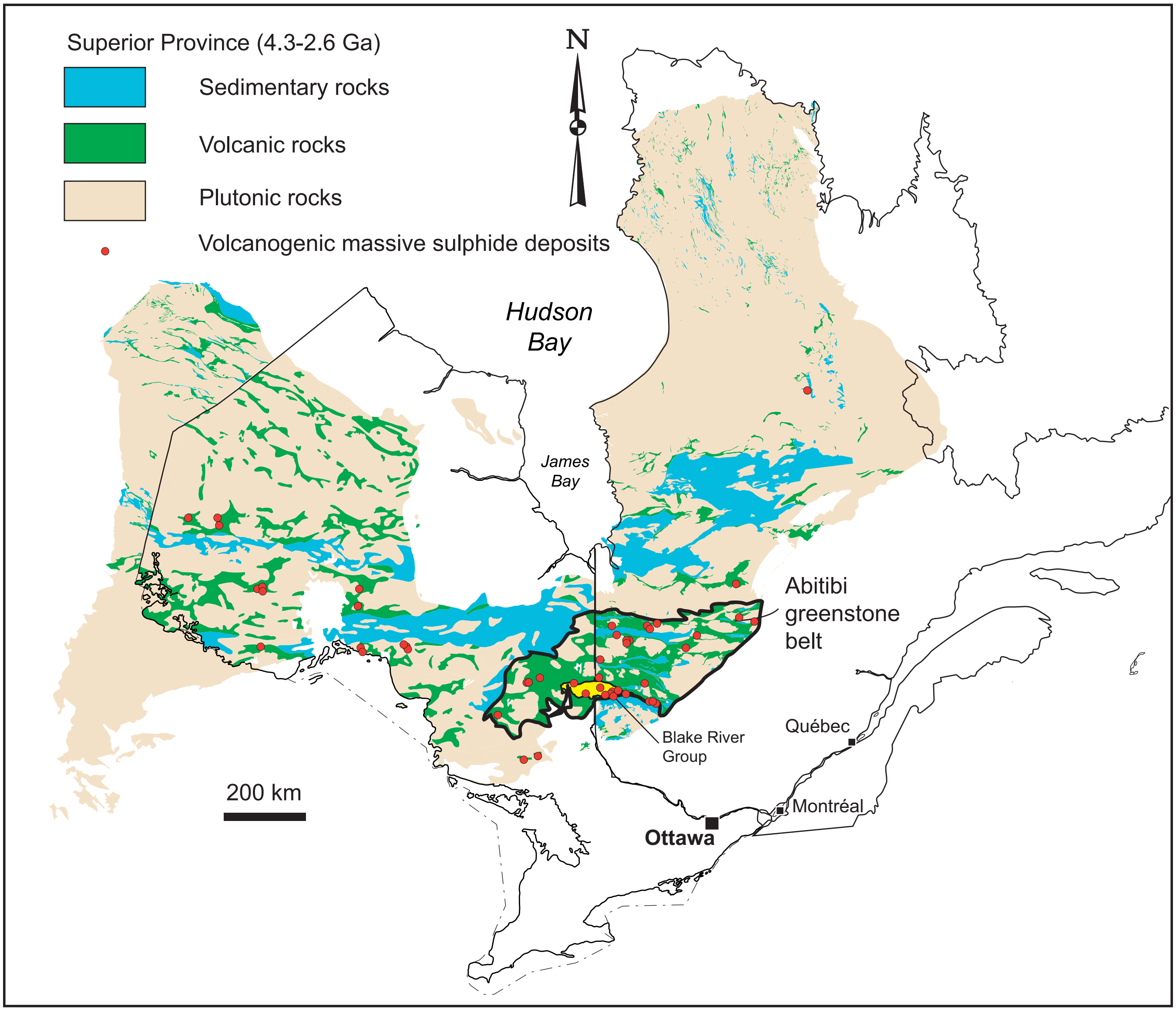

Figure 2. Simplified map of the Superior Province showing the location of the Abitibi greenstone belt and of the Blake River Group (in yellow). The principal VMS deposits of the Superior Province are also shown, highlighting the clustering of deposits in the Abitibi greenstone belt, more particularly in the Blake River Group. Modified from Thurston et al. (2008).

years, very precise U-Pb geochronology was instrumental in defining the ages of various volcanic packages within the Blake River Group. However, the new age dates cast some doubt on long-standing stratigraphic correlations between different parts of the district. Participants will have the opportunity to appreciate the importance of the different types of research done in the district and how the results of decades of research can be integrated in a new interpretation of the Blake River Group geological and metallogenic evolution.

GEOLOGY OF THE BLAKE RIVER GROUP – AN OVERVIEW

The Superior Province is the largest coherent Archean craton in the world, formed between 4.3 and 2.6 Ga (O'Neil et al., 2010; Percival and Stott, 2010). It consists of a wide variety of intrusions, mainly felsic, sedimentary basins and greenstone belts (Fig. 2). These rocks are metamorphosed from sub-greenschist facies to granulite facies. The Superior Province has been previously subdivided into subprovinces based on lithological characteristics (Card and Ciesielski, 1986), and recently in superterranes, terranes and domains separated by major structures (Stott et al., 2010).

The Blake River Group is the youngest and richest volcanic sequence of the Abitibi greenstone belt (AGB), the largest greenstone belt in the World (lozenge shape 310 km × 720 km; Fig. 2). The AGB is known for its unique endowment in VMS deposits, Ni-Cu-PGE magmatic deposits, and orogenic gold deposits among others (Ayer et al., 2002; Thurston et al., 2008)

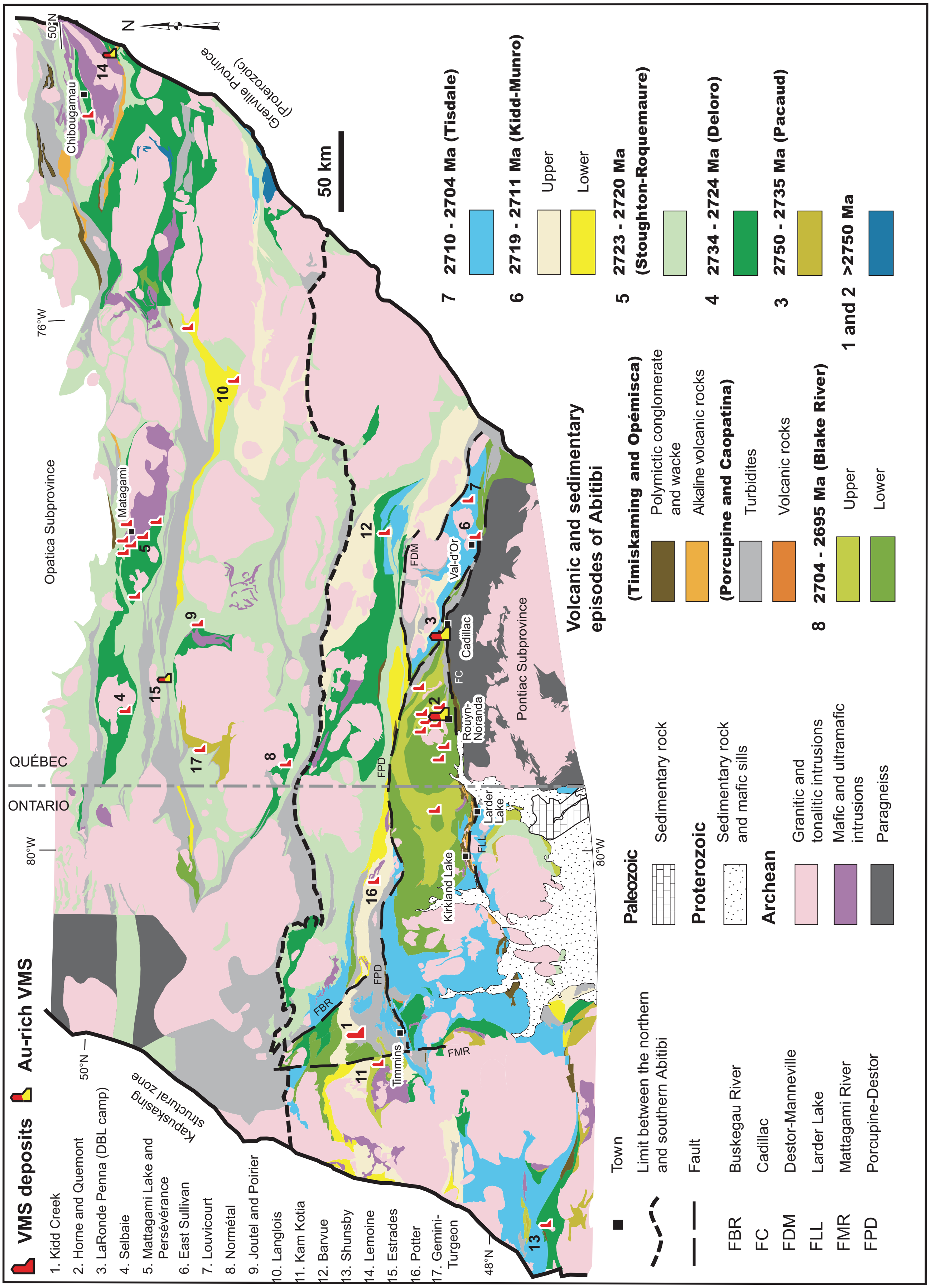

Figure 3. Map of volcanic and sedimentary episodes of the Abitibi greenstone belt, with location of the VMS and Au-rich VMS deposits. Modified from Thurston et al. (2008).

The AGB was formed over a period that spans approximately 150 m.y. (2790-2640 Ma). It has been subdivided into eight episodes of major submarine volcanic activity based on recent regional and detailed mapping and compilation (Fig. 3): 1) ~2790 Ma; 2) ~2758 Ma; 3) 2750-2735 Ma; 4) 2734-2724 Ma; 5) 2723-2720 Ma; 6) 2719-2711 Ma; 7) 2710-2704 Ma; 8) 2704-2695 Ma. Although numerous major faults and high-strain corridors cut across the AGB, stratigraphic sections are commonly well preserved. Many of those episodes are favorable periods for VMS formation. However, the 2704-2695 Ma volcanic episode represents the richest in terms of total accumulation of metals. This new framework also enables us to better understand the evolution of the AGB, which was previously thought to systematically young to the south .

The BRG locally comformably overlies the volcanic rocks of the 2710-2704 Ma Tisdale volcanic episode in the western part. No such comformable contacts are present in the eastern part of the BRG. However, some felsic volcanic rocks in the BRG yielded inherited zircons (e.g., Mercier-Langevin et al., 2007a). In some areas the BRG, sedimentary rocks (turbidites) of the Cadillac and Kewagama groups, both younger than 2687 and 2689 Ma, respectively (Davis, 2002; Lafrance et al., 2005; Mercier-Langevin et al., 2007a), are in paraconcordant to structural contact with the volcanic rocks. The BRG is also locally discordantly overlain by the polymictic conglomerates and alkalic volcanic rocks of the Timiskaming Group (~2680 to 2669 Ma, Goutier et al., 2009b), and by the Proterozoic conglomerates of the Cobalt Group (Fig. 4). Some Archean synvolcanic (gabbro, diorite, tonalite) and syntectonic intrusions (syenite, diorite, granodiorite, granite), and Proterozoic gabbro dykes (diabase) cut the Blake River Group volcanic rocks.

The BRG consists of a number of submarine volcanic and volcaniclastic sequences (Fig. 4A). The volcanic rocks are predominantly bimodal in composition (basalt – basaltic andesite – andesite versus rhyodacite – rhyolite). Some volcaniclastic units are pyroclastic in origin but most result from flow fragmentation with varying importance of transport processes (Ross et al., 2007; Mercier-Langevin et al., 2008; Ross et al., 2008a, 2008b, 2009, 2010, 2011a,b). Primary textures and volcanic-volcaniclastic facies are generally very well preserved in the BRG considering the fact that these rocks are Archean in age. This, combined with a decent exposure and high quality outcrops allows for detailed studies of volcanic facies and lateral variations (e.g., Dimroth et al., 1976, 1978; Dimroth and Rocheleau, 1979; Cousineau and Dimroth, 1982). Consequently, the rocks of the BRG are perhaps those that have been the most intensely mapped and studied in the Superior Province.

Through the years, the BRG stratigraphic framework has evolved from a simple succession of volcanic rocks (e.g., Goodwin, 1982) towards models suggesting multiple distinct volcanic sequences (e.g., Péloquin et al., 1990), or sequential caldera-forming events (e.g., Pearson and Daigneault, 2009) (Fig. 5). This evolution of ideas is explained by a better access to the territory with time, by more detailed and large-scale mapping and improved maps, an increasing amount of detailed studies, especially around ore deposits, and a better coverage at depth due to aggressive drilling campaigns by many mining and exploration companies. The main differences between past and current models reside in a better understanding of the relationship between units and between the BRG volcanic rocks and the overlying sedimentary rocks. An impressive U-Pb geochronology program conducted in recent years has been fundamental in providing a clearer picture of the volcanic architecture and evolution of the BRG.

The volcanic architecture of the central part of the BRG has been established by Spence (1967), Spence and de Rosen-Spence (1975), de Rosen-Spence (1976), Gibson (1989) and Gibson and Watkinson (1990). These authors have defined five major volcanic periods, zones or cycles (andesite – rhyolite), down to the scale of individual flows, placing the VMS lenses of the Noranda central camp in their correct stratigraphic position. This is how the "*Mine Sequence*" was assigned to the third volcanic cycle. The ore lenses associated with this sequence were formed during volcanic hiatuses that are more or less materialized by a single stratigraphic horizon. The first (west of the Flavrian Pluton) and fifth (east of the D'Alembert fault) volcanic cycles were not studied in great detail in those years.

New mapping and U-Pb geochronology in the central part of the BRG as well as in its eastern and western parts provided significant evidence for a more complex volcanic architecture than previously thought (e.g., Fig. 6). A new definition and nomenclature of the BRG units is underway in light of the recent work conducted in this area. Figure 7 shows the position of the major formations or domains of the BRG. The rock units of the BRG define a number of structural blocks, comprising homoclinal panels, complexly folded assemblages, and faulted blocks (Fig. 7). The impressive number and high precision of the U-Pb ages obtained in the last few years allow for the subdivision of the BRG into four time-stratigraphic intervals (2704 to 2701.7, 2701.7 to 2699.3, 2699.3 to 2696.7, and 2696.7 to 2695 Ma), which provide a well-defined framework to help understand the hydrothermal evolution of this geological entity.

In Quebec, the BRG is bounded by two major fault zones: the Porcupine-Destor fault to the north, and the

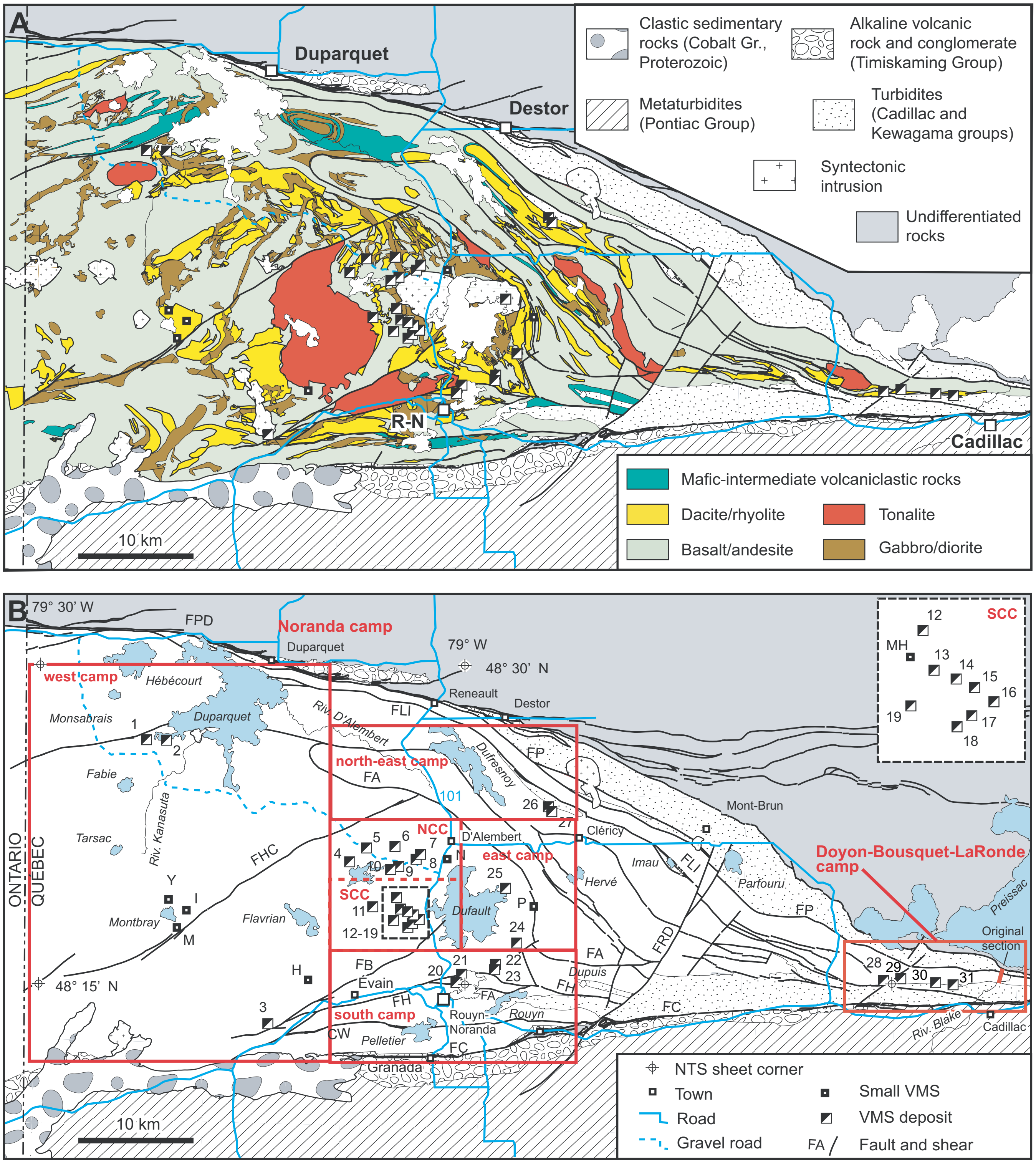

Figure 4. A) Simplified geological map of the Rouyn-Noranda area (Quebec portion of the Blake River Group). Modified from the Système d'Information Géominière (SIGEOM) of the MRNF. **B)** Location of the mining camps of the Noranda District, from west to east: Noranda west camp, Noranda south camp, Noranda southern central camp (SCC), Noranda northern central camp (NCC), Noranda north-east camp, Noranda east camp, and the Doyon-Bousquet-LaRonde camp. The map also shows the principal faults and orebodies. The deposit numbers refer to the numbering in Table 1. The Blake River and the original type section are located in the lower right corner of the map (in red). CW = Wasa shear zone, FA= Andesite fault, FB= Beauchastel fault, FC= Cadillac fault, FH= Horne Creek fault, FHC= Hunter Creek fault, FLI= Lac Imau fault, FPD= Porcupine-Destor fault, FRD= Ruisseau Davidson fault, H= Halliwell prospect, I= Inmont prospect (Robb-Montbray), M= Montbray prospect, MH= Moosehead prospect, N= Newbec, P= Pinkos prospect, R-N= Rouyn-Noranda, Y= Yvanex prospect.

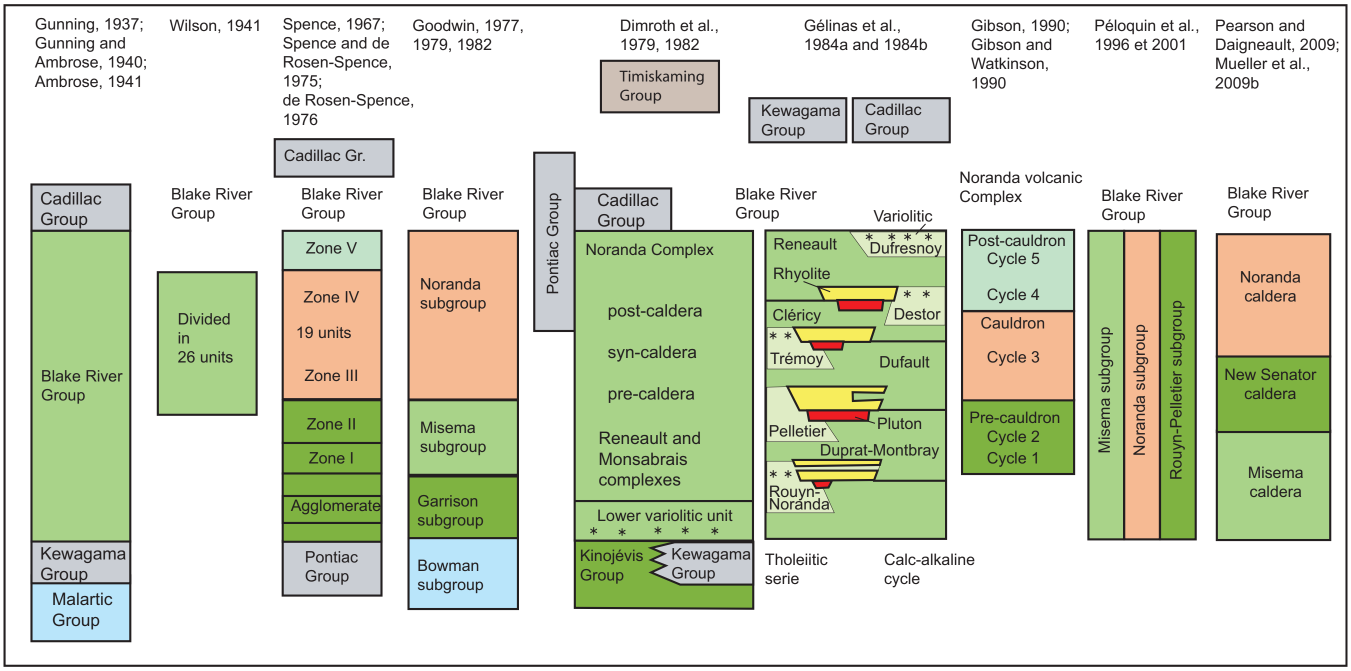

Figure 5. Previously proposed stratigraphic schemes for the Blake River Group.

Larder Lake-Cadillac fault to the south (Fig. 4A and 4B). Rocks of the BRG were subjected to major north-south shortening events (regional D2). However, the deformation is heterogeneously distributed within the BRG; the central part is characterized by tilting of the strata and by the presence of major folds, whereas the northern and southern margins are characterized by the presence of laterally extensive shears and tight folds. The BRG rocks are affected by lower greenschist (north) to lower amphibolite (south) grade metamorphism (Jolly, 1978, 1980; Dimroth et al., 1983; Gélinas et al., 1984; Powell et al., 1995; Dubé et al., 2007a).

METALLOGENY OF THE BLAKE RIVER GROUP – AN OVERVIEW

Ninety VMS deposits were formed in the AGB over a period of about 42 m.y., with a cumulative tonnage (production, reserves and resources) of approximately 810 Mt of base and precious metal-rich ore. Almost half of that cumulative tonnage is associated with the Blake River Group (Mercier-Langevin et al., 2009a).

The 2704-2695 Ma volcanic episode is the richest in terms of total accumulation of metals. It comprises the Blake River Group (BRG) that contains the most important concentration of VMS deposits of the Superior Province and of any other Archean sequence. Approximately half of the total VMS tonnage of the AGB is located in the BRG, and about 90% of the total "VMS gold" of the AGB is found in the BRG. Horne (54 Mt plus 170 Mt of sub-economic sulphides) and LaRonde Penna (~79 Mt) together contain more than 40% of the total VMS gold of the entire AGB (Mercier-Langevin et al., 2010c). The BRG volcanic and intrusive rocks host a wide spectrum of types of mineralization (Couture, 1996) : 1) VMS deposits (Cu-Zn-Ag-Au ±Cd ±Se), 2) Au-rich and auriferous VMS deposits (Au-Cu-Zn-Ag ±Pb), 3) intrusion-related disseminated Cu mineralization (Cu ±Mo), 4) auriferous volcanogenic disseminated sulphides, 5) intrusion-hosted auriferous quartz-sulphide vein systems, 6) magmatic/hydrothermal sulphides (Ni-Cu ±EGP), 7) mesothermal (or "orogenic") quartz-carbonate and disseminated gold deposits (Au-Ag ±Te), and 8) syenite-hosted Au-Cu deposits.

The BRG hosts 31 VMS deposits, including 20 past or current producers (Table 1). The location of these deposits is shown in Figure 4B. Ore zones or lenses that are located less than 500 m-apart are considered part of a single ore body or deposit (empirical criteria porposed elsewhere, e.g., Mosier et al., 2009). A lower limit of 0.2 Mt has been used to differentiate deposits from prospects, except for orebodies smaller than 0.2 Mt that have been mined (e.g., D'Eldona deposit). The VMS deposits of the BRG (Rouyn-Noranda mining district) are largely clustered in two mining camps: Noranda and Doyon-Bousquet-LaRonde, with a few deposits/prospects scattered elsewhere in the BRG (Fig. 4). The Noranda camp comprises the deposits numbered 3 to 27, whereas the Doyon-Bousquet-LaRonde camp comprises the deposits numbered 28 to 31 (Table 1). The Noranda camp can be further divided in smaller camps (Fig. 4B): the Noranda south camp (Horne, Quemont, D'Eldona and Delbridge deposits), the southern central camp (Amulet, Millenbach, Corbet), the northern central camp (West Ansil, Ansil,

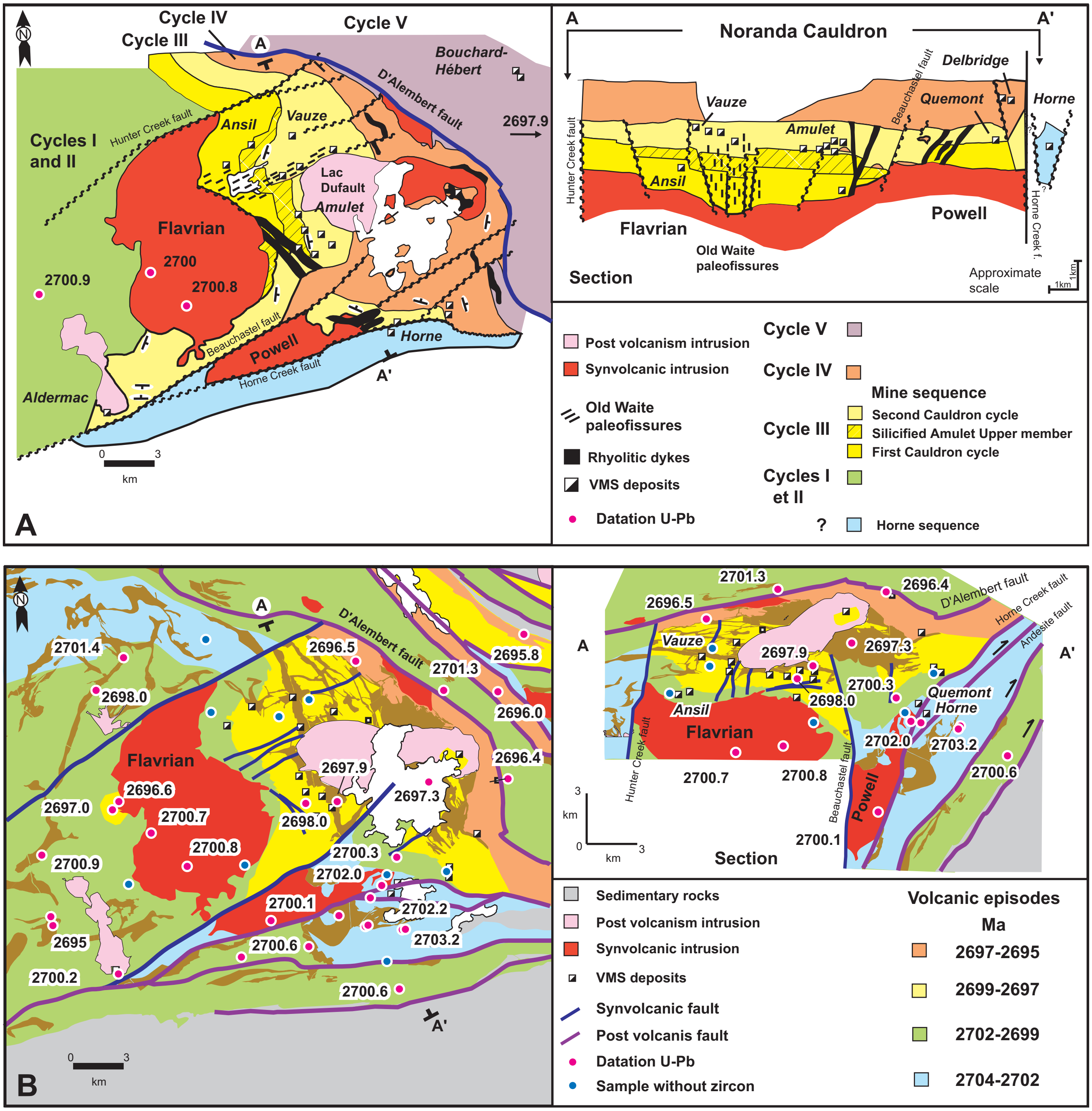

Figure 6. A) Simplified geological map of the Noranda camp and schematic reconstitution (N-S section) of the Noranda camp volcanic architecture. Modified from Gibson and Galley (2007). **B)** New geological map of the Noranda camp based on four distinct volcanic episodes. This new interpretation is largely based on new U-Pb geochronology. Note that no U-Pb ages were available in this area prior to 2001. Major modifications to the current and inferred primary volcanic architecture can be seen on these figures: the Horne and Quemont are hosted in the oldest rocks of the area, on each side of the Beauchastel fault, and the segmentation of the cycle 5 volcanics into many strata of various ages. The section to the right has been done by projecting the units at right angle to the fold axes.

Old Waite, Vauze, East Waite and Norbec), the west camp (Aldermac, Baie Fabie-Magusi, Inmont and Halliwell), the east camp (South Dufault, Gallen-West MacDonald, Pinkos), and the northeast camp (Mobrun, Bouchard-Hébert).

The VMS deposits of the Rouyn-Noranda mining district, especially those located in the southern and northern central camp, define the archetypal "Noranda type". These deposits are characterized by lenses or masses of sulphides sitting on top of discordant sulphide stringers (feeders) that are formed near tholeiitic to transitional effusive centers. The VMS deposits that are located in the south and northeast camps (e.g., Horne and Bouchard-Hébert) are generally larger, tabular in shape and were formed, at least in part, by sub-

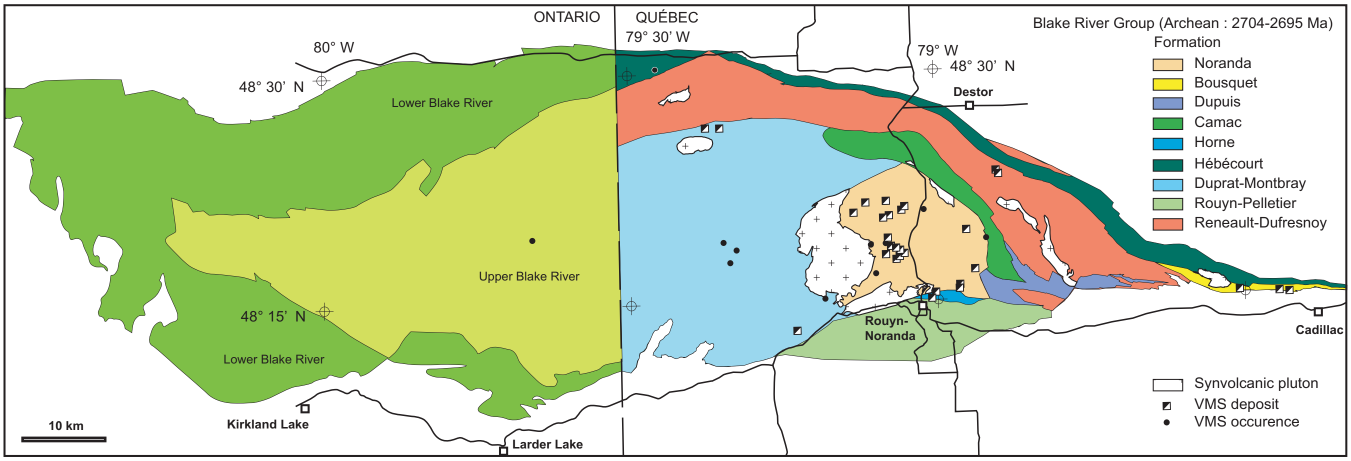

Figure 7. Distribution of the Blake River subdivisions in Quebec (formations) and Ontario (assemblages).

seafloor replacement of felsic volcaniclastic rocks. They are associated with extensive, concordant to locally discordant sericite and quartz alteration envelopes and proximal zones of chlorite ± carbonate alteration of varying intensity.

The Doyon-Bousquet-LaRonde camp is characterized by an exceptional concentration of Au-rich volcanogenic mineralization forming disseminated, semi-massive and massive sulphide lenses that are locally rich in base metals. These Au-rich lenses are associated with widespread sericitization and with significant concordant to discordant proximal garnet-biotite-sericite±quartz-chloritoid-rutile alteration zones or with proximal aluminous alteration zones (staurolite, kyanite, andalousite, quartz, sericite, sulphides). The mineralization and its associated alterations are preferentially developed in a sequence dominated by transitional to calc-alkaline felsic volcaniclastic units (Mercier-Langevin et al., 2007d and references therein).

The first time-stratigraphic interval of the BRG (2704 to 2701.7 Ma) is associated with the formation of a tholeiitic lava plain and isolated felsic centres. The Horne and Quemont Au-rich VMS deposits are associated with this early volcanic event. The Quemont felsic centre is developed in a graben-like depression borded by the Beauchastel fault.

The second time-stratigraphic interval (2701.7 to 2699.3 Ma) is characterized by bimodal volcanism in the central part of the BRG, by the emplacement of large synvolcanic plutons (Flavrian, Powell, Fabie), development of a graben or trap-door-style caldera on the east side, formation of a large volume of more vesicular andesitic volcanic rocks (lavas and volcaniclastic rocks) around the central part and continuation of the tholeiitic lava plain development in the periphery. The Aldermac, Ansil, Corbet, Inmont and Yvanex VMS deposits were formed during this volcanic event.

The third time-stratigraphic interval (2699.3 to 2696.7 Ma) is the most prolific of in terms of VMS formation. Gradual inilling of the trap-door caldera and continuity of andesitic volcanism around the central part is characteristic of this volcanic episode. This interval includes the Mine Sequence, or southern and northern central camps VMS deposits (Amulet, Millenbach, Waite, Norbec, etc.), which are hosted in a bimodal volcanic package. The Au-rich VMS deposits of the Doyon-Bousquet-LaRonde camp were formed at about the same time, although in a different environment characterized by transitional to calc-alkaline, intermediate to felsic flow-domes and associated volcaniclastic rocks developed over the tholeiitic lava plain.

The fourth time-stratigraphic interval of the BRG (2696.7 to 2695 Ma) consists of felsic volcanic rocks and mafic-intermediate volcanoclastic rocks. This interval includes several tholeiitic to transitional rhyolites and synvolcanic plutons (Monsabrais, Cléricy). The VMS deposits of the Bouchard-Hébert mine and that of Canagau prospect in Ontario were formed during this last BRG-related volcanic event.

DAY 1: GEOLOGY, STRATIGRAPHY AND GEOCHRONOLOGY OF THE BLAKE RIVER GROUP AND RELATIONSHIPS WITH VMS DEPOSITS

Jean Goutier (MRNF), Pierre-Simon Ross (INRS-ETE), Vicki McNicoll (GSC-Ottawa), Claude Dion (MRNF), Patrick Mercier-Langevin (GSC-Qc), Phil Thurston (Laurentian U.), Benoît Dubé (GSC-Qc), Harold Gibson (Laurentian U.)

Objectives

This first day of field trip will aim at giving an overall appreciation of the stratigraphic, hydrothermal and tectonic architecture of the BRG and allow participants to observe some of the principal volcanic facies of the BRG. A few stops will also allow examination of alteration zones associated with VMS deposits and occurrences plus some exhalative units that are characteristic of the Noranda southern and northern central camps.

Stop 1-1: Facies variations in basalts from a lava plain

Coordinates

UTM, NAD 83, zone 17, 648180 m E, 5343080 m N

Stop description

Outcrops near *parc* Lapointe, within the city limits of Rouyn-Noranda, expose a succession of submarine mafic lava flows (Fig. 8). The strain intensity in this area is very low and the metamorphic grade is relatively low at greenschist facies, allowing for the good preservation of typical subaqueous mafic-intermediate flows. A lava plain setting has been proposed by Dimroth et al. (1982) to explain the nature and architecture of such widespread tholeiitic lava flows near the stratigraphic base of the BRG.

These outcrops, and other outcrops scattered elsewhere in the region, allowed Dimroth et al. (1978) to develop facies models for mafic subaqueous lavas, in which massive lavas grade laterally or vertically into pillowed flows and then fragmental facies such as pillow breccias and hyaloclastite (Fig. 8). Gibson et al. (1999), in contrast, do not reckon that massive to pillowed transitions are common, and consider that there are two separate types of mafic flows, massive and pillowed, each of which can have a fragmental facies. Nevertheless, we will see (and discuss) at least one massive to pillowed transition at Stop 1-1.

The flows near *parc* Lapointe are oriented WNW and dip steeply to the northwest. Topography allows for a 3D examination of the volcanic facies. Gabbroic sills invade the volcanic sequence and can be difficult to differentiate from massive lavas.

An unpublished geochemical analysis from this outcrop (P. Mercier-Langevin) yielded 46.7% SiO_2, 9.1% MgO, 33 ppm Zr, 14.3 ppm Y (Zr/Y = 2.3), 1.74 ppm La, and 1.49 ppm Yb (La/Yb = 1.16). The trace element ratios indicate a tholeiitic affinity on both the Barrett and MacLean (1999) and Ross and Bédard (2009) discrimination diagrams.

Stop 1-2: Rhyolites, Cléricy area

Coordinates

UTM, NAD 83, zone 17, 654204 m E, 5358180 m N

> ***NOTE:*** *Visitors must cross on a private property to access the outcrops, please ask permission from the landowners before proceeding.*

Stop description

Outcrops visited are located on the top of a hill, north of the road between the D'Alembert and Cléricy villages (Fig. 9). The volcanic rocks in this area belong to the Reneault-Dufresnoy formation or domain. This sequence is steeply inclined to the NE and lies between subaqueous massive to fragmental basaltic andesites. The stratigraphic top is to the NE as indicated by pillows. This stop provides a good opportunity to observe a succession of flow-banded rhyolitic units that are associated with hyaloclastites and different types of breccia deposits formed in a submarine environment.

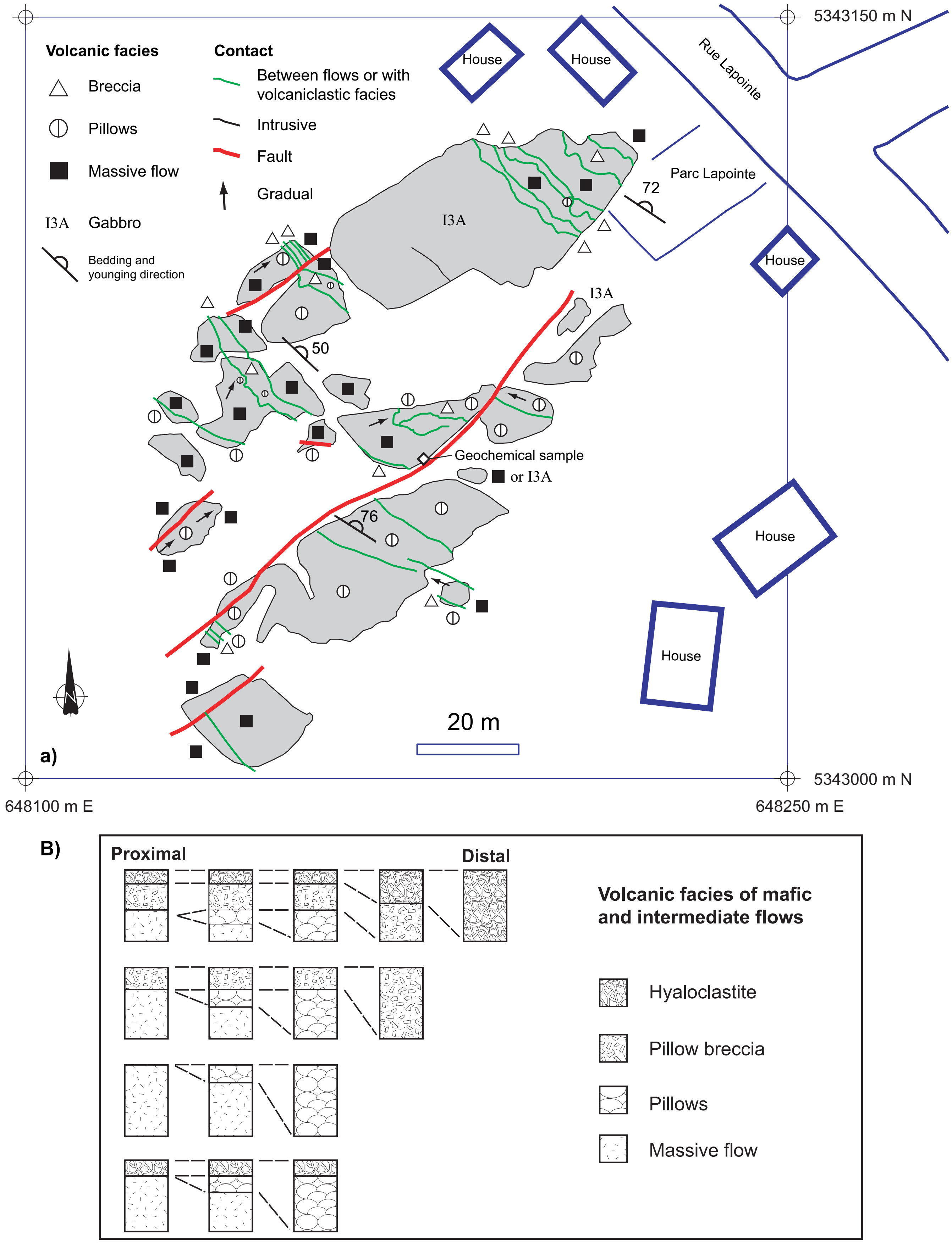

Figure 8. A) Map of volcanic facies variations in tholeiitic basalts SW of parc Lapointe in Rouyn-Noranda (Stop 1-1). Map grid is UTM nad 83 zone 17. **B)** Schematic facies variations likely to be encountered in mafic to intermediate lava flows. After Dimroth et al. (1978).

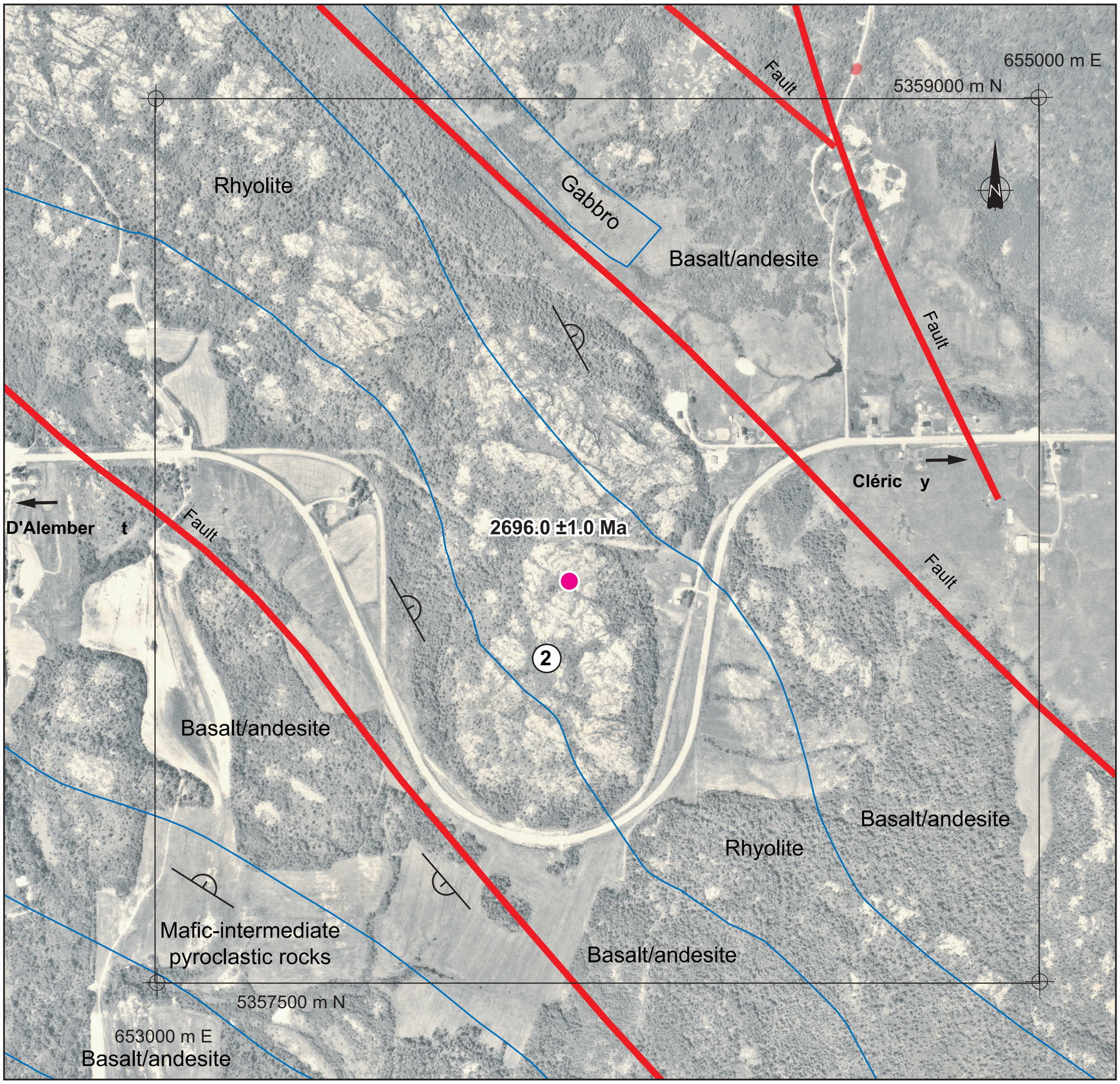

Figure 9. Aerial photograph showing the visited outcrop at stop 1-2, with the location of lithologic contacts.

Rhyolites from these outcrops are rich in silica (>79 % SiO_2) and have a transitional magmatic affinity on the Ross and Bédard (2009) discrimination diagrams. These rocks are among the youngest of the BRG with an age of 2696.0 ±1.1 Ma (Lafrance et al., 2005).

Stop 1-3: The D'Alembert tuff

Coordinates

UTM, NAD 83, zone 17, 642336 m E, 5367998 m N

> ***NOTE:*** *Visitorsmust cross a private property to access the outcrops, please ask permission of the landowners before proceeding to the outcrops from Highway 101.*

Stop description

Major mafic to intermediate volcaniclastic units are relatively abundant in the peripheral areas of the BRG. Such rocks are found in the stratigraphic footwall of the LaRonde Penna deposit (Lafrance et al., 2003; Mercier-

Langevin et al., 2008) and of the Bouchard-Hébert 1100 lens (Caumartin and Caillé, 1990; Larocque and Hodgson, 1993). A better knowledge of these rocks is important to understand the stratigraphy and volcanic architecture of the BRG, with implications for VMS exploration.

A systematic field-based study of the main mafic to intermediate volcaniclastic units in the BRG (e.g., Goutier et al., 2007; Mercier-Langevin et al., 2008; Ross et al., 2007, 2008a, 2008b, 2009, 2011a, 2011b) was undertaken in 2006 as part of the TGI-3 Abitibi project. The objectives were to determine the physical characteristics, geochemical signatures, stratigraphic positions, ages, and origins of these rocks. A further aim of this investigation was to test whether the major volcaniclastic units were correlative, as implied in the megacaldera model of Pearson and Daigneault (2009).

The D'Alembert tuff is a bedded volcaniclastic unit which extends about 12.5 km from Baie D'Alembert in Lake Duparquet east of Highway 101. The exposed stratigraphy is approximately 300 m-thick (Dimroth and Demarcke, 1978), whereas the minimum total stratigraphic thickness ranges between 545 m and 820 m. Pillowed lavas are exposed north and south of the D'Alembert tuff, which strongly suggests that the volcaniclastic rocks were deposited under water.

Despite the folding of the sequence, penetrative deformation remains minor in the volcaniclastic rocks, especially for the lapilli tuffs and tuff breccias. Base metal mineralization is found in at least two locations along the northern contact of the D'Alembert tuff. The westernmost occurrence is known as the Baie D'Alembert showing and has been described in Ross (2010).

Tassé et al. (1978) described a number of detailed stratigraphic sections in the D'Alembert tuff; we have relogged and sampled their easternmost one (Ross et al., 2011a) and this locality will be examined during stop 1-3. The updated section displays 227 m of near-vertical volcaniclastic stratigraphy, including many unexposed intervals, plus 11 m of gabbro at the top (Fig. 10). There are no intercalated lavas or mudstones in the section, suggesting relatively quick emplacement of the coarse volcaniclastic beds by density currents, and a consistent abundance of volcanic debris in the water column.

The thickest bed in the section is at least 24 m-thick. Of 27 at least partly exposed beds, 16 display normal grading, 12 have reverse grading at the base, and only 3 have diffuse internal stratification at the top. Wide, shallow channels, which are inferred to have been excavated during passage of the following density currents, are sometimes seen in fine-grained bed tops. Typically, such basal erosional surfaces are overlain by a thick, coarse-grained deposit with reverse grading at its base. The thickest, coarsest beds, which often lack a stratified division, were clearly produced by high-concentration density currents.

The largest measured clast in the stratigraphic section, found at ~200.5 m, is 60 cm long on a horizontal plane. Rare vertical outcrops reveal that the long axis of most clasts is sub-vertical, but the clasts are not strongly elongated. The shape of large clasts varies in the stratigraphic section, ranging overall from sub-rounded to angular. From 165 m upwards, the largest clasts are typically angular to sub-angular, and in some beds something approaching a jigsaw-fit texture is seen. The large fragments are not in contact with each other and are separated by smaller clasts, but judging from their shapes, they were formerly in contact and came from a larger domain of cooled magma. Brittle failure of this domain of cooled magma created the large clasts, which subsequently moved a few cm to dm from each other, during transport.

Dimroth and Demarke (1978) performed detailed petrography on rocks from this area and indicated that the volcaniclastic samples do not contain "pumice" or many free crystals, as opposed to those exposed further to the west. In the area that we will visit, volcaniclastic rocks are essentially monomictic with >95% of clasts consisting of plagioclase-phyric juvenile fragments with an average of 12% vesicles. Two other important observations made by Dimroth and Demarcke (1978) were that the deposits are not welded, which means they were emplaced cold, and that particles clearly derived from pillow lavas are absent.

Thirteen samples collected from the relogged section (spaced as regularly as possible over 227 m of volcaniclastic stratigraphy) were analysed for major and trace elements. All these samples have a similar composition to one another. This geochemical homogeneity in volcaniclastic samples suggests that the magma which erupted to produce beds found in the stratigraphic section was itself quite homogeneous, and that juvenile clasts were not severely contaminated by non-juvenile material.

For the volcaniclastic strata exposed further west, an abundant source of scoriaceous clasts and free plagioclase crystals is needed, and the most likely source is one or several large and vigorous submarine explosive eruption column(s) created from disintegration of a plagioclase-phyric, vesiculated magma (Ross et al., 2007, 2011a). It is supposed that the explosive eruptions which generated the D'Alembert tuff took place under water. Following their

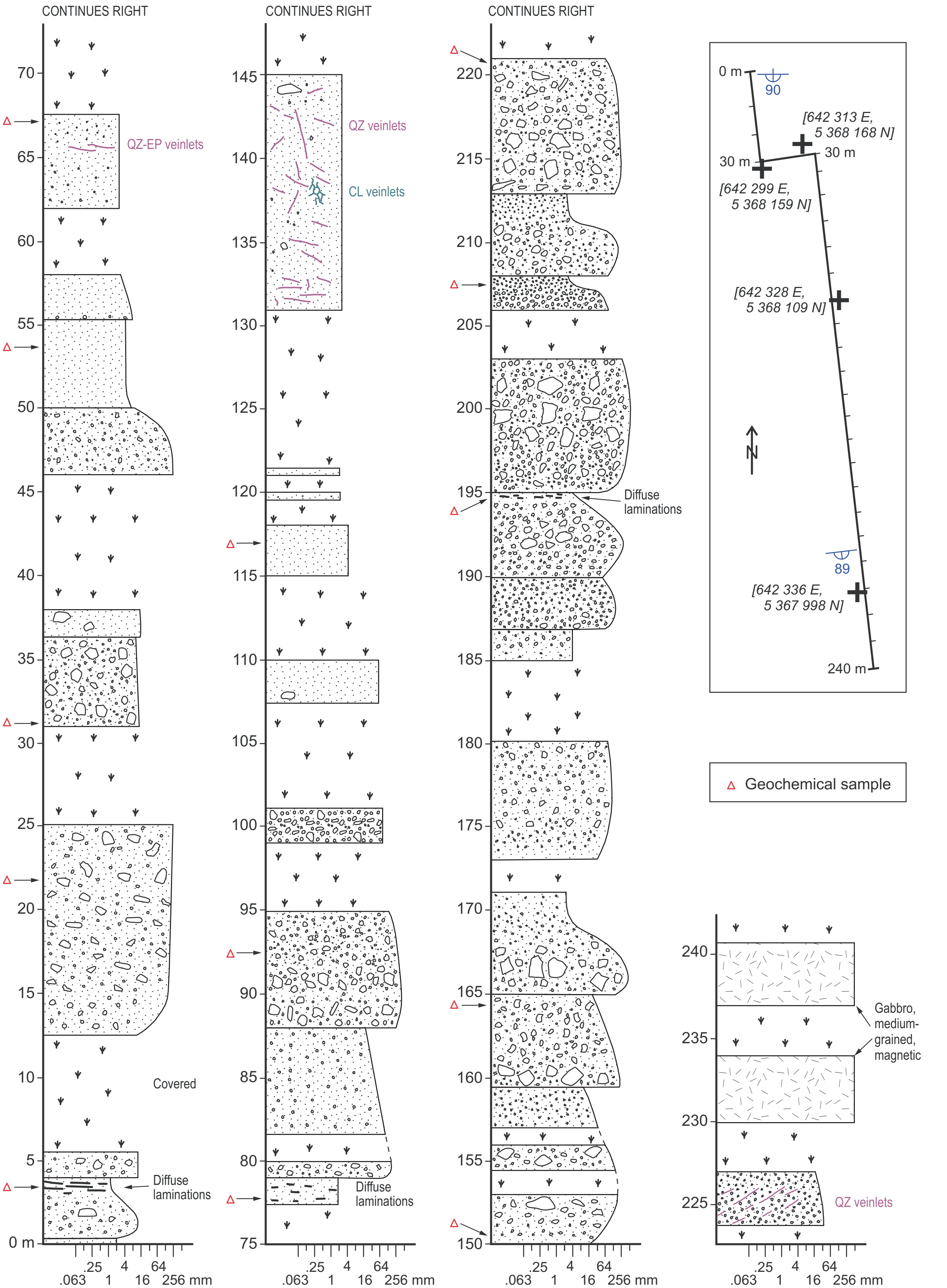

Figure 10. Relogged section through the D'Alembert tuff, after Ross et al. (2011a). Note the thickness and coarseness of the volcaniclastic beds, the reverse and normal grading, and the lack of interbedded lavas or sedimentary rocks.

introduction into the ocean, the fragments were either (1) directly entrained in debris flows and turbidity currents (eruption-fed aqueous density currents of White (2000), for example due to eruption column collapse), or (2) temporarily deposited on the seafloor and then remobilized in density currents. Note that these submarine debris flows are not pyroclastic flows sensu stricto (White, 2000) since gas is not the interstitial medium between fragments in the flows.

The transport and deposition mechanisms envisaged within this section are the same, but the origin of the fragments likely differs. Instead of scoriaceous clasts and free crystals, the deposits contain abundant porphyritic, weakly vesicular juvenile fragments of homogenous composition. Dimroth and Demarcke (1978) proposed that these fragments were derived from the "collapse or localized explosion of andesite domes and spines" which had already crystallized at the time of the eruption.

Stop 1-4: Volcanic rocks and sulphide-bearing stratified horizons in the Lake Hébécourt area

Coordinates

No specific UTM location.

> ***NOTE:*** *Drill core from the Hébécourt area is stored at the Norbec mine site. Authorization must be obtained from the company to get access to the mine site.*

Stop description

The Hébécourt Formation (Goutier, 1997) is a monotonous basalt-dominated volcanic unit that occurs mainly in the northern part of the BRG in Québec, from the Ontario border to the LaRonde mine and beyond (Fig. 7). As those of stop 1-1, these rocks were also interpreted as a lava plain by Dimroth et al. (1982), and were informally correlated with similar basalts containing variolitic horizons in the southernmost BRG. The Hébécourt Formation contains very few rhyolites, and its VMS potential has been considered low, resulting in less exploration work than in other areas of the BRG. However two rhyolites west of Lake Hébécourt, in the NW corner of the BRG in Québec, have recently been shown to have approximately the same age as rocks hosting the giant gold-rich Horne VMS deposit, which suggests that older parts of the BRG stratigraphy should be reassessed for their VMS potential.

The BRG west of Lake Hébécourt, including the tholeiitic Hébécourt Formation and the overlying transitional to calc-alkaline volcanic rocks, was recently studied as part of an M.Sc. project at INRS-ETE (Rogers, 2010; Rogers et al., 2010a, 2010b). The studied area (Fig. 11) was selected because it contains an unusually large accumulation of felsic rocks that are associated with some Zn-Cu mineralization and hydrothermal alteration zones (Cloutier, 1975; Fraser, 1991; Martin, 1994; Bambic 1998), as well as sulphide-bearing stratified horizons (Carignan and Lafrance, 2008).

The study combined physical volcanology with chemo-stratigraphy to establish the location of effusive centers in the volcanic units; and used pyrite geochemistry in sulphide-bearing stratified horizons with whole-rock geochemistry in the underlying volcanic units to identify hydrothermal up-flow zones. As a consequence, five main units were identified in the Hébécourt Formation, ranging from basalt to rhyolite. Likely effusive centers were located for three felsic units [low-Ti (porphyritic) rhyolite, high-Ti (aphyric) rhyolite, upper rhyolite] and a basaltic andesite unit. Known Zn-Cu mineralization includes sulphide stringers and disseminations located within the flank breccia of the low-Ti rhyolite dome. Higher in the stratigraphy, this sector corresponds to the inferred volcanic vent area for the basaltic andesite unit (Fig. 12).

This stop will consist of a poster presentation, accompanied by examination of drill core.

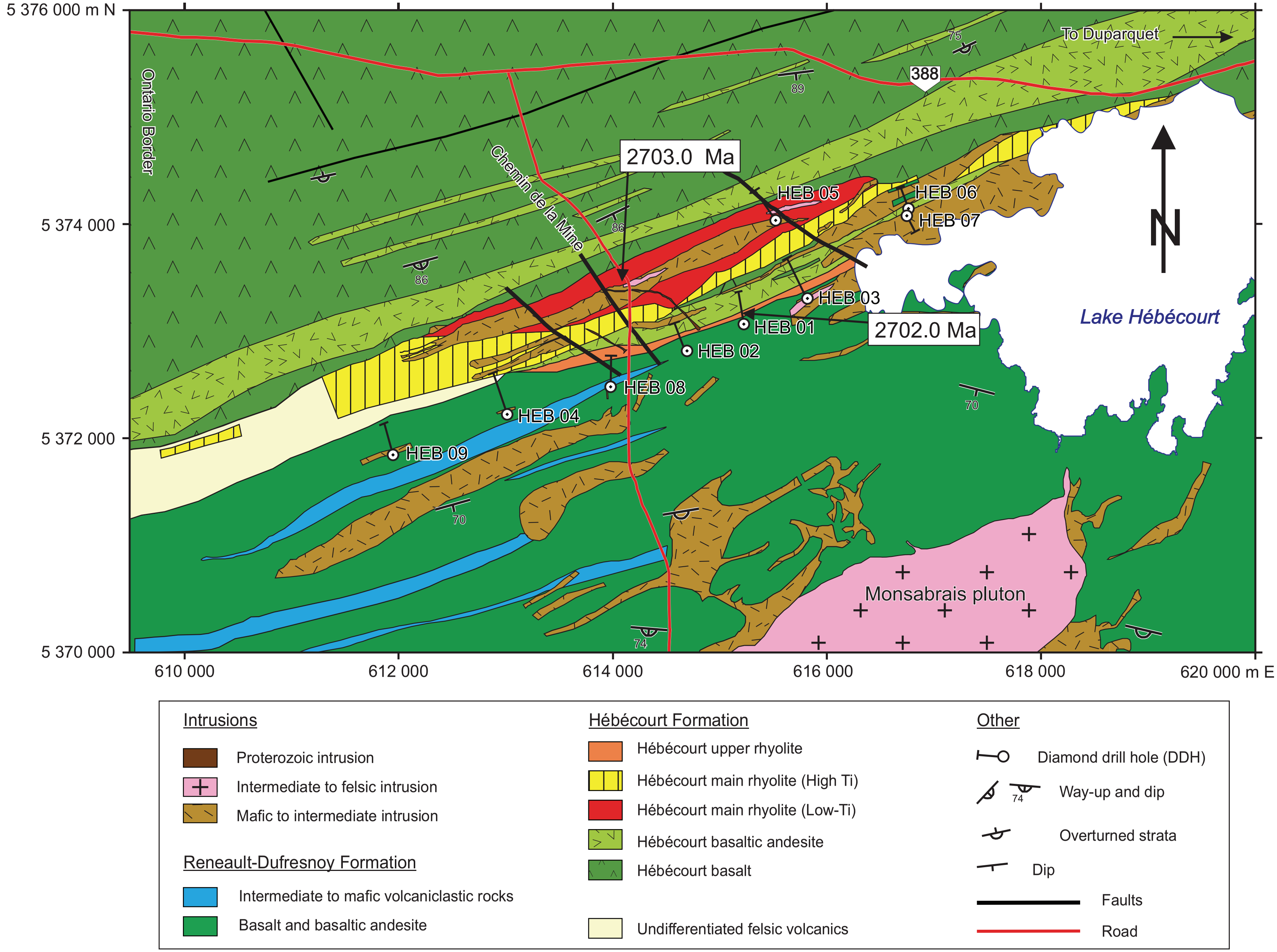

Figure 11. Map of the top of the Hébécourt Formation and the base of the Reneault-Dufresnoy formation west of the Lake Hébécourt. Modified from Rogers (2010). The map grid is in UTM nad 83 zone 17 (in kilometres). Only diamond drill holes from Cogitore Resoruces Inc., which were strudied by Rogers (2010) are shown for clarity, but all available data was integrated to generate this map. The two U-Pb ages for the Hébécourt rhyolite were done by V. McNicoll at the Geological Survey of Canada.

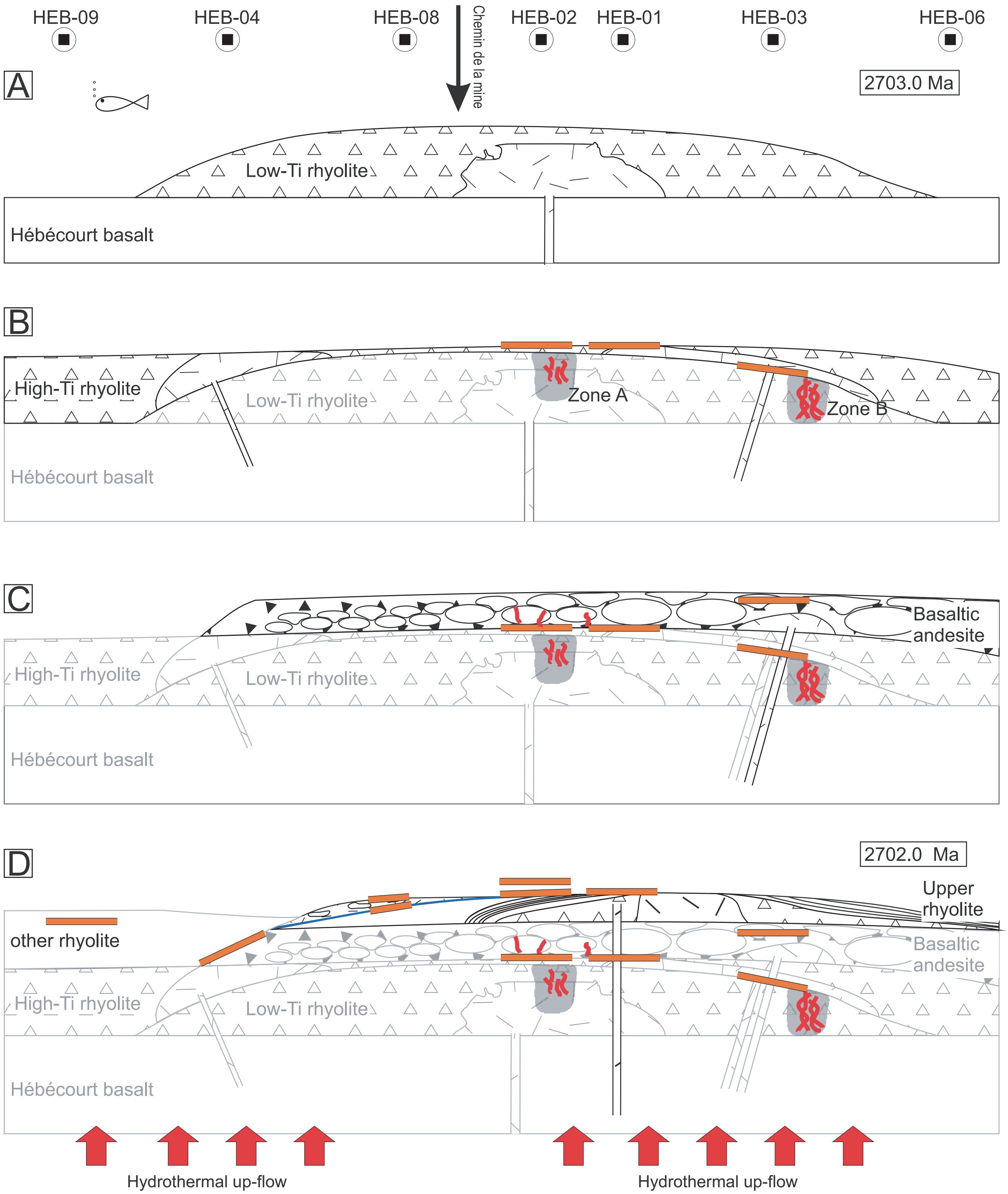

Figure 12. Geological evolution of the top part of the Hébécourt Formation west of Lake Hébécourt. Modified from Rogers (2010). Schematic pre-deformation longitudinal sections are not to scale. Hydrothermal up-flow within volcanic units probably occurred more or less continuously during the time period shown. **A)** Deposition of the low-Ti subunit of the main rhyolite. Triangles represent the fragmental facies and randomly orientated dashes represent the massive facies. **B)** Eruption of the high-Ti subunit of the main rhyolite, from two separate vents. Also shown is the Zone A and Zone B alteration and mineralization. Thick orange lines represent the location of known sulphide-bearing laminated horizons (some may be more continuous than shown). **C)** Eruption of the youngest intercalation of the Hébécourt basaltic andesite. Filled triangles represent hyaloclastite and the pillows decrease in size to the west. **D)** Eruption of the upper rhyolite from the easternmost vent, as the western vent is unknown.

Stop 1-5: The Waite rhyolite and Amulet andesite (northern central camp)

Coordinates

UTM, NAD 83, zone 17,
643044 m E, 5357992 m N

Stop description

The northern central camp corresponds to the area comprising the VMS deposits shown on Figure 13A, plus the Ansil and West Ansil that are located further to the west, at a slightly lower stratigraphic position (Fig. 4B). Most of the ore lenses in this sector are situated on top of the Waite rhyolite and are covered by the Amulet andesite. These two units are part of the Noranda formation or domain. Mineralization in this area was first discovered by surface prospecting, then at greater depth by geophysics, drilling and geological modeling.

A series of outcrops will be visited. These outcrops expose the Waite rhyolite and the pillowed flows of the overlying Amulet andesite. Rocks in this area are weakly deformed and dip gently to the east (20°-30°). A background greenschist facies metamorphism is gradually overprinted by up to amphibolite grade contact metamorphism around the Lac Dufault pluton. The contact metamorphism is particularly well developed in the VMS-related alteration zones, which will be further described at Stop 1-6.

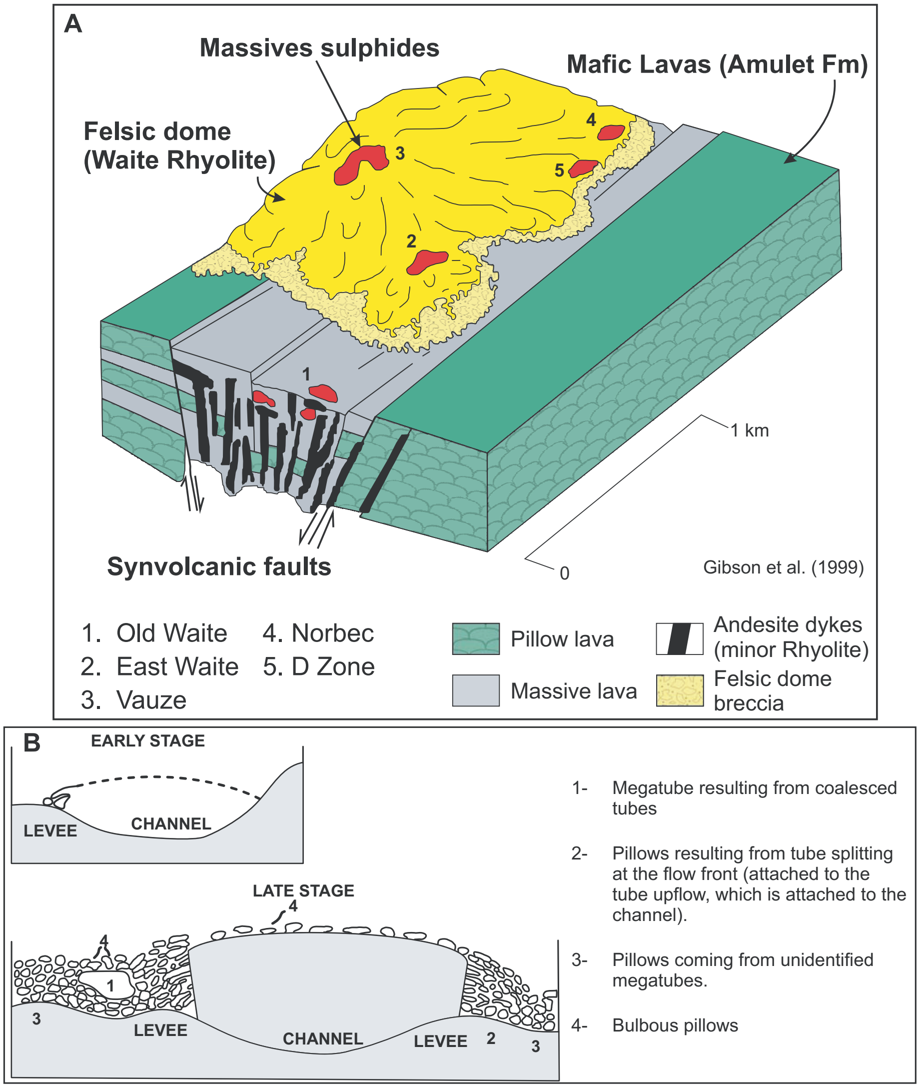

Figure 13. A) Schematic reconstruction of the Old Waite paleofissure in the north central camp (stop 1-5), after Gibson et al. (1999). The model illustrates that synvolcanic faults controlled volcanic vents for both mafic and felsic rocks; emplacement of dykes; circulation of hydrothermal fluids; and ultimately, formation of several VMS deposits. Note how most of the mafic flows are restricted to a graben and do not grade laterally into pillowed flows. **B)** Schematic section showing the formation of volcanic levees, with lateral facies changes, in the Norbec deposit vicinity (stop 1-5), after Cousineau (1982).

Two attempts were made at dating the Waite rhyolite. Despite a fairly high Zr content (~270 ppm Zr), the sample did not yield usable zircons. This makes it difficult to directly constrain the age of the northern central camp VMS deposits and to confidently correlated them with those of the southern central camp that were dated at 2698 Ma (see Stop 1-7). However, the rock units of the northern central camp are cut by the northern extension of the Dufresnoy gabbro, which has been dated at 2697.9 Ma (see Stop 1-8).

The first outcrop that will be looked at corresponds to one of the U-Pb sampling sites where the Waite rhyolite is fine-grained, very weakly feldspar-phyric (< 1mm). Lobes, flow-banding and hyaloclastic breccias characterize the Waite rhyolite in this area. A second outcrop exposing an exhalite will be visited. This exhalite is situated at the contact between the Waite rhyolite and the Amulet andesite that is also known as the "Main Contact". This exhalative horizon consists of finely laminated tuff and chert, with varying amounts of sulphides. Its thickness varies between a few centimetres and 5 metres near the Norbec VMS deposit located approximately 1300 m downdip (Cattalani et al., 1993). Outcrops of pillowed andesite (Amulet andesite) will then be observed. The

Amulet andesite flow succession was studied in detail by Cousineau (1982) who interprets its evolution and emplacement mechanism differently than Dimroth et al. (1978) (Fig. 13B).

Stop 1-6: Exhalites and metamorphosed alteration zones (southern central camp)

Coordinates

UTM, NAD 83, zone 17, 642886 m E, 5352578 m N

Stop description

The southern central camp contains several VMS deposits along the same horizon, correlated in part with northern central camp VMS deposits. Several exhalites (Ridler, 1971) are known from the southern central camp, located in between andesitic sequence or felsic-andesitic sequence (Fig. 14). These marker horizons contain chert, sulphides, and other components, and have been used extensively and successfully for VMS exploration in the central camp. Stop 1-6 exposes the lower A (Amulet) exhalite also known as the "*Main Contact*" or the "*Mine Contact*". This exhalite is correlated with the exhalite observed in the previous stop. The exhalite, characterized by chert and pyrite, is several centimetres thick and drapes over megapillows from the Millenbach andesite

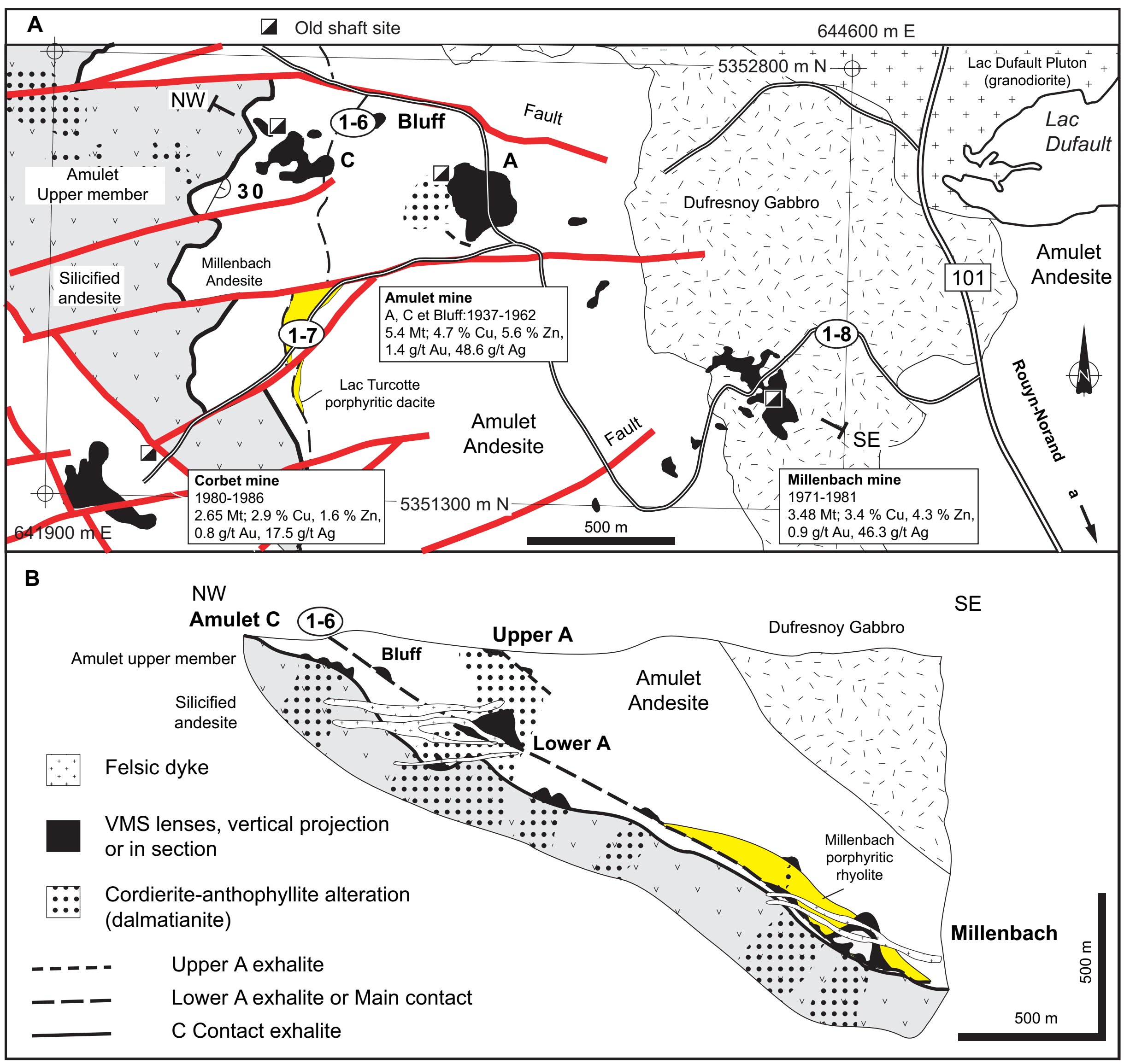

Figure 14. A) Geological map of the southern central camp showing the location of the former Amulet, Millenbach and Corbet mines, and the position of Stops 1-6 to 1-8. **B)** Geological section showing the location of the VMS lenses of the Amulet-Millenbach cluster along two distinct exhalative units that join near the Millenbach deposit. Most of the hydrothermal alteration is found in the footwall sequence. These alteration zones consist of porphyroblastic chlorite, anthophyllite and cordierite ("dalmatianite") due to contact metamorphism around the Lac Dufault pluton. Modified from Knuckey et al. (1982), Gibson (1989), Bertrand (1990), and Péloquin et al. (1996).

(SiO_2=63.77 wt.%; Zr/Y=6.94; La/Yb=5.05; Th/Yb=0.76). This sequence is overlain by a massive flow of the Amulet andesite (SiO_2=57.01 wt.%; Zr/Y=3.70; La/Yb=3.51; Th/Yb=0.45). At depth, this horizon merges with the C contact at the Millenbach VMS deposit (Fig. 14).

If time allows, we will also visit a classic example of a contact-metamorphosed chloritic alteration zone. The metamorphism was due to the influence of the nearby Lac Dufault Pluton and caused the altered volcanic rock to form porphyroblasts of cordierite-anthophyllite (de Rosen Spence, 1969). This texture is locally known as "dalmatianite" and is very useful to identify an alteration pipe on outcrop or in drill core.

Stop 1-7: Lac Turcotte porphyritic dacite

Coordinates

UTM, NAD 83, zone 17, 642727 m E, 5351861 m N

Stop description

The Lac Turcotte porphyritic dacite is a small felsic lens situated stratigraphically above the lower A exhalite, between the Millenbach andesite and the Amulet andesite (Figs. 14 and 15). The rock is massive and contains 7 vol.% phenocrysts (quartz and feldspar, 1 mm). Breccias and flow-banding occur locally. This dacite is thought to be equivalent to the Millenbach rhyolite (Knuckey et al., 1982). This rock was known to contain zircons but previous work by Vaillancourt (1996) did not yield an age. The Lac Turcotte dacite is a good example of the difficulties associated with dating rocks in the BRG; felsic volcanic rocks from the BRG are difficult to date by U-Pb methods due to the small size of zircons and low U contents. Several attempts at dating volcanic rocks from the Noranda camp (specifically, in the "*Mine Sequence*") have failed (e.g., Mortensen, 1987, 1993; Machado, pers. comm., 1990; Vaillancourt, 1996). However, improved techniques and selective sampling helped to increase our chances of success in dating difficult rocks. As a result, a new sample from the Lac Turcotte dacite was collected and dated at 2698.5 ±2.0 Ma (David et al., 2006). Analysis of further zircons from this sample confirmed the

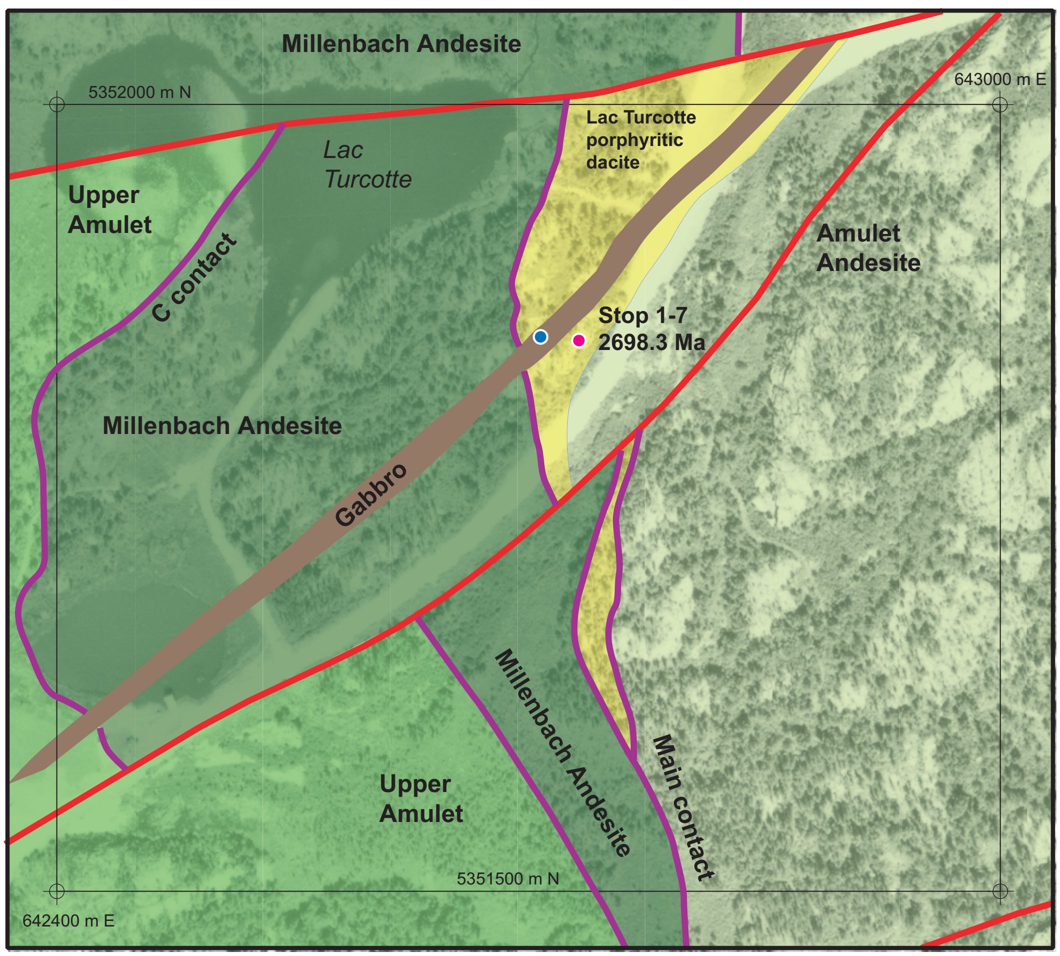

Figure 15. Geological map of the Lac Turcotte area showing the location of Stop 1-7. The outcrop north of the road exposes a porphyritic, transitionnal dacite aged of 2698.3 +1.2/ 1.0 Ma (David et al., 2011), an aphyric andesite (Millenbach andesite), a thin exhalite (Main contact), and a gabbro dyke. South of the road are two exhalites, one above the dacite, the second underneath the dacite. These rocks are covered by a weakly porphyritic, calc-alkaline basaltic andesite.

2698.3 +1.2/-1.0 Ma age (David et al., 2011). This age is similar to the upper member of the Bousquet Formation (see Part 5 below) and indicates simultaneous graben-filling (Noranda formation) and calc-alkaline volcanism (Bousquet Formation).

Stop 1-8: Dufresnoy gabbo

Coordinates

UTM, NAD 83, zone 17, 644544 m E, 5351905 m N

Stop description

The Dufresnoy gabbro has a thickness of several hundred metres. It is oriented NNW-SSE and dips moderately to the NE (50º). The gabbro cuts the host sequence of the northern and southern central camp VMS deposits. Displacement of the mineralized horizon on both sides of the gabbro suggests that an apparent reverse movement happened in this area. This stop is a U-Pb sampling site. The dated sample gave an age of 2697.9 Ma (Fig. 6), which is similar to the age obtained for the rhyolites of the central camp. The age and setting of the Dufresnoy gabbro is therefore important in constraining the age of the central camp VMS deposits. The exposed gabbro at stop 1-8 is coarse-grained with decimetre-scale pegmatitic sections. This outcrop presents textures that are similar to those observed in gabbros of the Rouyn-Noranda area (Kuiper, 2010).

DAY 2 AM: GEOLOGY, STRATIGRAPHY, AND GEOCHRONOLOGY OF THE BLAKE RIVER GROUP AND RELATIONSHIPS WITH VMS DEPOSITS (CONTINUED)

Claude Dion (MRNF), Patrick Mercier-Langevin (GSC-Qc), Pierre-Simon Ross (INRS-ETE), Jean Goutier (MRNF), Vicki McNicoll (GSC-Ottawa), Benoît Dubé (GSC-Qc), Alan Galley (GSC-Ottawa)

Objectives

The morning stops of this second day of field trip will aim at giving an overall appreciation of the stratigraphic, hydrothermal, and tectonic architecture of the BRG and allow participants to observe some of the principal intrusive and volcanic facies of the western part of the BRG (west camp; Fig. 4B). The first stop will represent an opportunity to see and discuss the nature of the Flavrian synvolcanic intrusion and its role in the formation of VMS deposits of the northern and southern central camps (Fig. 4B). The next two stops will allow one to observe alteration and mineralized zones typical of the west Noranda camp, west of the Flavrian synvolcanic intrusion.

Stop 1-1: Flavrian Pluton

Coordinates

UTM, NAD 83, zone 17, 636513 m E, 5348252 m N

Stop description

The synvolcanic Flavrian Pluton is the largest intrusion in the BRG (~12 x 7 km). The intrusion has a sill-like shape that is moderately inclined towards the ENE. Trondhjemite and tonalite form the bulk of the volume (Fig. 16). Subsidiary phases include diorite and hybrid phases containing diorite and tonalite. Contacts can be sharp or gradational (Goldie, 1976; Kennedy, 1985; Perreault et al., 1987; Paradis et al., 1988; Galley, 2003). Several phases of the pluton have geochemical compositions similar to adjacent volcanic rocks (Paradis et al., 1988).

The trondhjemite represents the largest exposed phase of the Flavrian (Fig. 16). Its aspect and grain-size (1-7 mm) are variable. Igneous minerals include plagioclase (albite or oligoclase), ≥20% quartz, ≤10% K-feldspar, and ≤10% mafic minerals (Allen and Goldie, 1978). The trondhjemite was emplaced in two main stages, as a series of composite sills (Kennedy, 1985; Galley, 2003). The trondhjemite was emplaced in three different stages as a series of composite sills (Kennedy, 1985; Galley, 2003). The late trondhjemite lacks evidence of hydrothermal overprint, suggesting that it postdates the VMS deposits of the northern and southern central camp (Kennedy, 1985; Galley, 2003). This is also supported by the age differences

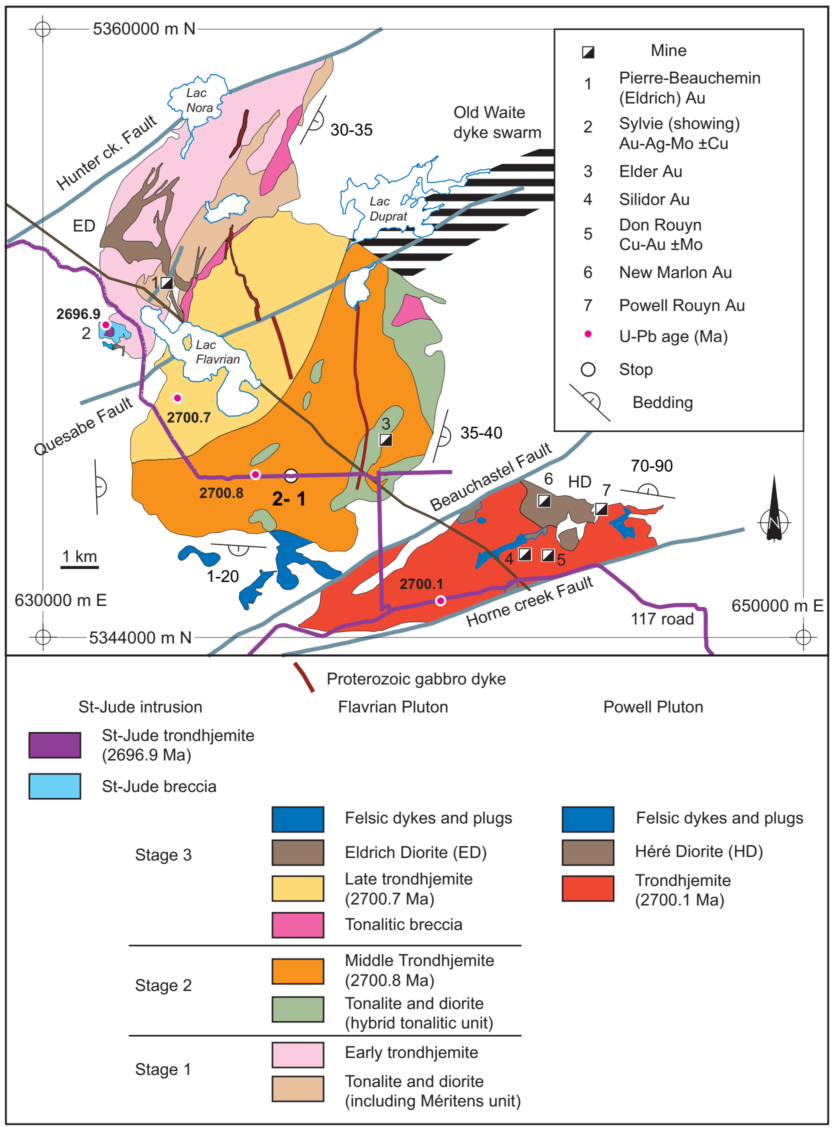

Figure 16. Geological map of the Flavrian and Powell synvolcanic plutons, after Goldie (1976), Kennedy (1985), Richard (1998) and Galley (1998). This map illustrates the three main intrusive stages of the Flavrian Pluton.

between the pluton and the volcanic rocks hosting the VMS deposits. Stop 2-1 exposes the main stage trondhjemite. This easily accessible outcrop likely represents the sampling site for the 2700.8 +2.6/-1.0 Ma date of Mortensen (1993). This age is similar to the late trondhjemite stage (2700.7 Ma) and trondhjemitic phase of the Powell Pluton (2700.1 Ma). Late phases of the Flavrian intrusion host Au-Ag-Mo±Cu mineralizations, including the St-Jude mineralized, breccia-style intrusive system (Kennedy, 1985; Galley and van Breemen, 2002).

Stop 2-2: Inmont stripped outcrop

Coordinates

UTM, NAD 83, zone 17, 624016 m E, 5351917 m N

Stop description

The Inmont prospect, discovered in 1925 and also known as Robb-Montbray, shows several features characteristic of the VMS deposits of the Noranda camp (Mercier-Langevin et al., 2010b). An easily accessible stripped outcrop (Fig. 17) exposes part of the Inmont system on surface (Fig. 17). Two NW-SE oriented rusty corridors developed in a rhyolite characterize the Inmont area. The zone 2 is the northernmost mineralization. It consists of a 460 m-long and 180 to 315 m-wide sulphide-bearing zone. The zones 1 and 3 form another mineralized area situated approximately 90 to 300 m south of the zone 2. The zones 1 and 3 form a 760 m-long and 90 to 150 m-wide mineralized corridor. A diorite-gabbro dyke separates these two zones. The zone 3 presents the most significant mineralization. The surface expression of this zone is exposed on a stripped outcrop a few metres west of the access road. An exploration shaft, constructed in the 1920s was located east of the access road. Ore samples can still be found at this place. Underground exploration and drifting done in the 20s was not promising enough to warrant production. Interestingly tough, a ~5 kg plate (1.8 m-long by 1 m-wide and 2.5-5 cm-thick) made of approximately 50 wt.% native gold (2.3 kg) and complex tellurides (Thomson, 1928), including montbrayite ($(Au,Sb)_2Te_3$) and frohbergite ($FeTe_2$) was discovered between the 125 ft and 225 ft levels. This plate was formed along a sub-vertical shear plane (Peacock et Thompson, 1946). The Inmont area is the type locality for frohbergite and montbrayite.

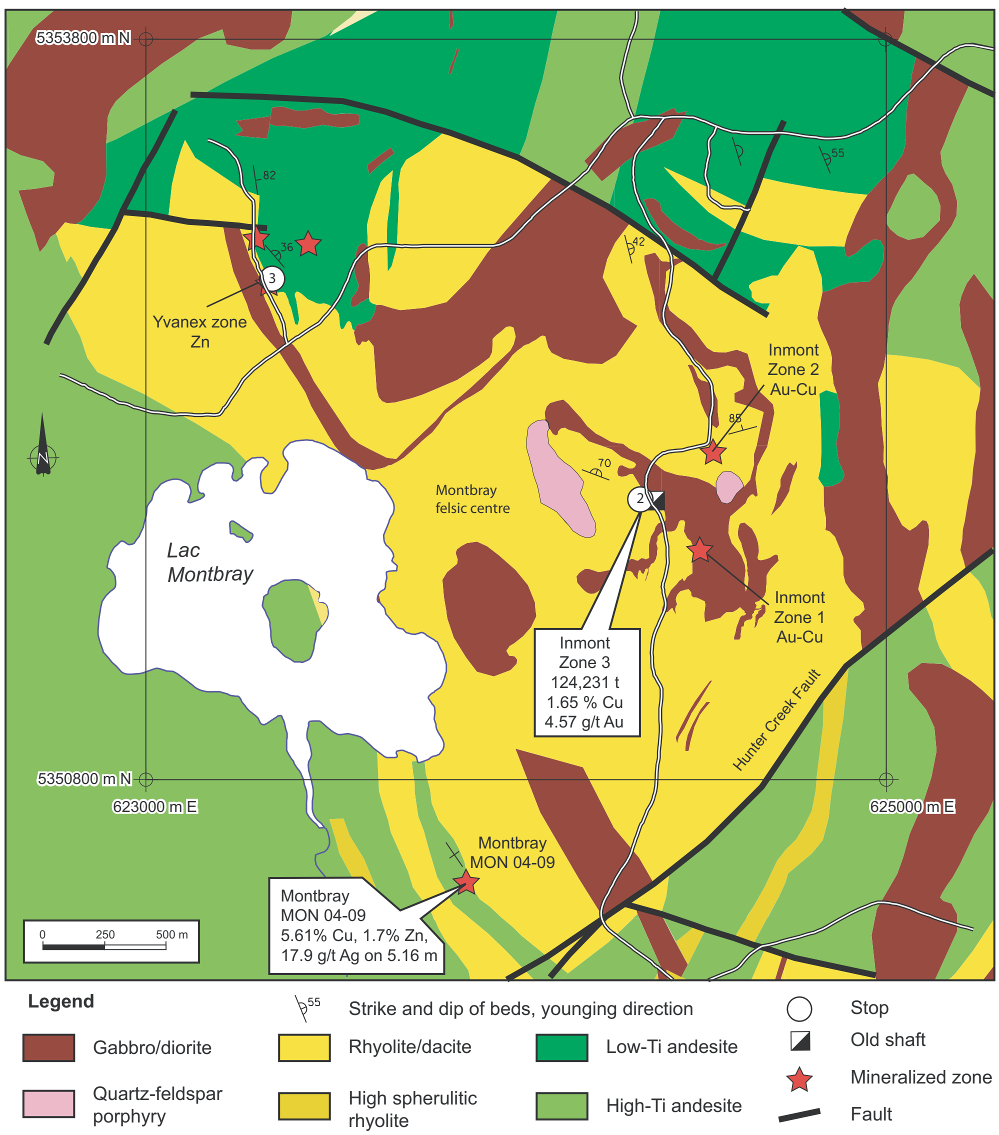

Figure 17. Geological map of the Montbray Lake area illustrating the location of the mineralized zones of the Inmont (Robb-Montbray) prospect (Stop 2-2), and of the Yvanex prospect (Stop 2-3).

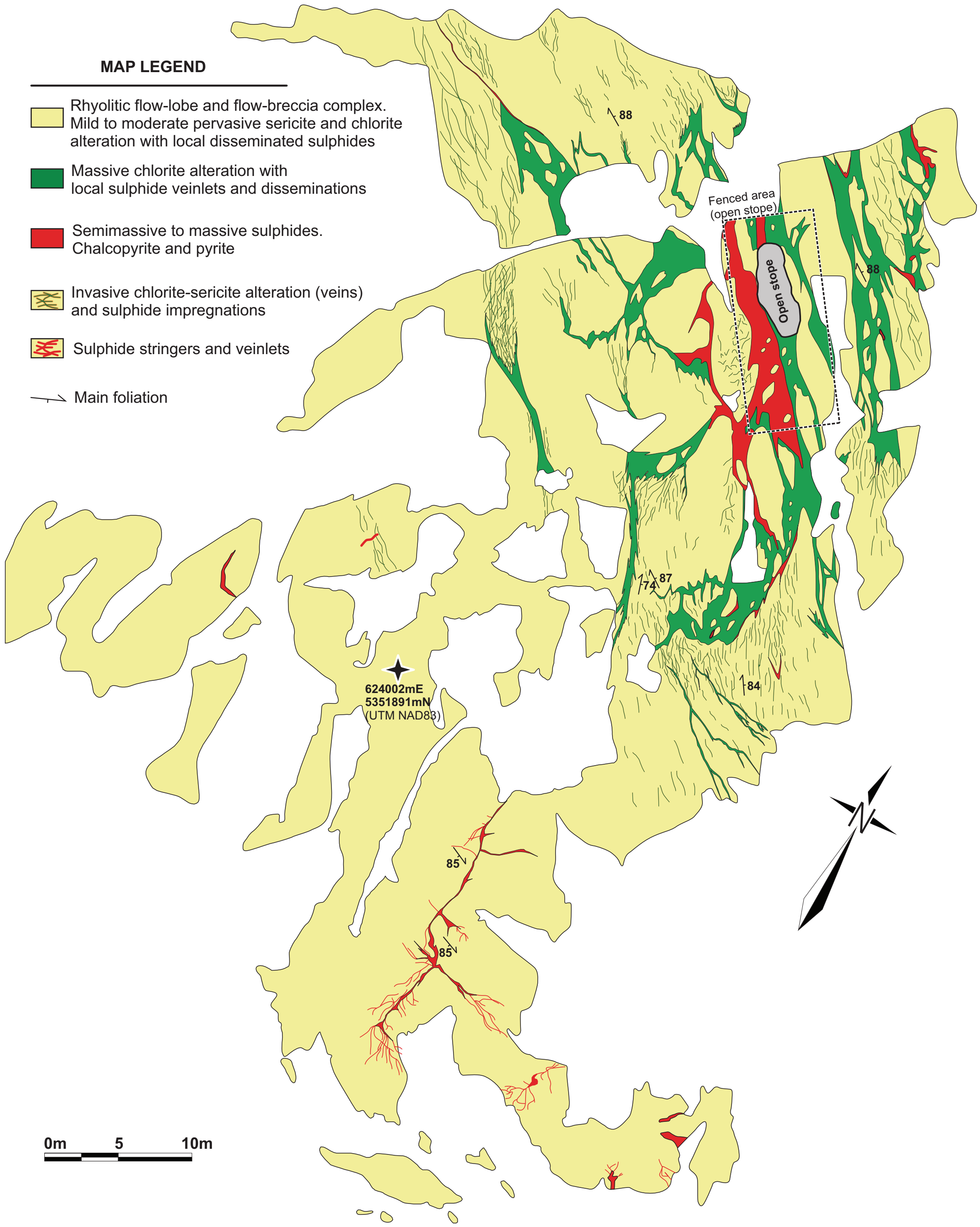

Figure 18. Surface map of the Inmont Zone 3 stripped outcrop. The map shows the distribution of the main alteration zones and mineralized veins. Modified from Mercier-Langevin et al. (2010b).

About 1360 t of ore grading 6.5% Cu, 8.23 g/t Au and 17.1 g/t Ag were further extracted in the 30s (Tremblay, 1982, 1987). This ore came essentially from a 9 m-long by 1 m-thick chalcopyrite-rich mineralized lens extending from surface to a depth of about 125 ft. A part of this lens is still visible at surface near the fenced area (Fig. 18). Intermittent exploration was conducted in this area since then. The zone 3 resources are estimated at 124 231 t grading 1.65% Cu and 4.57 g/t Au (Nantel and Du Tremblay, 1988).

The mineralized zones of the Inmont prospect are hosted in the Montbray rhyolite that forms the main unit of the Montbray-Four Corners felsic center (Figs. 17 and 18). The Montbray rhyolite consists mainly of brecciated and flow-banded domes and lobes (flow-breccia complex). The rhyolite is aphyric and has a transitionnal to tholeiitic magmatic affinity (Barrett and MacLean, 1991; Mercier-Langevin et al., 2010b). This unit is 1500 m-tick at most and represents an important felsic center west of the Flavrian Pluton. A transitionnal magmatic affinity characterizes the rhyolite, which is intercalated with andesites and some exhalites, forming a variably east-dipping (25 to 90º) north-trending bimodal sequence. This sequence is cut to the south by the Hunter Creek fault (Fig. 17), a regional scale ENE-trending structure with an apparent senestral displacement of a few hundred metres. The Montbray rhyolite is cut by a >1 km-long and ~150 m-wide NE-SW discordant sodium-leached corridor, which includes the Inmont mineralized zones (Bernier, 1990).

The stripped outcrop was mapped in detail (Mercier-Langevin et al., 2010b; Fig. 18) illustrating the main alteration assemblages and facies observed in this area. The mineralization and its alteration system are emplaced within flow-banded, lobate and volcaniclastic rhyolites. The distribution of the alteration is strongly controlled by the volcanic facies and structures with fracture-controlled chlorite veins, and diffuse quartz, sericite and chlorite gradually replacing or invading the lobe contacts, the flow-banded rhyolite, and the volcaniclastic rhyolite. This architecture is typical of the "Noranda-type" model of volcanogenic massive sulphide systems with mostly discordant, well-defined chlorite alteration pipes surrounded by diffuse sericite-chlorite and quartz alteration within flow-dominated sequences. The alteration at Inmont is characterized by massive removal of silica, strong depletions in CaO and Na_2O and gains in FeO-MgO (Barrett and MacLean, 1991). In intensely chloritized zones, Ti may also have been slightly mobilized (Mercier-Langevin et al., 2010b). The chlorite has a variable MgO/Al_2O_3 ratio (Davies and Whitehead, 2006). The alteration index (AI: Ishikawa et al., 1976) and chlorite-carbonate-pyrite index (CCPI: Large et al., 2001) are very high in the intensely chloritized areas. Chalcopyrite-rich sulphide separates analyses from Inmont (Mercier-Langevin, unpublished data) show that the ore is significantly to strongly enriched in Au, Se, In, Sn and Te and anomalous in Co and As compared with other VMS deposits of the BRG.

Stop 2-3: Yvanex prospect stripped outcrop

Coordinates

UTM nad 83, zone 17, 622 488 m E, 5 352 814 m N

Stop description

The Yvanex prospect represents another VMS mineralization associated to the Montbray rhyolite (Fig. 17). Contrary to the Inmont prospect visited earlier (Stop 2-2), this zone forms an exhalative layer located at the contact between a rhyolite and an overlying andesitic unit (Fig. 19). Moreover, this exhalite presents evidences of remobilization by debris flows.

The Yvanex prospect was discovered in 1973 following a drilling campaign by Yvanex Developments targeting a mercury soil anomaly associated with an INPUT anomaly identified by a MRNQ regional survey. Two small subeconomic mineralized lenses were outlined, with resources of about 218 600 t grading 0.5% Cu, 1.54% Zn, 0.34 g/t Au and 10.97 g/t Ag.

The remobilized exhalite layer exposed on the visited outcrop rests on a slightly altered and pyrite mineralized rhyolitic breccia and tuff breccia unit (Meleskie, 1980) (Fig. 19). The fragments are angular and often show leached rims. The rhyolite is cut by centimetre to metre-wide ENE chlorite-altered felsic dykes. The chlorite content gives a dark color to the rock, which gives the impression of a more mafic composition.

The 2 to 3 m-wide exhalite layer is oriented NNE and dips moderately to the east. It consists of decimetre-thick beds of mudrock and pyrite-rich laminated mudrock. Beds of matrix-supported conglomerate and breccia or clast-supported conglomerate are interstratified with the mudrocks. Fragments of mudrock, chert, sulphide and felsic volcanic rock are aligned with their long-axes parallel to the main structural fabric. The larger round fragments in the clast-supported conglomerate are slightly imbricated. Felsic fragments, some of which are highly vesicular, are generally rounded. Mudrock beds show some evidences of syn-sedimentary deformation, as folding, convolute or disrupted bedding and pinch and swell structures. Regional deformation, generally low in the area, is indicated by isoclinal folding. A cleavage is superimposed on the primary structures. Among the sulphides, pyrite dominates, with minor quantities of chalcopyrite (± malachite) and sphalerite.

The exhalite is overlain by a thin layer of andesitic tuff and by a massive amygdaloidal and feldspar-phyric andesite flow. The contact between the exhalite and the andesite is cut and displaced by a ENE-trending fault exhibiting a dextral normal displacement.

The exposed sulphide-rich layer is interpreted as a channelized debris flow that remobilized parts of an exhalitive bed in an unstable position along the slope of a volcanic edifice. This debris flow layer is however very

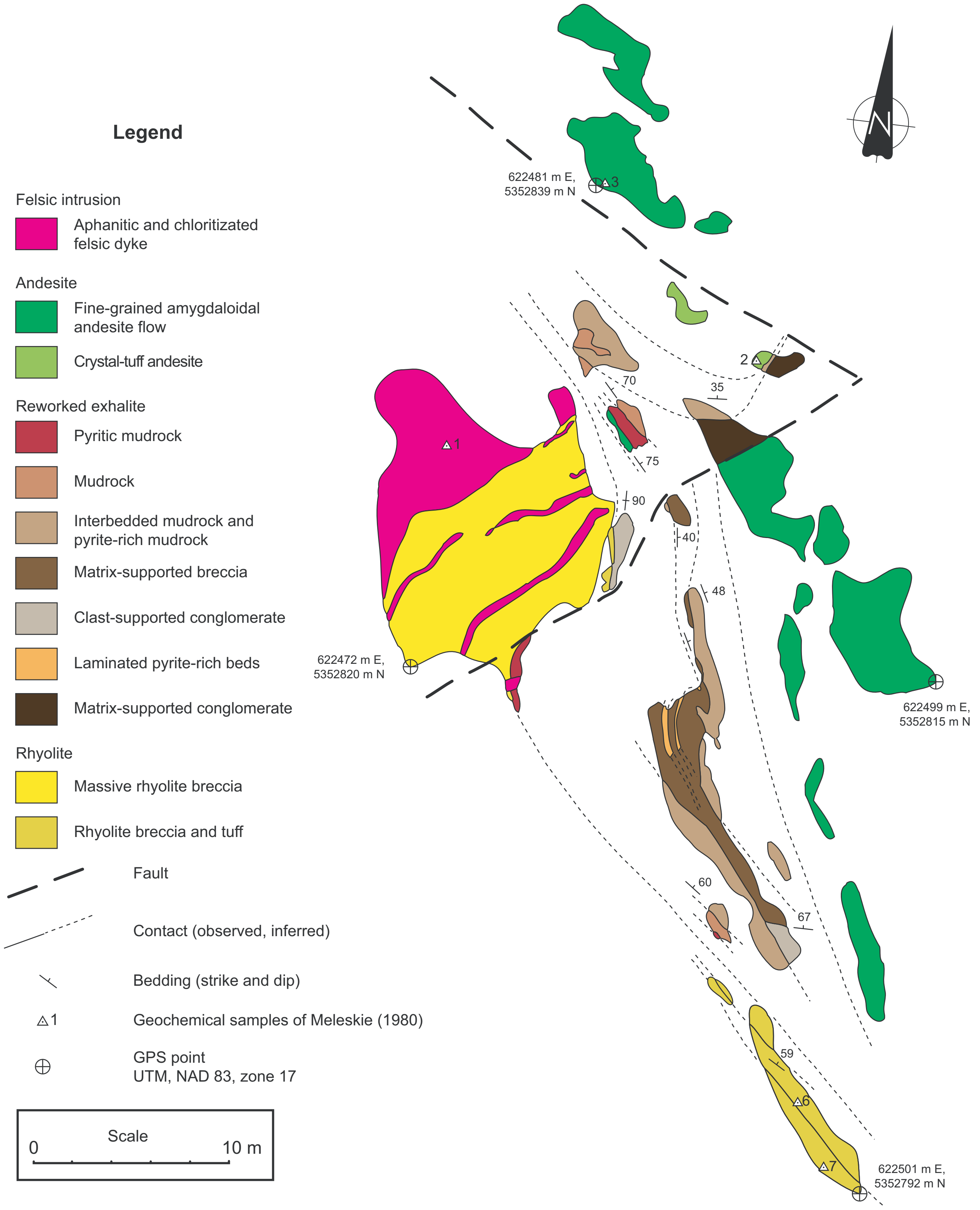

Figure 19. Detail geological map of the Yvanex prospect stripped outcrop (Stop 3-3). From Stewart and Baldwin (1982) and Meleskie (1980).

restricted, the lateral and depth extension of the exhalite showing a well-preserved and homogeneous bedded appearance. The exhalite can be followed for a few kilometres to the north along the rhyolite-andesite contact and is cut by a ENE fault to the south.

DAY 2 PM: FELSIC HOST-ROCK SUCCESSIONS OF VMS DEPOSITS IN THE NORANDA CAMP

Thomas Monecke (Colorado School of Mines), Harold Gibson (Laurentian U.), Mark Hannington (Ottawa U.), and Vicki McNicoll (GSC-Ottawa)

Introduction

The Rouyn-Noranda mining district contains some of the most thoroughly studied and documented VMS deposits of any Archean volcanic complex in the world. Research conducted on the exceptionally well preserved massive sulphide deposits has, and will continue to make, a significant contribution to the understanding of VMS and the development of genetic and exploration models for this deposit type. Although perhaps best known for its massive sulphide deposits of the central camp, which are hosted by effusive basalt and basaltic andesite flows and subordinate rhyolite flow-dome complexes, the bulk of the production within the Rouyn-Noranda district came from massive sulphide deposits hosted by felsic host rock successions dominated by volcaniclastic rocks.

It is the purpose of this part of the field trip to introduce participants to the volcanic setting of felsic-hosted VMS deposits within the Noranda camp. Based on the field observations, participants will be able to contrast and compare the nature and style of massive sulphide mineralization and associated hydrothermal alteration of deposits hosted in flow-dominated and volcaniclastic-dominated host rock successions. This part of the field trip will take participants to three outcrop areas within the felsic volcanic successions hosting the Horne, Quemont, and D'Eldona-Delbridge deposits in the Noranda south camp. In addition, one outcrop on the Pinkos property will be examined (Fig. 20).

Geological setting

VMS deposits of the Noranda northern and southern central camps (Fig. 4B) are hosted by one of the largest volcanic centers within the Blake River Group (BRG) (Fig. 20). This centre has an approximate diameter of 35 km and is composed of 7.5 to 9 km of bimodal volcanic strata of predominantly tholeiitic to midly transitional affinity comprising numerous alternating mafic and felsic units crosscut by synvolcanic dykes of dioritic and gabbroic composition (Gélinas et al., 1984; Gibson and Watkinson, 1990; Péloquin et al., 1990; Kerr and Gibson, 1993).

Historically, the central part of the BRG has been envisaged to represent a single, large shield-like, bimodal, volcanic edifice that, unfolded, had an original diameter of some 40 to 50 km (Spence and de Rosen-Spence, 1975; de Rosen-Spence, 1976; Dimroth et al., 1982; Gibson, 1990; Péloquin et al., 1990). Dimroth et al. (1982) proposed that the central part of the Blake River Group (formerly called the Noranda volcanic complex) formed an island arc volcano that

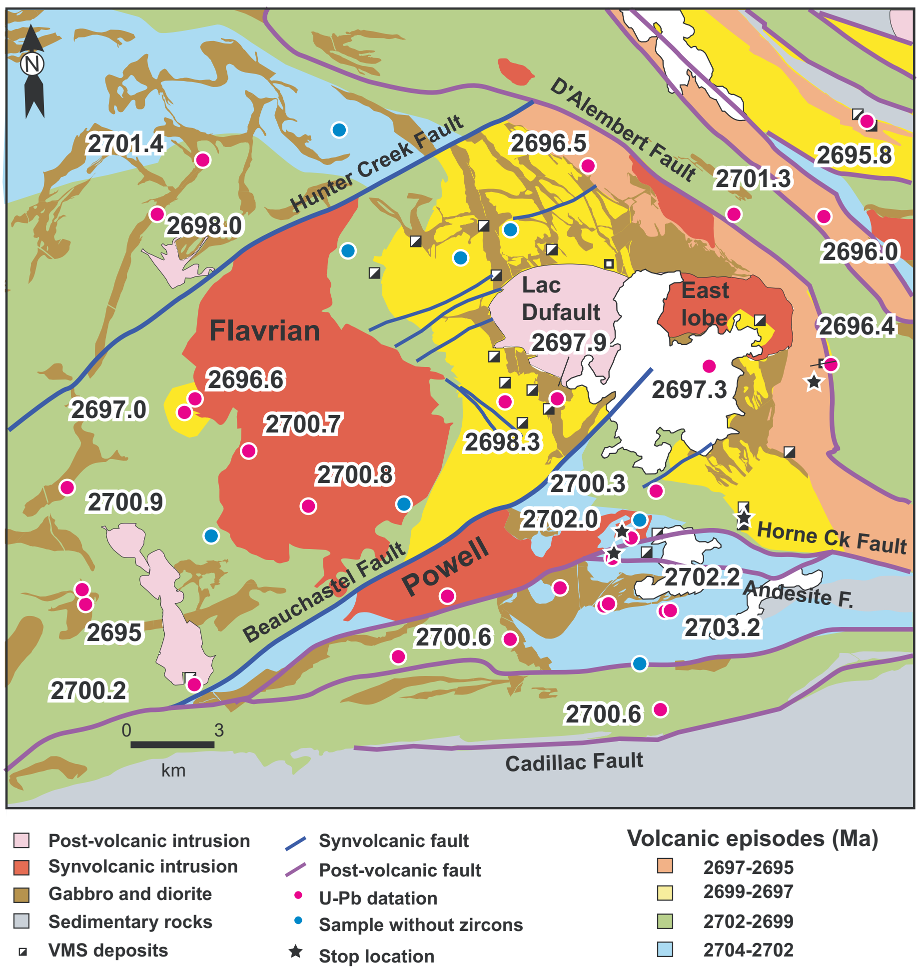

Figure 20. Generalized geological map of the central part of the Blake River Group, showing major structural elements and the distribution of extrusive and intrusive rocks. The locations of VMS deposits are highlighted.

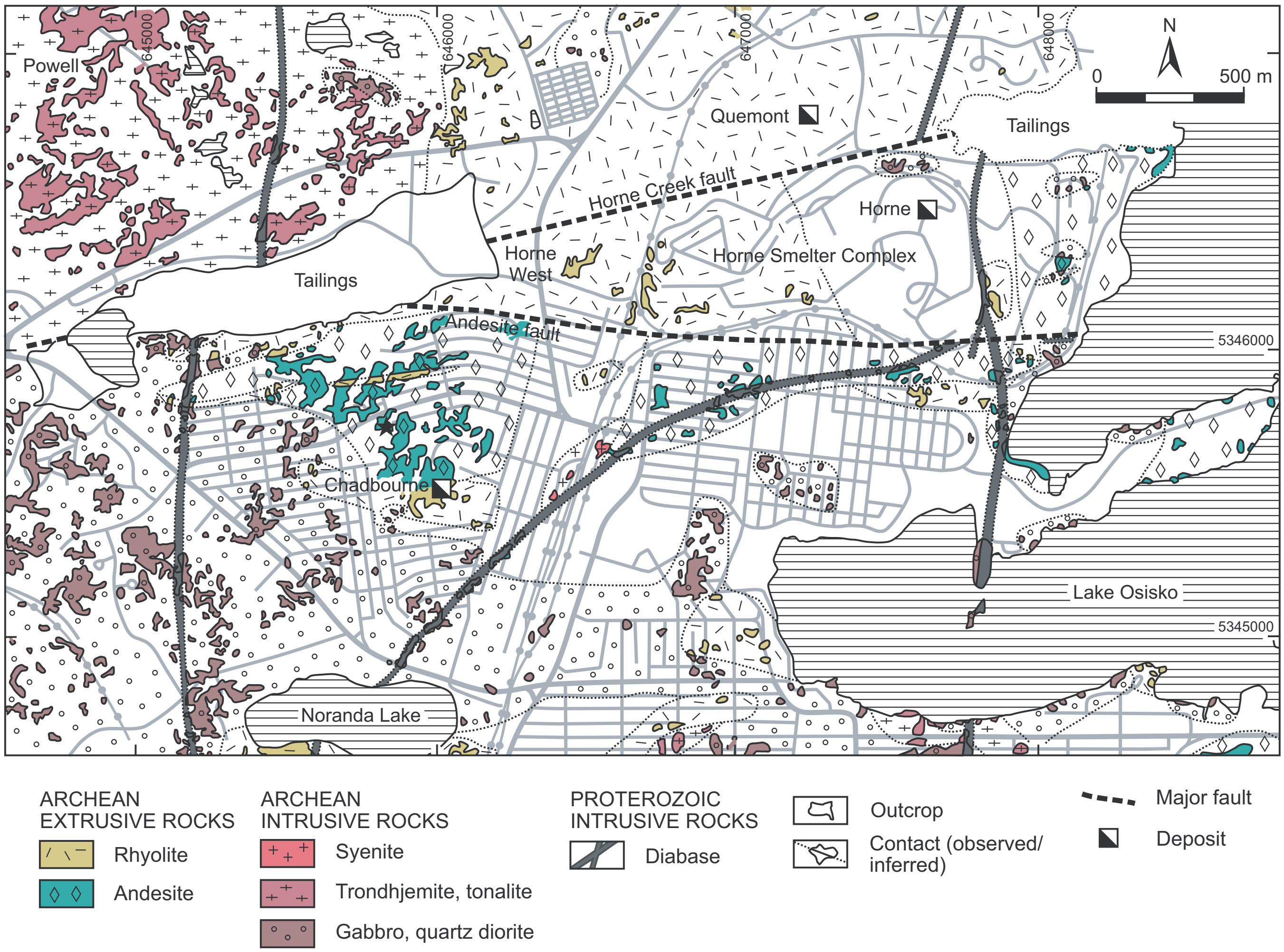

Figure 21. Geology of the Horne block and surrounding areas (modified from Wilson, 1941 and Monecke et al., 2008).

was built upon a low relief, deep water, basaltic lava plain. Parts of this basaltic lava plain are exposed south of Rouyn-Noranda and north of the Larder Lake-Cadillac fault zone. The recent identification of a komatiite xenolith (<1 m^2) showing spinifex texture in a rhyolite raft within the Lac Dufault pluton suggests that this lava plain may have included or was underlain by a succession containing komatiitic flows (Kuiper et al., subm.). Recent geochronological research (McNicoll et al., subm.) suggests that the central part of the Blake River Group consists of several distinct volcanic sequences that evolved during discrete episodes of volcanism and are now in most cases in structural juxtaposition (Fig. 20).

The importance of major faults dissecting the central part of the Blake River Group has long been recognized as lithological correlation across these structures has proven to be difficult in most cases. Accordingly, this area has been subdivided into a number of structural blocks, bounded by faults and their extrapolations (de Rosen-Spence, 1976; Péloquin et al., 1990). The areas between the Hunter Creek and Beauchastel faults and the Beauchastel and Horne Creek faults are referred to as the Flavrian and Powell blocks, respectively. The Horne block lies to the south between the Horne Creek and the Andesite faults (Figs. 20 and 21).

Previous research largely focused on the Flavrian block that is host to the VMS deposits of the Noranda northern and southern central camps. The volcanic stratigraphy hosting massive sulphide deposits in the central camps, referred to as the "Central Mine Sequence" or "Mine Zone" in previously published literature and company reports, is dominated by coherent basalt, andesite, and rhyolite that are intercalated with lesser amounts (<5%) of volcaniclastic deposits. Mafic volcanic rocks form predominantly pillowed and massive flows, massive facies being confined to areas proximal to eruptive fissures, whereas porphyritic, amygdaloidal, or spherulitic rhyolites were emplaced as tabular flows and low relief domes (Spence and de Rosen-Spence, 1975; Gibson et al., 1984; Kerr and Gibson, 1993). Volcanism of the northern and southern central camps host sequences occurred in a below-storm-wave-base, presumably deep, marine environment. Geochronological research suggests that the volcanic strata that hsot the VMS deposits of the northern and southern central camp were deposited in a relatively short time span between 2700.7 Ma and 2697.9Ma (Mortensen, 1993; Lafrance et al., 2005; David et al., 2011; McNicoll et al., subm.; Fig. 20). The stratigraphy in the central camp is interpreted to represent the infilling of a primary volcano-tectonic subsidence structure located south of the Hunter Creek fault (Dimroth et al., 1982).

In contrast to the northern part of the Noranda camp, only limited research has been carried out to the south, hampering stratigraphic correlation between the Flavrian block as well as the Powell and Horne blocks to the south. Historically, volcanic strata in the Quemont area of the Powell block have been considered to represent the southern limit of the Noranda subsidence structure (Lichtblau and Dimroth, 1980). However, recent U-Pb zircon dating showed that volcanic rocks in this area are significantly older than volcanic rocks within the Noranda subsidence structure (McNicoll et al., subm.; Fig. 20) casting doubt on previous palinspatic reconstructions.

The volcanic stratigraphy of the central part of the Blake River Group is intruded by the synvolcanic Flavrian and Powell plutons (Fig. 20). The Flavrian Pluton has been described in the introduction and at stop 2-1. The Powell Pluton located to the south of the Beauchastel fault shares many similarities with the Flavrian Pluton. A sample from the Powell yielded an age of 2700.1 Ma (McNicoll et al., subm.; Fig. 20). Although the Powell and Flavrian plutons are essentially of the same age, it is important to note that they intruded volcanic host rock successions of different ages. Therefore, they are not necessarily simply parts of a larger pluton that was dissected by the Beauchastel fault.

Synvolcanic diorite-gabbro intrusions are widespread in the Blake River Group (e.g., Fig. 20). They occur as large sheet-like dykes and sills that generally have a northwesterly strike. The dykes form a particularly dense network in the area north and west of the Lake Dufault pluton. The gabbro dykes commonly occupy low- to medium-angle reverse faults that thrust up volcanic strata on their east margins. Recent U-Pb dating of one gabbro unit yielded an emplacement age of 2697.9 Ma (McNicoll et al., subm.), which further supports the conclusion that the central camp host sequence was essentially formed by 2698 Ma.

As mentioned in the introduction, the structural style is not uniform across the BRG. North-south structural shortening within the central portion of the group is accommodated by broad, generally northeast-trending, open folds and north-south to north-northwest trending, east dipping reverse faults. Consequently, strata in the central camp are east-facing and characterized by a dip of 30º (5 to 82°) to the east (Spence and de Rosen-Spence, 1975; Gibson and Watkinson, 1990).

Within the Noranda camp, regional metamorphic isograds overprint synvolcanic hydrothermal alteration as well as contact metamorphic aureoles including those surrounding the Lac Dufault pluton (Powell et al., 1995). Relative age constraints suggest that regional metamorphism occurred between 2677 and 2643 Ma (Powell et al., 1995).

Massive sulphides in volcaniclastic-dominated host-rock successions

Decades of exploration in the Noranda camp have shown that VMS deposits occur throughout the 2000 m-thick sequence of the northern and southern central camps, but are concentrated at two stratigraphic horizons within the Flavrian block (Gibson, 1990). These favorable stratigraphic horizons, two of which have been seen at stops 1-5 and 1-6, are marked by the occurrence of fine-grained volcaniclastic deposits that are composed of thinly bedded to laminated fine-grained volcanic detritus, including formerly glassy volcanic shards. In proximity to massive sulphide mineralization, these thin volcaniclastic units contain increased amounts of sulphides and secondary siliceous material, presumably due to sulphide infiltration and hydrothermal alteration of the volcaniclastic material or incorporation of fine-grained detritus from the massive sulphide accumulations forming local topographic highs on the ancient seafloor. The fine-grained volcaniclastic units record periods of relative volcanic quiescence, a prerequisite for the seafloor accumulation of significant amounts of massive sulphides in volcanic successions dominated by lava flows.

The deposits of the Noranda northern and southern central camps are clustered around rhyolitic and andesitic vent areas that are localized along synvolcanic faults. These faults are interpreted to have formed directly above the shallow magma chamber now represented by the Flavrian Pluton (Spence and de Rosen-Spence, 1975; Knuckey et al., 1982; Gibson, 1990; Gibson and Watkinson, 1990; Kerr and Gibson, 1993). A number of major discoveries in the district have been made by targeting intersections between the fine-grained volcaniclastic marker horizons and inferred synvolcanic faults in areas showing evidence for extensive hydrothermal alteration of the volcanic rocks. In many cases, individual massive sulphide lenses are stacked in several deposits over vertical distances of as much as 300 metres whereby individual lenses occur at paleoseafloor positions marked by the presence of the fine-grained volcaniclastic deposits described above. Massive sulphide deposition at the seafloor resulted in the formation of mound-shaped deposits.

Mineral exploration in the camp, detailed mapping, and scientific studies have established an excellent understanding of the distribution of hydrothermal alteration assemblages with respect to the mound-shaped massive sulphide deposits, leading to the classical model of alteration zonation around massive sulphides. Most massive sulphide deposits in the Noranda central camp are associated with discordant, crudely cylindrical hydrothermal alteration pipes that underlie and less commonly overlie the massive sulphide deposits. Typical alteration pipes contain an inner chloritic zone surrounded and capped by an outer sericitic zone (Knuckey et al., 1982; Riverin and Hodgson, 1980). In some cases, however, the situation is complicated by the fact that synvolcanic faults provided cross-stratal conduits for hydrothermal fluids, producing stacked massive sulphide orebodies. In these systems, the hanging wall alteration of one deposit forms the footwall of the overlying orebody.

In contrat, massive sulphide deposits located outside the central camp (i.e. in the west, south, northeast and east camps (see Fig. 4B) are hosted by dominantly felsic volcanic successions that contain variable proportions of volcaniclastic rocks. The style of mineralization and the nature of the associated hydrothermal alteration of those deposits are quite different from those located in the lava-flow-dominated volcanic successions of the Noranda central camp. In the volcaniclastic-dominated successions, a significant proportion of the mineralization formed in the subseafloor environment through processes of sulphide infiltration and replacement (Kerr and Gibson, 1993; Gibson and Galley, 2007; Monecke et al., 2008). Although synvolcanic structures may have been important in controlling fluid flow, hydrothermal discharge was typically unfocused resulting in the formation of hydrothermal alteration halos that are comparably large in size. Vertical and horizontal stacking of tabular or sheet-like ore lenses forming through replacement processes is widespread. Deposits in volcaniclastic-dominated host rock successions can be large in size as subseafloor replacement represents an efficient mechanism of metal precipitation. This likely explains why the Horne and Quemont deposits are the two largest VMS deposits of the Noranda camp. Likewise, the Bouchard-Hébert deposit, the third largest VMS deposit of the Noranda camp, is hosted in dominantly volcaniclastic strata.

Volcanic setting of the Horne massive sulphide deposit

The Horne deposit represents the largest VMS deposit in the Rouyn-Noranda mining district. Between 1927 and 1976, the mine produced 260 t of Au and 1.13 Mt of Cu from 53.7 Mt of ore that graded 2.22 wt.% Cu and 6.1 g/t Au (Table 1, Kerr and Mason, 1990) mak-

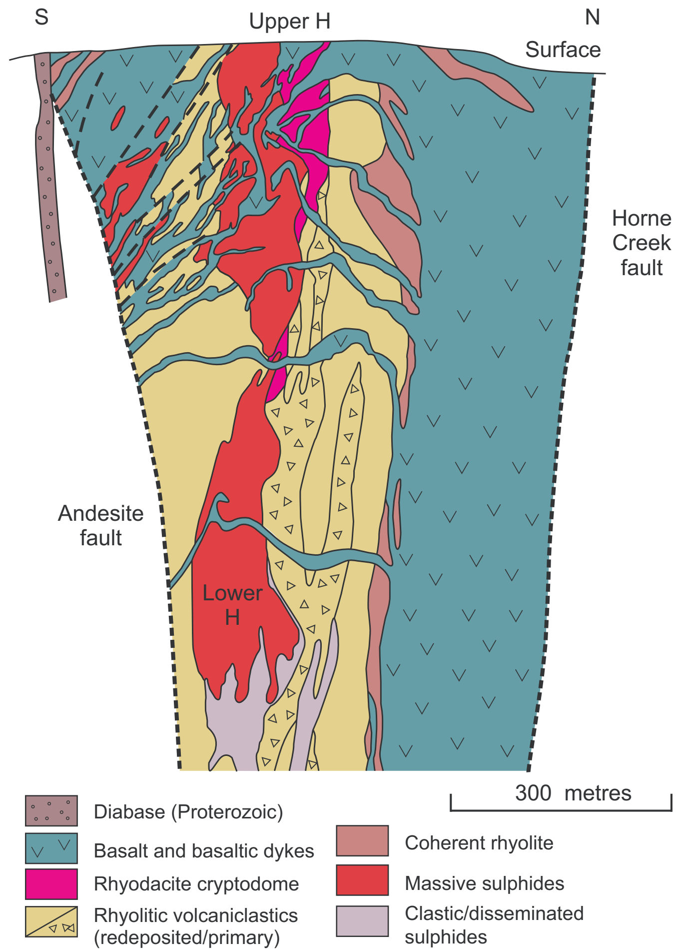

Figure 22. Vertical, north-south cross-section through the Horne deposit showing the Upper and Lower H ore bodies (modified from Kerr and Gibson, 1993).

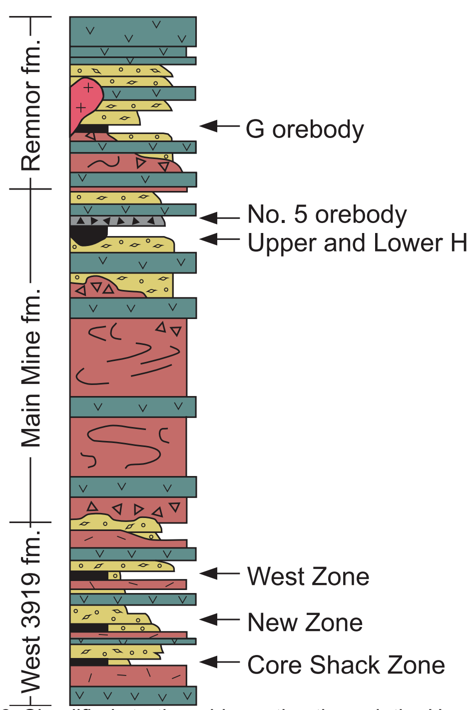

Figure 23. Simplified stratigraphic section through the Horne deposit (modified from Gibson et al., 2000).

ing it the largest gold producer of its class in the world (Hannington et al., 1999; Dubé et al., 2007a). If the ~170 Mt of subeconomic sulphides are taken into consideration, the Horne deposit represents the largest VMS accumulation of the entire Abitibi greenstone belt.

The Horne deposit is located within an E-W-trending package of dominantly felsic volcanic rocks that forms part of the Horne block (Fig. 21). The volcanic stratigraphy within the mine area faces to the north, strikes approximately WNW-ESE, and steeply dips to the north (Wilson, 1941; Hodge, 1967; Sinclair, 1971; Kerr and Mason, 1990; Kerr and Gibson, 1993; Gibson et al., 2000; Monecke et al., 2008). The bounding Horne and Andesite faults converge approximately 2.2 km to the west of the Horne deposit and dip steeply towards one another (Figs. 21 and 22).

The dominantly felsic volcanic succession hosting the Horne deposit consists of coherent rhyolite and related volcaniclastic deposits, interpreted to represent subaqueous lava flows with lesser synvolcanic intrusions, redeposited syn-eruptive volcaniclastic deposits, and possible primary pyroclastic deposits (Kerr and Mason, 1990; Kerr and Gibson, 1993; Gibson et al., 2000; Monecke et al., 2008). Kerr and Gibson (1993) informally divided the volcanic host rocks of the Horne deposit into three conformable formations which, from stratigraphic footwall to hanging wall, include the West 3919, Main Mine, and Remnor formations (Fig. 23).

Nearly all historic production from the Horne deposit came from the Upper and Lower H ore bodies, which occur near the top of the Main Mine formation. The Upper H body extended from surface to a mine depth of 395 m, whereas the Lower H ore body was located at a mine depth of 365 to 945 m (Fig. 22). These two ore bodies were approximately circular in horizontal cross section, but were elongate and plunged steeply to the east, parallel to the dip of the surrounding volcanic host rocks (Price, 1934; Hodge, 1967; Gibson et al., 2000). The Lower H ore body is stratigraphically overlain by a massive to semi-massive sulphide body, referred to as the No. 5 Zone (Sinclair, 1971). This tabular zone consists of numerous lenses of massive pyrite interbedded with intensely altered felsic volcaniclastic rocks. The No. 5 Zone extends for a strike length of more than 1000 m to a depth of at least 2650 m and ranges from approximately 30 to 140 m in thickness (Sinclair, 1971; Fisher, 1974; Gibson et al., 2000). Due to low metal grades, this zone has not been mined extensively (Gibson et al., 2000). A small massive pyrite lens, referred to as the G Zone, is located in the Remnor formation, which stratigraphically overlies the volcanic rocks hosting the Upper H and Lower H ore bodies as well as the No. 5 Zone (Kerr and Mason, 1990; Gibson et al., 2000).

The sulphide mineralization of the Horne deposit is crosscut by two suites of intrusive rocks that are interpreted to be synvolcanic in age. The oldest intrusions are porphyritic cryptodomes of intermediate composition that cut the western side of the Upper H ore body (Kerr and Gibson, 1993; Gibson et al., 2000). In addition, the occurrence of basaltic dykes and sills is widespread. The mafic intrusions commonly form dyke swarms that extend towards the package of mafic rocks located to the northeast of the Horne deposit.

Stop 2-4: Outcrops at the Horne West property

Coordinates

UTM nad 83, zone 17, 646 475 m E, 5 346 275 m N

Stop description

The Horne West outcrop forms part of the West 3919 formation as defined by Kerr and Gibson (1993). According to these authors, the volcanic succession exposed at the property is located in the footwall of the Horne deposit and is probably positioned several hundreds of metres below the Upper and Lower H ore bodies. The outcrop is located approximately 1 km to the west of the Horne deposit and represents the best exposed sections of the Horne stratigraphy (Monecke et al., 2008).

The lower portion of the Horne West succession is dominated by a proximal facies association comprising coherent rhyolite and associated juvenile volcaniclastic rocks that formed by autobrecciation and quench fragmentation (Monecke et al., 2008). The coherent rhyolite units are interpreted to have been emplaced near their vents where quenching in the subaqueous environment and mixing with unconsolidated or poorly consolidated volcaniclastic material along intrusive contacts limited the areal extent of the rhyolitic lava. The limited sizes of the coherent rhyolite units (stratigraphic thicknesses of <50 m) suggest successive eruptions of small volume magma batches.

The dominantly coherent volcanic rocks are overlain by voluminous, mass-flow-transported coarse volcaniclastic deposits (Fig. 24). The abundance of chlorite wisps that are interpreted to represent formerly glassy particles and the occurrence of altered pumice clasts within these deposits suggest that the debris was, at least in part,

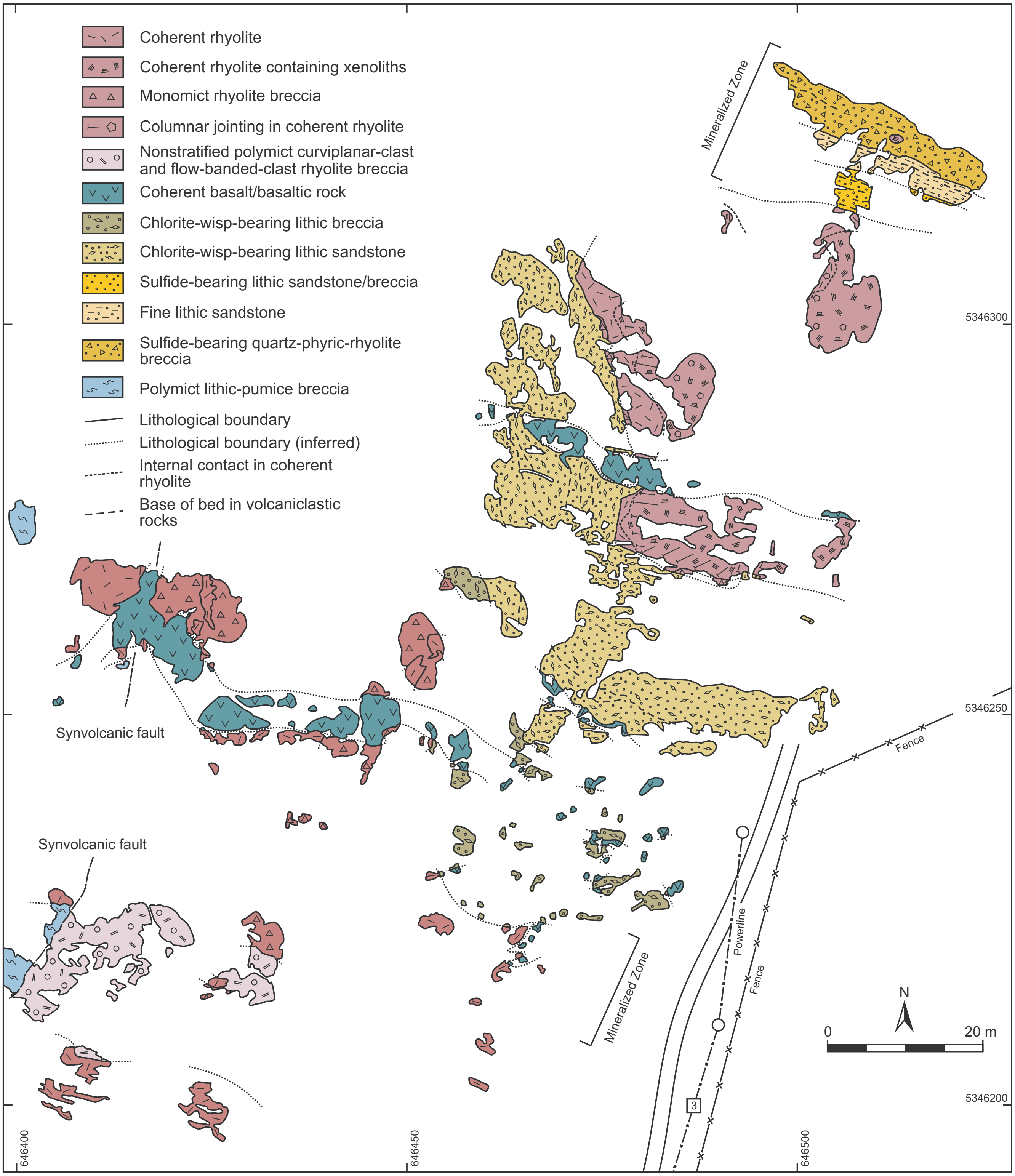

Figure 24. Simplified geological map of the Horne West property (modified from Monecke et al., 2008).

a product of explosive felsic volcanism taking place within or outside the immediate study area. The explosive volcanic activity is interpreted to have been broadly contemporaneous with the effusive or shallow intrusive rhyolitic volcanism in the Horne West area.

The central and upper portion of the exposed Horne West succession is dominated by a large rhyolite unit that shows a distinct flow foliation. Columnar jointing is locally well developed. The rhyolite unit is typified by a core zone that contains abundant mafic xenoliths. The xenoliths range from 1-2 cm to 1.5 m in size. Contacts between the xenoliths and the enclosing rhyolite are sharp but range from straight to irregular and scalloped. Flow bands within the host unit typically envelop the xenoliths but are locally truncated. The contact relationships between the mafic xenoliths and the rhyolite suggest that the mafic clasts were incorporated into the rhyolite melt through magma mingling implying the contemporaneous existence of a felsic and mafic magma chamber at depth.

The upper contact between the rhyolite and the enclosing volcaniclastic facies is sharp and/or sheared. However, logging of historic drill core shows that the stratigraphic position of the upper rhyolite contact varies along strike and down dip, implying that the margin of the rhyolite unit was at least locally intrusive. Additional constraints are provided by the occurrence of two large (150x100 cm and 65x33 cm, respectively) xenolith-bearing rhyolite clasts in the volcaniclastic facies that overlies the rhyolite, as observed in outcrop. Incorporation of rhyolite clasts into the mass-flow emplaced volcaniclastic deposits provides evidence that the rhyolite locally emerged at the ancient seafloor. The rhyolite may have breached the seafloor during emplacement or, alternatively, it became exposed during synvolcanic faulting.

A second relatively thick unit of volcaniclastic rocks occurs stratigraphically above the coherent rhyolite in the northern portion of the Horne West outcrop. These rocks are divided into three volcaniclastic facies (Fig. 25). At surface, the coherent rhyolite is in contact with a sulphide-bearing lithic sandstone/breccia facies. This facies is overlain by a 3 m-thick fine lithic sandstone. Several ballistically-emplaced clasts of aphyric rhyolite occur in the fine lithic sandstone, the largest of which has a long axis of approximately 20 cm. Bedding sags beneath these ballistic fragments indicate that the fine lithic sandstone was wet and cohesive when the projectiles landed. Deposition of the fine lithic sandstone facies was followed by a drastic change in sedimentation as manifested by the presence of overlying beds of sulphide-bearing quartz-phyric rhyolite breccia. This facies is very thickly bedded with some beds exceeding a stratigraphic thickness of 5 m. The beds are reversely graded at the base, but overall are normally graded. This is consistent with an emplacement by high-concentration mass flows, with the reverse grading being caused by shear at the base of flow during transport. The coarse portions of the breccia beds are framework-supported and contain abundant cobble- to boulder-sized quartz-phyric rhyolite fragments. In addition, large pyrite-dominated sulphide clasts occur that are typically concentrated in the lower portion of individual beds. Most sulphide clasts are recessive and weathered, and their locations are marked by extensive pitting of the outcrop surface. Some of the pits exceed 50 cm in diameter suggesting that the sulphide clasts were of substantial size. The sulphide clasts are likely locally sourced as clasts, as indicated by their abundance and as clasts of that size and density cannot be transported by mass-flows over long distances. Proximity of the source of the massive sulphides to the rhyolite emplacement unit containing the mafic xenolith, which was exposed at the seafloor at the time of mass-flow deposition, suggests that massive sulphide formation occurred near a volcanic vent.

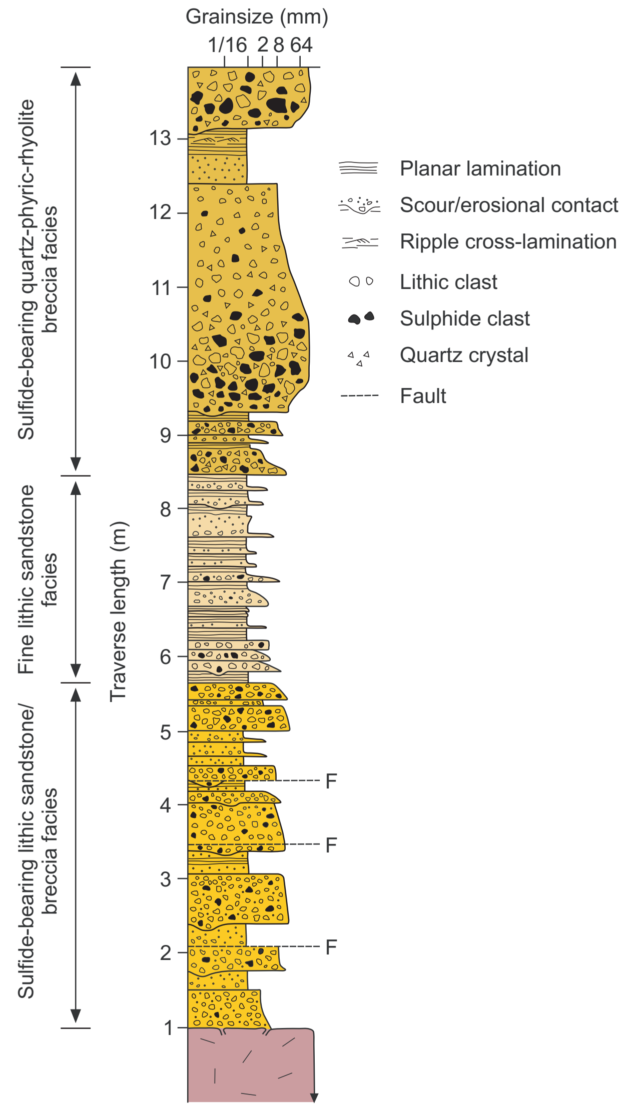

Figure 25. Schematic graphic log of the upper portion of the Horne West succession. The log is based on outcrop observations.

Disseminated sulphide mineralization and associated hydrothermal alteration are conspicuous features of the Horne West stratigraphy. Significant gold grades were encountered in zones of disseminated sulphide mineralization occurring in the immediate footwall of coarse volcaniclastic rocks containing abundant sulphide clasts (Figs. 24 and 25). These volcaniclastic deposits define two paleo-seafloor positions within the volcanic succession at which massive sulphide accumulations must have been exposed at the time of mass-flow deposition of the volcaniclastic material. This relationship indicates that gold mineralization associated with sulphide infiltration and replacement of the volcanic strata at Horne West formed at the fringe of, or marginal to, a long-lived, stratigraphically stacked, hydrothermal ore system. Based on the field relationships, gold mineralization at Horne West is considered to be of synvolcanic origin.

A synvolcanic fault has been mapped in the western portion of the Horne West area. This fault offsets volcaniclastic strata on the property and is marked by the occurrence of several synvolcanic felsic and mafic dykes. The synvolcanic fault likely represented the bounding structure of a seafloor depression or graben in which synvolcanic sulphide mineralization occurred. Mass-flow deposition of volcaniclastic material appears to have been channeled into the fault-bounded seafloor depression. Contouring of the disseminated sulphide mineralization using exploration drill hole data suggests that the fault-bounded basin (graben) plunges steeply to the east with the mineralization trend being parallel to the Upper and Lower H orebodies. This finding suggests that the mineralization at Horne West formed in a paleo-graben similar to the one hosting the Horne deposit (Kerr and Mason, 1990; Gibson et al., 2000).

Coherent basalt intrusions are widespread in the lower and central portion of the Horne West succession and may represent feeders to the mafic volcanic succession located to the northeast of the Horne deposit. The basaltic dykes and sills show variable alteration intensities suggesting that they were emplaced during or after the waning of the hydrothermal activity in the Horne West area. This suggests that felsic volcanic activity and formation of sulphide mineralization were followed by a change in volcanism towards a more mafic composition.

Host-rock succession of the Quemont deposit

The Quemont deposit represented the second largest deposit in the Noranda camp. Discovered in 1945, the mine produced 13.82 Mt of ore grading 1.32% Cu, 2.44% Zn, 5.49 g/t Au, and 30.9 g/t Ag (Table 1). The deposit is located to the north of the Horne Creek Fault within the Powell block, approximately 1.5 km north of Rouyn-Noranda. The host rock succession of the Quemont deposit is dominated by felsic volcanic rocks with volcaniclastic units forming a significant proportion of the overall stratigraphy, which is not unlike the host rock succession of the Horne deposit.

Over thirty years ago, the research groups of E. Dimroth and L. Gélinas independently mapped Quemont hill, a large outcrop area to the north of the deposit. However, the mapping projects were not completed at the time. Almost all original data collected during decades of underground operation at Quemont was destroyed during a fire at the mine site. Remaining mine plans and published figures in excursion guidebooks and thesis (e.g., Weeks, 1963) suggest that the massive sulphides at Quemont were hosted by rhyolite breccia at or near the contact with quartz porphyritic coherent rhyolite. The rhyolite breccia and the porphyritic rhyolite are folded into a westerly plunging anticline, the axis of which strikes N80°W. Further crossfolding on approximately a north axis has produced a domal effect on the original anticline. The south flank of the structural dome has been truncated by the Horne Creek fault.

The geological relationship between the Horne and Quemont deposits has been a matter of debate over the past decades as these deposits, the two largest and gold-rich massive sulphide accumulations in the Noranda mining camp, are located only 800 metres-apart on opposite sides of the Horne Creek fault. The Horne Creek fault today clearly represents a major structural discontinuity with different structural styles on both sides of the fault, different rhyolite geochemical signatures, and significant apparent displacements along the fault, although the fault itself is only marked by several centimetres of fault gouge where observed (H. Poulsen, pers. comm. 2008). It is currently envisaged that the Horne Creek Fault represents a long-lived structure with initial movement taking place during volcanism. However, late deformation events are significant and it makes it difficult to really evaluate the nature and extent of this inferred early evolution of the Horne Creek Fault. Recent U-Pb zircon dating of a coherent rhyolite sampled in proximity to the Quemont mine site yielded an age of 2702.0 Ma (McNicoll et al., subm.). This age date implies that the felsic volcanic successions hosting the Horne and Quemont deposits are similar in age.

Stop 2-5: Outcrop of sediment-matrix rhyolite breccia, Quemont

Coordinates

UTM nad 83, zone 17, 647 415 m E, 5 347 410 m N

Stop description

A significant portion of the outcrop area on Quemont hill is dominated by rhyolite breccias that are texturally similar to those described to host the Quemont deposit (Ryznar et al., 1967). This rhyolite breccia facies shows a crude stratification and is dominated by clasts having curviplanar margins. This breccia facies hosts abundant rhyolite sills. The contact relationship between the lava and the crudely stratified breccia facies is complex in detail and marked by an intricate interpenetration between the coherent rhyolite and the breccia (Fig. 26). The contacts between the lava and the breccia facies are typified by a clastic texture with blocky to irregularly shaped clasts derived from the lava within the host breccia. The rhyolite clasts are partially detached or completely separated from the coherent facies. The field relationships suggest that the rhyolite was emplaced as small intrusions and sills

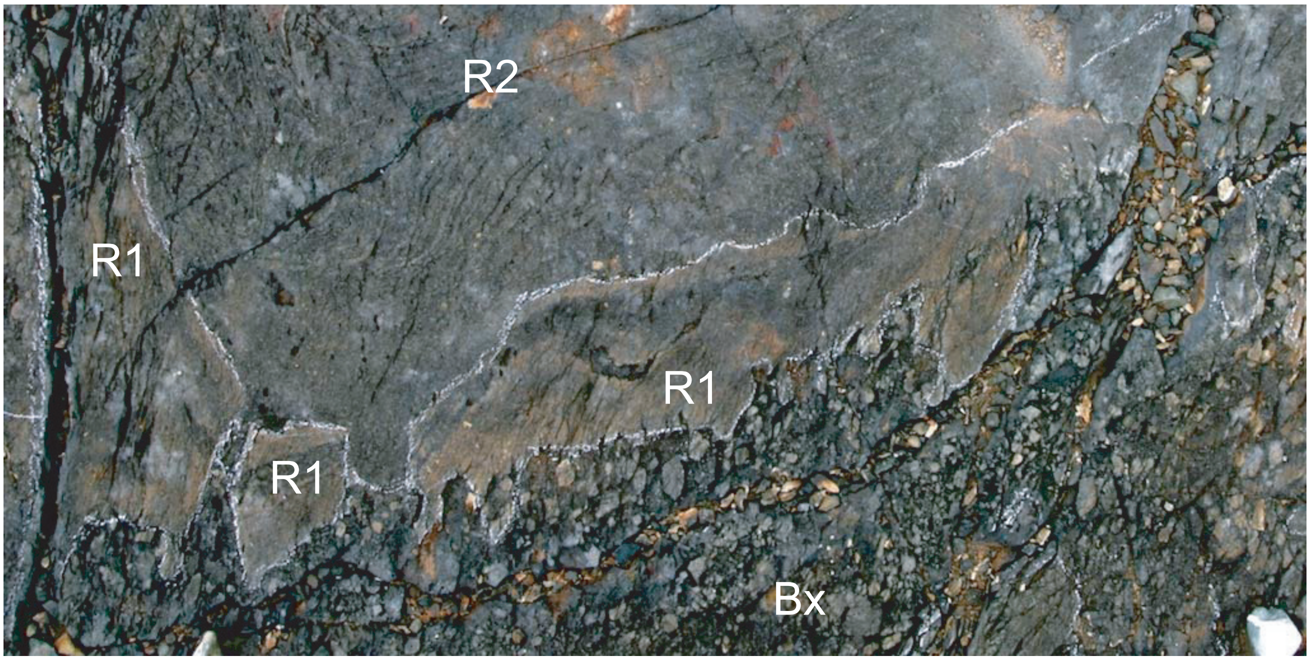

Figure 26. Field photograph of the contact relationship between a crudely stratified rhyolite breccia (Bx) and a rhyolitic sill composed of two texturally distinct rhyolite generations (R1 and R2). The textural evidence suggests that intrusion of the lava occurred when the breccia facies was still wet and unconsolidated. Field of view is approximately 1.2 m.

into the still wet and unconsolidated rhyolite breccia facies. In the outcrop investigated, the sill formed from two distinct lava batches. The interior of the sill exhibits a well-developed flow foliation.

The observed relationship is critical as it indicates that massive sulphide formation through replacement processes within the rhyolite breccias was broadly contemporaneous with intrusive activity. Massive sulphide formation occurred in a proximal (near-vent) volcanic environment.

Stop 2-6: Outcrop of magma mingling between mafic and felsic dykes, Quemont

Coordinates

UTM nad 83, zone 17, 647 210 m E, 5 347 510 m N

Stop description

The volcaniclastic strata hosting the Quemont deposit are crosscut by a northeast striking mafic dyke swarm. Individual dykes range from several centimetres to several metres in thickness and dyke-in-dyke intrusions are common. The dyke swarm exposed on Quemont hill is interpreted to record a major period of crustal extension in the Quemont area.

The outcrop illustrates the occurrence of a composite dyke that formed by contemporaneous intrusion and mingling of rhyolitic and basaltic magmas. Along the contact between the two dykes, abundant basalt clasts are entrained into the feldspar and quartz porphyritic rhyolite dyke (Fig. 27). The abundance of basalt clasts decreases with increasing distance from the contact, with some clasts being located up to 1.5 m from the contact. The basalt clasts typically have fluidal shapes with the long axes of the clasts being broadly parallel to the dyke margins. This indicates that entrainment of the basalt clasts into the rhyolite occurred at a time when the basalt was still in a liquid state.

The observation of magma mingling at the outcrop scale is important as it implies the coexistence of mafic and felsic magma chambers at depth at the time the Quemont area underwent crustal extension. Similar evidence for

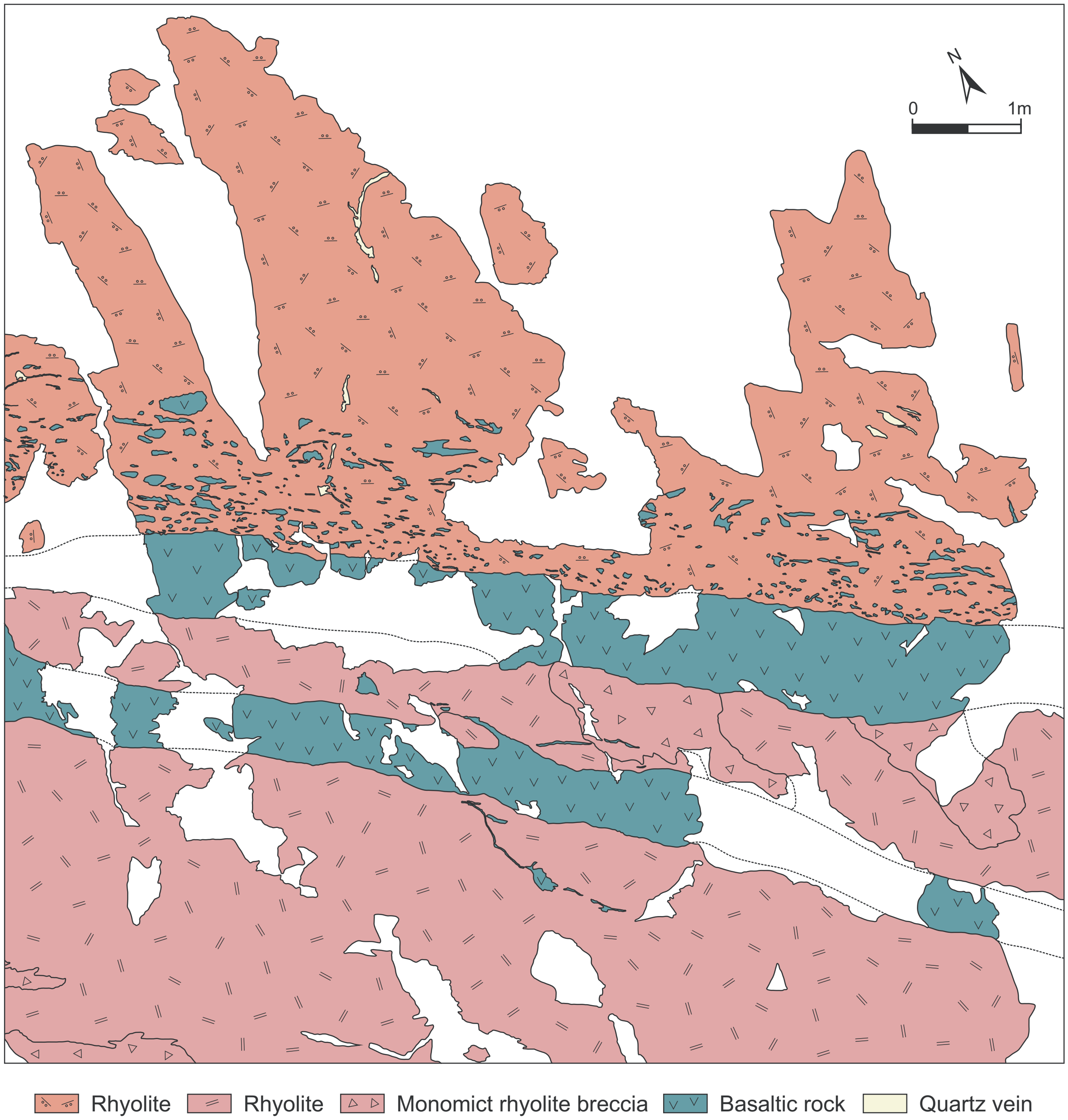

Figure 27. Map showing the contact between a mafic and felsic dyke at Quemont hill. Entrainment of mafic clasts into the felsic dyke is interpreted to have occurred through magma mingling (mapped by F. Huthmann and T. Monecke, 2009).

bimodal magmatism associated with crustal extension has been observed in several locations in the Noranda camp, including the outcrop at the Horne West property described above (Monecke et al., 2008) as well as the Moosehead

Volcanic setting of the D'Eldona-Delbridge deposits

An additional felsic volcanic centre in the Noranda camp is located in the D'Eldona-Delbridge area, approximately 3 km northeast of Rouyn-Noranda (Fig. 20). This volcanic centre is located at the eastern limit of the Powell block and clearly younger than the volcanic rocks hosting the Horne and Quemont massive sulphide deposits. However, no absolute age date is available for the D'Eldona-Delbridge area hampering direct stratigraphic correlation with texturally similar felsic volcanic rocks located north of the Beauchastel fault. At present, the felsic volcanic rocks at D'Eldona-Delbridge are considered to have formed at approximately 2699 Ma (Fig. 6), being slightly older than the volcanic rocks hosting the massive sulphides within the Noranda southern and northern central camps dated at 2698 Ma.The outcrop illustrates the occurrence of a composite dyke that formed by contemporaneous intrusion and mingling of rhyolitic and basaltic magmas. Along the contact between the two dykes, abundant basalt clasts are entrained into the feldspar and quartz porphyritic rhyolite dyke (Fig. 27). The abundance of basalt clasts decreases with increasing distance from the contact, with some clasts being located up to 1.5 m from the contact. The basalt clasts typically have fluidal shapes with the long axes of the clasts being broadly parallel to the dyke margins. This indicates that entrainment of the basalt clasts into the rhyolite occurred at a time when the basalt was still in a liquid state.

The D'Eldona massive sulphide deposit was discovered in 1947. Between 1950 and 1952, the deposit produced 80800 tonnes of ore grading 7.7% Zn, 62.4 g/t Ag, and 5.3 g/t Au (Table 1, Boldy, 1968). The Delbridge deposit was discovered along strike to the south in 1965 and subsequently developed via two underground galleries from the original D'Eldona shaft. Between 1969 and 1971, the Delbridge ore body produced 370.000 tonnes of ore grading 0.61% Cu, 9.6% Zn, 110 g/t Ag, and 2.1 g/t Au (Table 1, Barrett et al., 1993).

The host rocks of the Delbridge and D'Eldona deposits consist of a complex succession of aphyric and porphyritic coherent rhyolite and felsic to intermediate volcaniclastic rocks. The geological setting and volcanic facies architecture of the deposits was studied by Boldy (1968). He showed that the footwall of the massive sulphides is dominated by a coherent, quartz-phyric rhyolite dome that is overlain by a 1600 metres long and 400 m-thick rhyolite breccia pile. Individual beds within the rhyolite breccia unit are massive and poorly sorted or normally graded.

The massive sulphide lenses at Delbridge and D'Eldona are hosted by a fine-grained volcaniclastic unit that forms a distinct horizon within the rhyolite breccia pile. This unit is laminated, pale greyish white and typically quite siliceous. According to Boldy (1968), alternating laminations of volcaniclastic material and sulphide ore minerals have been locally observed. The unit ranges in thickness from several centimetres to over 10 m and can be traced for several hundred metres. The location of the massive sulphide lenses coincides with a local thickening of the fine-grained volcaniclastic unit.

Rhyolite breccias also form the immediate hanging wall of the massive sulphides. However, a distinct fine-grained mafic volcaniclastic unit occurs immediately to the south and appears to onlap with the rhyolite breccia pile at Delbridge. The mafic unit is overlain by a thin unit of porphyritic rhyodacite, which is overlain by a quartz-feldspar porphyritic rhyolite unit, an extensive aphyric rhyolite unit, and a thick andesite unit. At surface, an irregularly shaped aphyric rhyolite intrusion extends from the footwall rhyolite breccia to the aphyric rhyolite flow that forms the youngest felsic unit of the hanging wall. The felsic volcanic succession is overlain by a thick interval of mafic volcanic rocks.

Stop 2-7: Outcrop of fine-grained volcaniclastic marker horizon hosting the Delbridge deposit

Coordinates

UTM nad 83, zone 17, 650 990 m E, 5 347 630 m N

Stop description

The outcrop at the intersection between the access road to the D'Eldona deposit and a small road leading south to the Delbridge deposit represents the best exposure of the fine-grained volcaniclastic unit marking the location of the massive sulphide lenses within the D'Eldona-Delbridge felsic volcanic centre. The volcaniclastic unit is approximately 10 cm in thickness in outcrop, pale grayish white in color and laminated.

At the outcrop scale, the fine-grained volcaniclastic unit overlies poorly stratified rhyolite breccia that contains irregular lobes of coherent and flow-banded rhyolite that are up to several metres in diameter. The breccia consists predominantly of hyaloclastite that is compositionally similar to the rhyolite lobes and may have originated from the disintegration of the lobes. The facies relationships observed are consistent with those described for the distal portion of rhyolitic lobe-hyaloclastite flows elsewhere in the Noranda camp (de Rosen-Spence et al., 1980; Gibson, 1990). Crudely bedded coarse rhyolite breccia forms the immediate hanging wall to the fine-grained volcaniclastic marker horizon. The up to 60 cm-large rhyolite clasts in this breccia facies commonly show distinct polygonal shapes implying that the fragments were derived from columnar jointed rhyolite. The breccia facies likely formed by gravitational collapse of a jointed rhyolite dome. The D'Eldona-Delbridge massive sulphide deposits must have formed proximal to the vent site of this dome.

Iron-carbonate alteration is widespread in the D'Eldona-Delbridge area and most pronounced in the stratigraphic footwall of the fine-grained volcaniclastic marker horizon. The Fe-carbonate alteration is pervasive, but Fe-carbonates also occur in stockwork veinlets and as cement in coarse rhyolite breccia. The alteration is interpreted to be synvolcanic in origin although pronounced fabric development in proximity to the Horne Creek fault makes the interpretation of timing relationships somewhat ambiguous.

Massive sulphide mineralization of the Cyprus Rhyolite

The Cyprus Rhyolite represents a large felsic volcanic center located at the eastern limit of the Flavrian block. In this area, coherent rhyolite and associated juvenile volcaniclastic deposits are exposed over a strike length of more than 8 km. The Cyprus Rhyolite is located in the stratigraphic hanging wall of the Lac Dufault pluton.

The Lac Dufault pluton is divisible into two main phases. The western phase is associated with a pronounced metamorphic aureole that extensively overprinted the surrounding volcanic rocks and converted synvolcanic hydrothermal chlorite-sericite alteration pipes to cordierite-anthophyllite assemblages (de Rosen-Spence, 1969; Beaty and Taylor, 1982). A U-Pb zircon age of 2690.3+2.2/-2.0 Ma for the western phase granodiorite (Mortensen, 1993) indicates that this is a comparably young, post-volcanic intrusion. In contrast, the eastern phase is not surrounded by a contact metamorphic aureole and the hydrothermal alteration zone associated with the Gallen deposit, which occurs as a roof pendant within the intrusion, is not contact metamorphosed (Watkinson et al., 1990). This suggests that the eastern phase of the Lac Dufault pluton is synvolcanic.

The synvolcanic eastern phase of the Lac Dufault pluton is currently thought to represent the intrusive equivalent of a shallow magma chamber below the felsic volcanic centre represented by the Cyprus Rhyolite. Two different geochemical signatures of distinct magmatic affinities indicate possibly two distinct synvolcanic intrusive phases. Recent dating of the Cyprus Rhyolite yielded an age of 2696.4 Ma (McNicoll et al., subm.). This age indicates that the Cyprus Rhyolite belongs to some of the youngest volcanic rocks of the Blake River Group.

Exploration of the Cyprus Rhyolite between 2006 and 2008 indicated that this volcanic centre is also a host of massive sulphide mineralization. The mineral potential of the Cyprus Rhyolite was initially tested by widely spaced drill holes that targeted the top of the rhyolite unit at the intersections with north-east striking synvolcanic faults on the Pinkos property, which is located approximately 10 km north of Rouyn-Noranda (Press release of Alexis Minerals Jan. 9, 2007). Drillhole PNK-06-02 intersected 2.64 m of massive to semi-massive pyrite and sphalerite grading 8.1% Zn and 18.2 g/t Ag. The mineralized interval occurs within a 100 m-wide sericite and black chlorite alteration zone. A second, lower semi-massive pyrite intersection containing chalcopyrite stringer graded 0.33% Zn and 0.18% Cu over 2.86 m. During the summer of 2007, a Titan-24 survey was carried out over the Cyprus Rhyolite with the aim of detecting additional synvolcanic structures. The results indicated the presence of a low resistivity zone, interpreted to be caused by an altered synvolcanic structure in the area of the initial base metal discovery. Based on the geophysical survey, additional targets for drilling were defined. A drilling program of 5 additional holes for 3,600 m was conducted in 2008 (Press release of Alexis Minerals Jan. 10, 2008). Although the drill holes encountered highly altered rhyolite containing abundant disseminated sulphides, massive base metal mineralization was not intersected.

Despite the absence of economic mineralization, the findings at the Pinkos property are significant as they highlight the fact that even the relatively young Cyprus Rhyolite represents a viable exploration target in the Noranda east camp and that massive sulphide formation in the camp occurred at several discrete time periods between 2703 and 2696 Ma.

Stop 2-8: Outcrop of the Cyprus Rhyolite at the Pinkos property

Coordinates

UTM nad 83, zone 17, 653 960 m E, 5 352 515 m N

Stop description

The outcrop to the north of the gravel road exhibits spectacular columnar jointing within the Cyprus Rhyolite. This type of jointing divides the rhyolite into elongate prismatic columns that typically have hexagonal shapes in cross-section. The orientation of the columns suggests that the cooling surface was approximately parallel to the surface of today's exposure. The joints formed in response to contraction and incremental fracturing of the rhyolite as the cooling surface migrated into the solidifying lava.

The outcrop is typified by intense Fe-carbonate alteration that presumably formed in association with the nearby base metal mineralization. Fe-carbonate alteration is centered along the joints defining the sides of the columnar joints (Fig. 28). This suggests that the network of joints played an important role in focusing synvolcanic fluid flow. Additional evidence for the Fe-carbonate alteration being synvolcanic in origin is provided by the fact that flow-aligned vesicles within the rhyolite are commonly filled by Fe-carbonates. This suggests that the vesicles were empty at the time of fluid flow, which is consistent with the hydrothermal alteration being prior to diagenesis and metamorphism.

Along the centers of the joints, the Fe-carbonate alteration is overprinted by sericite alteration (Fig. 28). This implies that the formation of Fe-carbonates predates this more intense style of alteration. At a larger scale, the Fe-

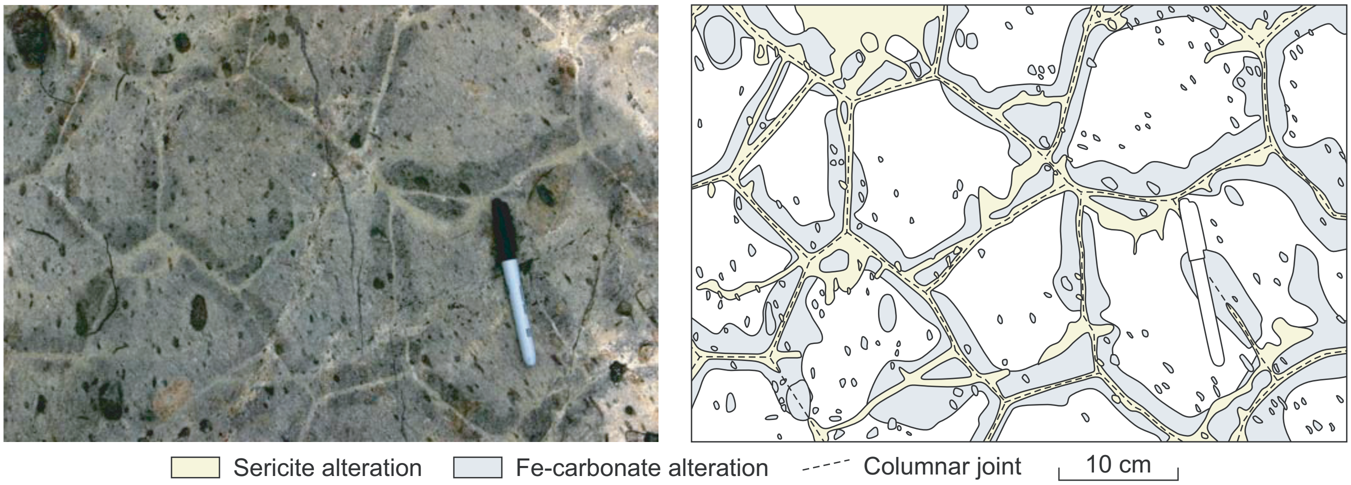

Figure 28. Columnar jointing at the Pinkos property and textural relationships between the columnar joints, Fe-carbonate alteration, and sericite alteration.

carbonate alteration represents an outer alteration zone that gives way to more intense sericite and/or chlorite alteration in proximity to the sulphide mineralization.

Discussion and conclusions – Day 2 PM

VMS deposits of the BRG located in the south and east Noranda camps (outside of the northern and southern central camps) are hosted by felsic host-rock successions that contain variable amounts of volcaniclastic material. The volcanology of the host rock succession represents a key control on the nature and style of mineralization and the associated hydrothermal alteration.

Volcaniclastic deposits are particularly important in the host rock successions of the two largest deposits, Horne and Quemont, where a significant proportion of the sulphide mineralization formed by processes of subsea-floor infiltration and replacement within the volcaniclastic strata. Sulphide formation occurred in fault-bounded depressions or grabens that were filled with volcaniclastic deposits. Due to the high permeability of the clastic strata, hydrothermal fluid flow was probably quite diffuse causing the formation of large alteration halos around the massive sulphide lenses.

In contrast, the host-rock successions of the D'Eldona-Delbridge deposits and the Pinkos occurrence contain a higher portion of coherent rhyolite units. Sulphide deposition at D'Eldona-Delbridge occurred at or immediately below the seafloor with the seafloor position being marked by fine-grained volcaniclastic deposits that formed by suspension sedimentation. Fluid flow through coherent volcanic rocks was strongly controlled by the existence of primary fluid pathways such as joints that formed during cooling of the lava. Synvolcanic faults clearly control the location of deposits within the felsic volcanic centers. Deposits in these settings are not unlike the classical mound-style deposits of the Noranda main camp that formed in lava-flow-dominated volcanic successions.

All massive sulphide deposits hosted in felsic host-rock successions of the Rouyn-Noranda district formed in proximal (near-vent) settings associated with the emplacement of synvolcanic sills or dykes and rhyolite lavas or domes. This observation provides an important exploration criterion that may be used for targeting within felsic host-rock successions.

Hydrothermal activity was associated with crustal extension as implied by the formation of fault-bounded seafloor depressions or grabens and the contemporaneous occurrence of bimodal magmatism. The observed evidence for the mingling of mafic and felsic magma is key in constraining this setting. Although the deposits are hosted by felsic volcanic rocks, massive sulphide formation broadly coincided with a major shift in volcanism. Both at Horne and D'Eldona-Delbridge, the felsic host-rock successions are immediately overlain by thick intervals of mafic volcanic rocks. The onset of mafic volcanism broadly overlapped with the waning stages of hydrothermal activity as demonstrated at Horne. The shift in the composition of volcanism is possibly related to continued extension promoting increased upwelling of mafic melts to shallow crustal levels.

It is remarkable that all felsic-hosted VMS deposits of the Noranda camp are characterized by anomalous enrichments of gold, which made them significant precious metal producers comparable in metal content to the world-class gold deposits of the Doyon-Bousquet-LaRonde mining camp. The unusual enrichment of gold in felsic-hosted synvolcanic massive deposits makes the Blake River Group a particularly interesting target for future deep exploration.

DAY 3: THE LARONDE PENNA WORLD-CLASS GOLD-RICH VMS DEPOSIT, DOYON-BOUSQUET-LARONDE CAMP – GEOLOGICAL SETTING, ALTERATIONS AND MINERALIZATION

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Introduction

Among the ninety VMS deposits of the Abitibi greenstone belt (AGB), six are gold-rich and two are auriferous (based on the classification proposed by Mercier-Langevin et al., 2010c). All six gold-rich VMS are located in the 2704-2695 Ma Blake River Group (BRG). Four of these gold-rich VMS deposits are world-class gold deposits (>100 t Au or 3.2 Moz Au : Singer, 1995; Mercier-Langevin et al., 2010c). Two of the six gold-rich VMS deposits of the AGB are located in the Noranda camp (Horne and Quemont), whereas the other four are located in the Doyon-Bousquet-LaRonde mining camp, including LaRonde Penna, Bousquet 2-Dumagami, Bousquet 1 and Westwood-Warrenmac (Figs. 1, 4, 29 and 30). Horne and LaRonde Penna are the two largest gold-rich VMS deposits ever found (Dubé et al., 2007a; Mercier-Langevin et al., 2010c).

Gold-rich VMS deposits are important exploration targets as their gold content contributes significantly to their total value and their polymetallic nature makes them less vulnerable to metal price fluctuations (Poulsen et al., 2000; Dubé et al., 2007a; Mercier-Langevin et al., 2010c). The AGB, and more specifically the BRG, represent the world most fertile and best exploration target for gold-rich VMS deposits.

The objective of this visit at LaRonde Penna is to illustrate the geological setting and main alteration attributes of the world's second largest gold-rich VMS deposit and the largest one currently in operation .

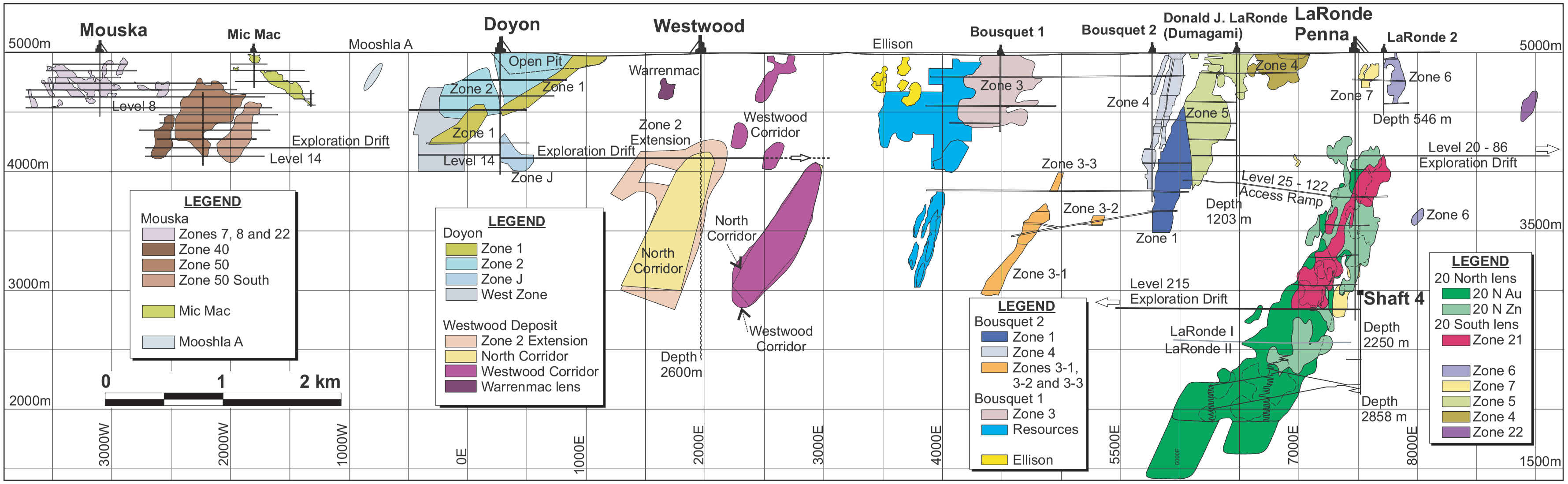
The LaRonde Penna deposit – An introduction

Production at the LaRonde Penna mine started in 2000. It is currently the largest Au, Ag, Cu, Zn and Pb producer in Québec. It is also one of the largest Au mine in Canada with a total content (production, reserves and resources) of 78.5 Mt of ore at 3.7 g/t Au, 39.7 g/t Ag, 0.3% Cu, 1.9% Zn, and 0.1% Pb for approximately 9.35 Moz or 291 t Au (Fig. 29). Its significant size also makes the LaRonde Penna deposit one of the largest Canadian VMS deposits.

The LaRonde Penna mine is located in the Doyon-Bousquet-LaRonde (DBL) mining camp in the eastern part of the BRG in the AGB (Figs. 29 and 30). The DBL camp is one of Canada's most prolific Au districts with approximately 28 Moz of contained Au. Gold is hosted in four main types of deposits: 1) Gold-rich volcanogenic massive sulphide (VMS) deposits; 2) synvolcanic sulphide-rich veins, stockworks and disseminations deposits; 3) intrusion-hosted sulphide-rich quartz veins; and 4) orogenic sulphide-rich Au-Cu veins (Mercier-Langevin et al., 2007c, d). In addition to Au, the DBL camp is also a major Zn, Cu, and Ag producer (Mercier-Langevin et al., 2007d).

The LaRonde Penna mine ore zones are hosted in the 2699-2697 Ma Bousquet Formation (Lafrance et al., 2003; Mercier-Langevin et al., 2007a) which constitutes one of the youngest assemblages of volcanic rocks of the BRG (Dubé et al., 2004; Mercier-Langevin et al., 2004; Lafrance et al., 2005; Goutier et al., 2007; 2009a; McNicoll et al., 2007; subm.). The Bousquet Formation and the deposits it hosts were subject to a considerable amount of academic work in the past (e.g., Valliant and Hutchinson, 1982; Tourigny et al., 1988, 1989, 1993; Stone, 1990; Marquis et al., 1990; Mercier-Langevin et al., 2007d and references therein), as well as more recent geological mapping and synthesis of earlier work (Lafrance et al., 2003), detailed geochronology (Lafrance et al., 2003; Mercier-Langevin et al., 2004, 2007a, 2008; Mercier-Langevin, 2005), 3D modelling (Fallara et al., 2004), and numerous thematic studies (e.g., Belkabir et al., 2004; Dubé et al., 2004, 2007b; Galley and Lafrance, 2007; Mercier-Langevin, 2005; Mercier-Langevin et al., 2004, 2007a, b, 2008, 2009b).

A detailed study of the LaRonde Penna deposit geology and mineralization was initiated by the Geological Survey of Canada (GSC) in collaboration with the Ministère des Ressources naturelles et de la Faune du Québec (MRNF) and Agnico-Eagle Mines Ltd. in 2000 as part of the joint GSC, MRNF, Agnico-Eagle Mines Ltd., Barrick Gold Corp., Cambior Inc. and Yorbeau Resources geological synthesis of the Doyon-Bousquet-LaRonde mining camp (Targeted Geoscience Initiative 1 Program). A second phase of research was undertaken in this area in 2006 with the Metallogenic Synthesis of the Doyon-Bousquet-LaRonde camp as part of the GSC Targeted Geoscience Initiative 3 Program and the MRNF Plan Cuivre joint project.



Total production, reserves and resources at the end of 2010 for the Doyon-Bousquet-LaRonde mining camp, Abitibi, Québec.

Deposit Type	Mine Name	Year	Cumulative production: Tonnage (Mt m)	Au in situ (g/t)	Au (tonnes)	Au (Moz)	Ag (tonnes)	Cu (tonnes)	Zn (tonnes)	Total metal budget (in situ): Tonnage (Mt m)	Au (g/t)	Au (tonnes)	Au (Moz)	Ag (tonnes)	Cu (tonnes)	Zn (tonnes)	Pb (tonnes)
Au-rich volcanogenic massive (±semimassive) sulphide lenses																	
	Dumagami	1988-1999	7.33	6.83	46.01	1.48	85.79	34198	4994	7.33	6.84	50.11	1.61	143	49	8	
	LaRonde Penna*	2000-	25.34	3.35	76.69	2.47	1349.88	68365	620388	78.53	3.70	290.77	9.35	3117	227148	1498922	50201
	Bousquet 2	1990-2002, 2007	8.22	8.56	66.64	2.14	0.42	45804	20	8.22	8.56	70.35	2.26		54		
	Warrenmac									0.31	6.90	2.16	0.07	17	626	14085	
		TOTAL	40.90	5.02	189.33	6.09	1436.08	148366	625402	94.40	4.38	413.40	13.29	3277	331038	1521353	50201
Au-rich sulphide veins, stockworks and disseminations																	
	Bousquet 1	1978-1996	7.45	5.70	39.49	1.27				29.62	3.36	99.61	3.20				
	Ellison									1.20	5.77	6.92	0.22				
	Westwood**									9.35	11.49	107.50	3.43				
		TOTAL	7.45	5.70	39.49	1.27				40.48	5.34	214.03	6.85				
Epizonal "intrusion-related" sulphide-rich Au-Cu vein systems																	
	Doyon	1980-2009	31.62	5.53	167.95	5.40				37.73	5.38	202.98	6.53				
	Mooshla A	1939-1940	0.004	29.66	0.13	0.00				0.004	29.66	0.13	0.004				
		TOTAL	31.62	5.54	168.08	5.40				37.73	5.38	203.11	6.53				
Shear-hosted sulphide-rich Au-Cu vein systems																	
	Mouska*	1989-	2.08	12.66	24.94	0.80		437		2.56	12.59	32.25	1.04		437		
	Mic Mac	1942-1947	0.72	4.62	3.34	0.11		1150		0.72	4.62	3.34	0.11				
	Orion-B2 shear									0.50	6.00	3.00	0.10				
		TOTAL	2.80	10.58	28.28	0.91		1587		3.79	10.19	38.59	1.25		1587		
	TOTAL camp DBL		**82.77**	**5.47**	**425.18**	**13.67**	1436.08	149953	625402	**176.40**	**4.94**	**869.10**	**27.92**		331038	1521353	50201

Mt m = metric tonnes
Moz = million ounces
* Current producers
** Advanced exploration

Figure 29. Composite longitudinal view (looking north) of the Doyon-Bousquet-LaRonde camp. The zones and lenses outline include production, reserves and resources altogether. The table gives the cumulative production and combined production, reserves and resources for the camp at the end of 2010.

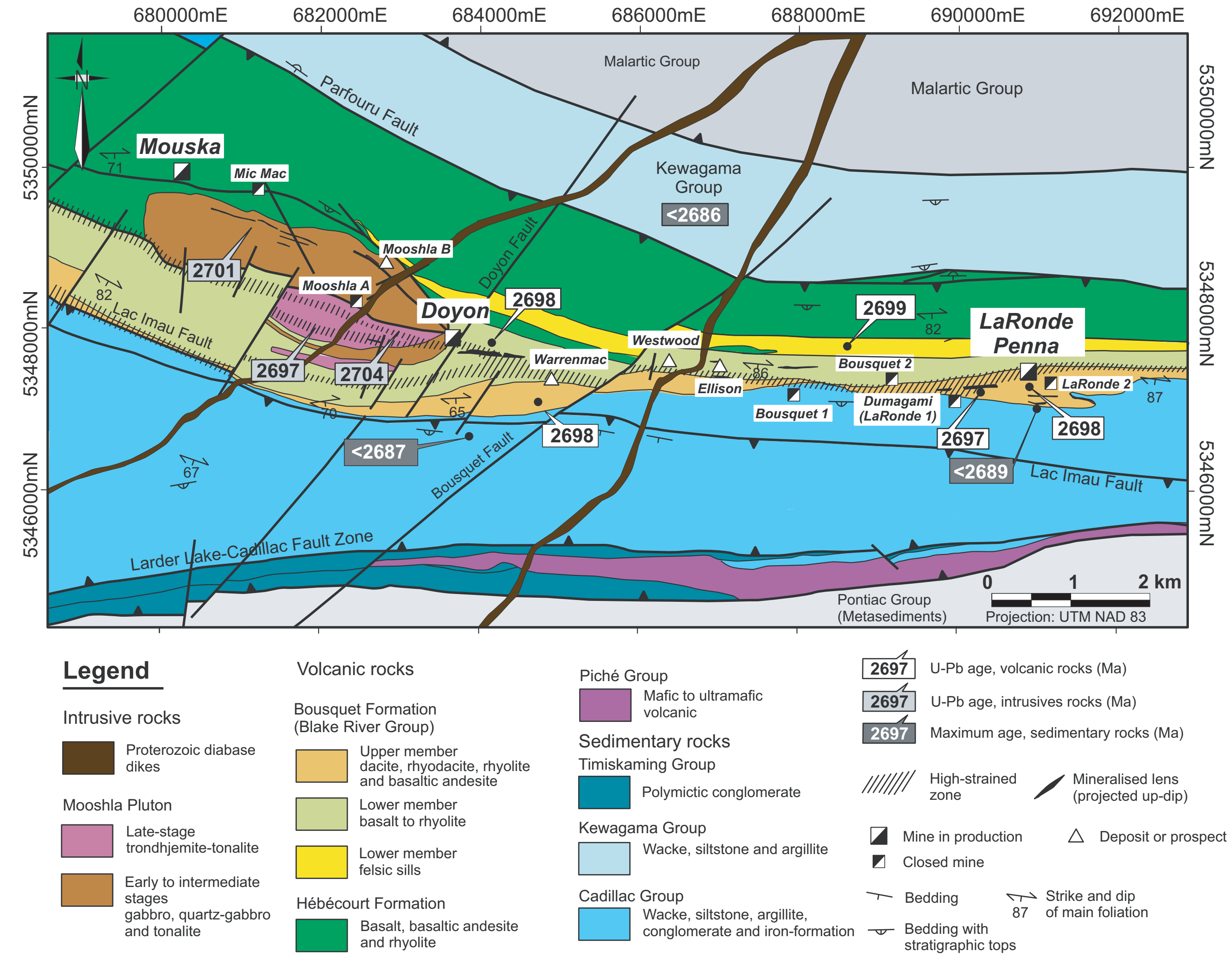


Figure 30. Simplified geology of the Doyon-Bousquet-LaRonde camp with the location of the main volcanogenic massive sulphide deposits and the Cu-Au vein systems related to the Mooshla synvolcanic pluton. Modified from Lafrance et al. (2003).

Geological setting of the LaRonde Penna deposit

The ore zones at LaRonde Penna are stacked from north (base) to south (top) within the Bousquet Formation (Fig. 30). The DBL camp stratigraphy has been defined in detail in Lafrance et al. (2003) and in Mercier-Langevin et al. (2007a, c, d) and is only briefly summarized here. The stratigraphy of the LaRonde Penna deposit is described in detail in Mercier-Langevin (2005) and Mercier-Langevin et al. (2007a, b).

The base of the stratigraphy is composed of massive to pillowed mafic tholeiitic volcanic rocks part of the Hébécourt Formation. The Hébécourt Formation is overlain by the Bousquet Formation (Lafrance et al., 2003), both being arranged in a southward-younging homoclinal sequence, with nearly vertical dips (Lafrance et al., 2003). Younger sedimentary rocks are found to the north (Kewagama Group; <2686 Ma; Davis, 2002) and to the south (Cadillac Group; <2689 Ma in the LaRonde Penna mine area: Mercier-Langevin et al., 2007a).

The Bousquet Formation is divided in a lower member and an upper member (Lafrance et al., 2003; Mercier-Langevin et al., 2007a). The 200 to 600 m-thick lower member of the Bousquet Formation is dominated by mafic to intermediate and tholeiitic to transitional rocks. It includes an 80 to 300 m-thick package dominated by volcaniclastic rocks at its base (Lafrance et al., 2003) and known as the Bousquet scoriaceous tuff units (Mercier-Langevin et al., 2008). The volcaniclastic rocks, ranging in grain size from tuff to tuff breccia, are basaltic to andesitic (rarely dacitic to rhyolitic) in composition and have a tholeiitic to transitional magmatic affinity (Lafrance et al., 2003; Mercier-Langevin et al., 2008). The Bousquet scoriaceous tuff units are overlain to the west by massive to fragmental felsic volcanic rocks of tholeiitic to transitional magmatic affinity (Lafrance et al., 2003). The upper part of the lower member of the Bousquet Formation consists of a succession of massive to pillowed, mafic to intermediate and tholeiitic to transitional flows (Fig. 30).

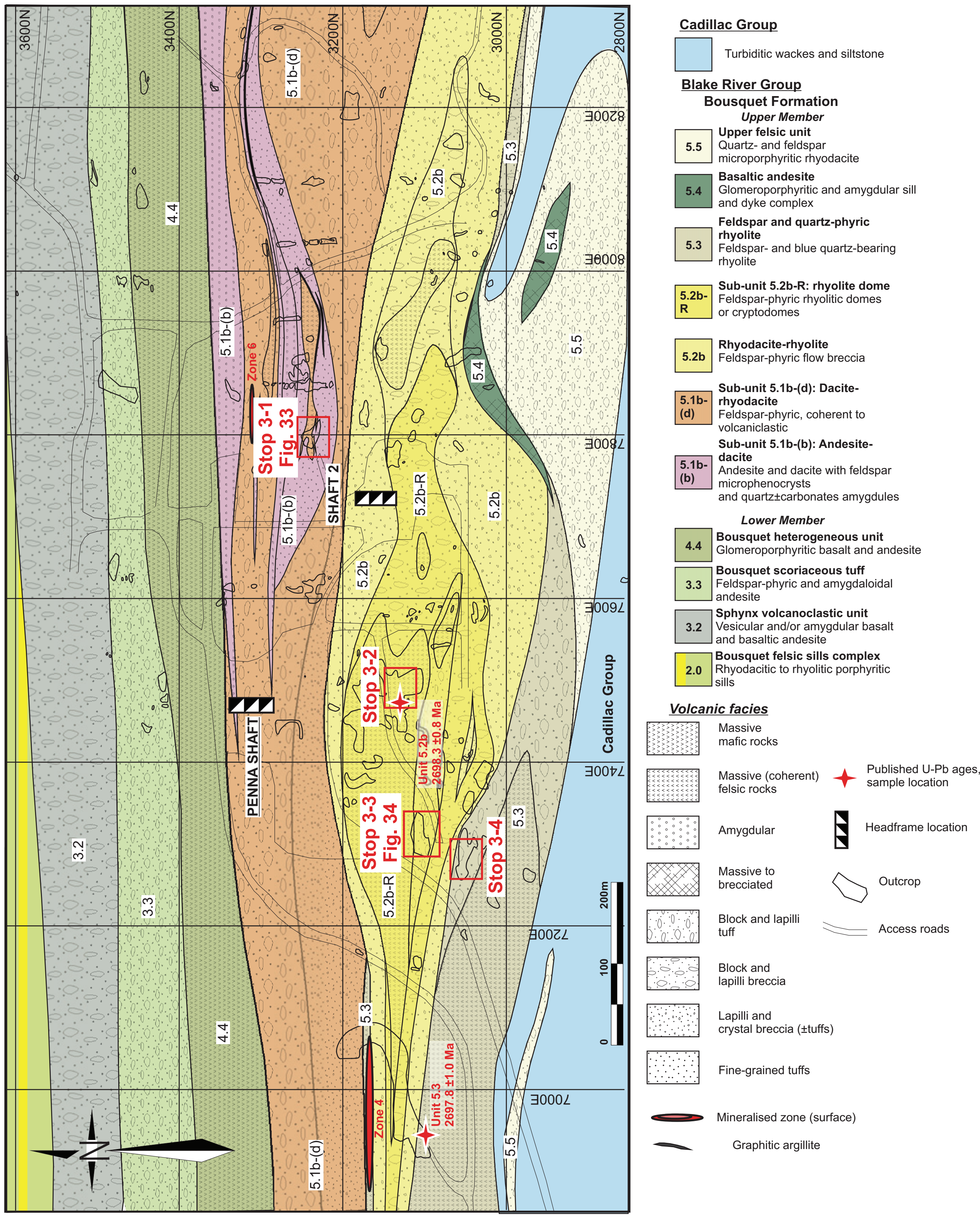


Figure 31. Distribution of the main units and subunits exposed on surface in the LaRonde Penna mine area. The location of the field stops are indicated. The main volcanic facies are also shown. The nomenclature used here refers to the size and relative abundance of fragments and do not refers to modes of emplacement. Fp=feldspar, Qz=quartz. Modified from Mercier-Langevin and Dubé (2010).

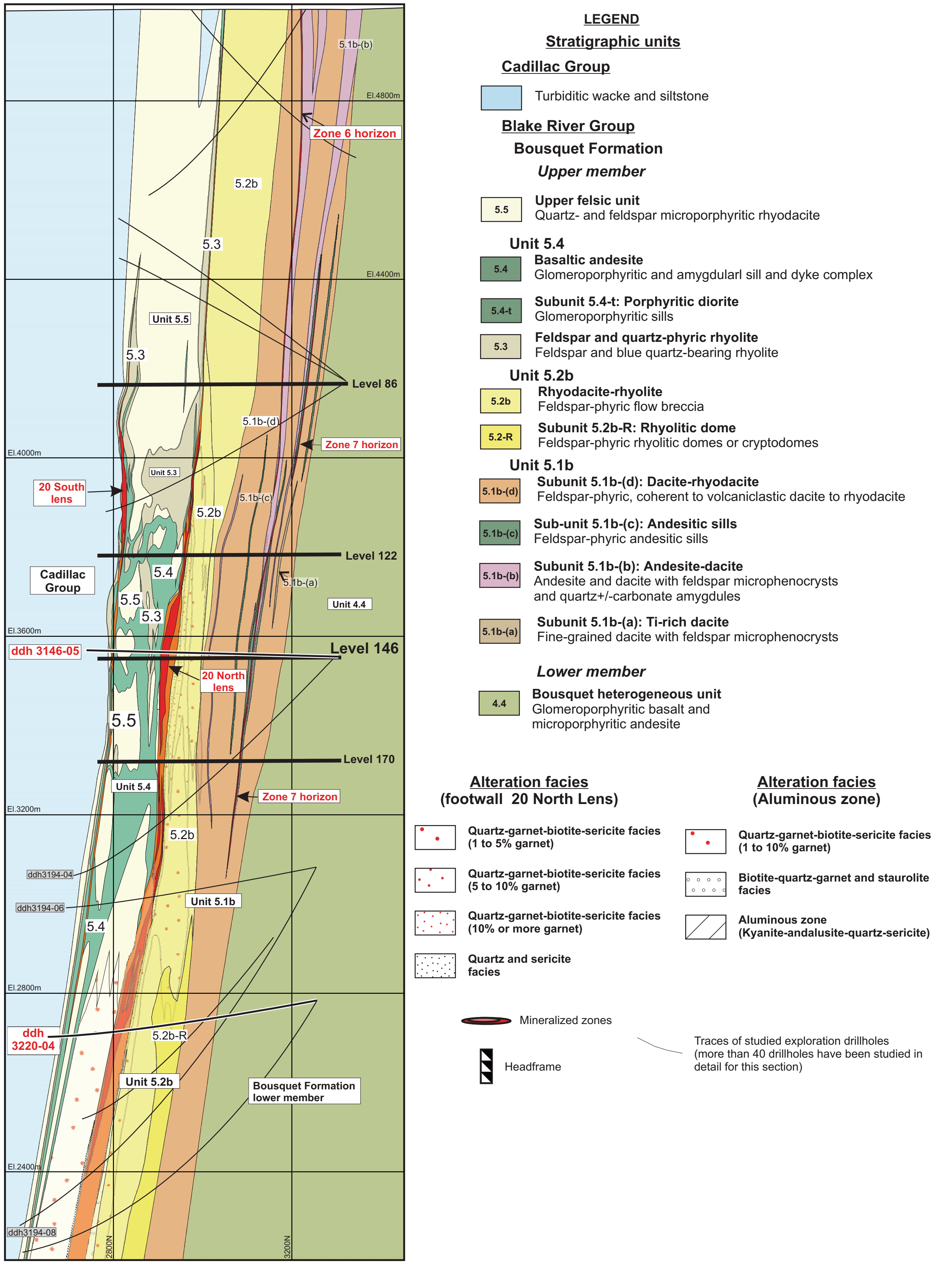


Figure 32. Distribution of the main units and subunits hosting the LaRonde Penna deposit ore lenses in section from surface (elevation 5000m) to a depth of 3200 metres (elevation 1800m). The drill holes (ddh 3146-05 and ddh 3220-04) observed during the field trip are located. Modified from Mercier-Langevin and Dubé (2010).

The upper member of the Bousquet Formation is dominated by transitional to felsic volcanic and shallow intrusive rocks of transitional to calc-alkaline magmatic affinity (Lafrance et al., 2003; Mercier-Langevin et al., 2007a, b) forming flows, lobes, flow-breccia deposits and sill complexes.

The LaRonde Penna mine ore lenses are hosted in the volcanic units of the Bousquet Formation upper member (Figs. 30, 31 and 32). Based on lithogeochemistry, mineralogy and facies, five different volcanic units were identified in the upper member of the Bousquet Formation at the LaRonde Penna mine. These are from the base to the top: Unit 5.1b (dacite-rhyodacite), Unit 5.2b (rhyodacite-rhyolite), Unit 5.3 (feldspar and quartz-phyric rhyolite), Unit 5.4 (basaltic andesite) and Unit 5.5 (upper felsic unit). Subunits were defined to better characterize the host sequence at LaRonde Penna (Mercier-Langevin et al., 2007a, b). Four informal subunits have been recognized in unit 5.1b and one subunit is present within unit 5.2b. The subunit present in unit 5.2b (called 5.2b-R) is forming a rhyolite cryptodome intruding the unit 5.2b flow-breccia deposits (see below). Most of these units will be seen during the visit and they are described in the following sections .

Stop 3-1: Unit 5.1b felsic lobes (subunit 5.1b-d) and andesitic volcaniclastics (subunit 5.1b-b), Zone 6 host sequence and setting, 20 North lens footwall

Coordinates

UTM nad 83, zone 17, 691 170 m E, 5 347 420 m N

Stop description

The lowermost part of the Bousquet Formation is exposed in this area of the LaRonde property (Fig. 31). This outcrop shows lobate dacitic to rhyodacitic flows intruding altered, unconsolidated andesitic volcaniclastic rocks (Fig. 33). This marks the beginning of the felsic-dominated volcanism of the Bousquet Formation upper member. This stratigraphic interval hosts the Zone 6 VMS at LaRonde, which is the lowermost mineralized lens in this area. The growth of felsic lobes and domes is intimately associated with the formation of the Zone 6 Au-rich VMS lens. Talus breccia deposits carrying abundant Au-rich massive sulphide clasts stripped from the Zone 6 lens illustrate the concomitant volcanism and hydrothermalism. The presence of Au-rich massive sulphide clasts illustrates the Au-rich nature of the volcanogenic massive sulphide system active in the LaRonde Penna area.

Stop 3-2 and 3-3: Subunit 5.2b-R dome/cryptodome, 20 North lens footwall, coherent facies (Stop 3-2) and lobate and brecciated facies (Stop 3-3)

Coordinates

Stop 3-2: UTM nad 83, zone 17, 690 838 m E, 5 347 283 m N

Stop 3-3: UTM nad 83, zone 17, 690 700 m E, 5 347 270 m N

Stop description

These two field stops allow for the observation of the volcanic architecture of a rhyolite dome in section (subunit 5.2b-R). This rhyolite dome was emplaced in the footwall of the 20 North lens, which is the principal orebody (80%) at LaRonde Penna (see below for a description). Stops 3-2 and 3-3 are located just south of the LaRonde Penna mine headframe, a few hundred metres apart (Fig. 31). A number of well-preserved volcanic facies are exposed in this area and help better understand the immediate depositional environment of the deposit.

Footwall rhyodacite-rhyolite - Unit 5.2b and subunit 5.2b-R: The 5.2b-R subunit was emplaced as a rhyolite dome/cryptodome (75% SiO_2, 0.4% TiO_2 and about 200 ppm Zr; Mercier-Langevin et al., 2007a, b) into the flow-breccia deposits of unit 5.2b (70% SiO_2, 0.65% TiO_2 and 180 ppm Zr; Mercier-Langevin et al., 2007b) that forms the footwall to the 20 North lens at depth. A U-Pb age of 2698.3 ±0.8 Ma was obtained from a sample taken on surface (Stop 3-2) in the coherent part of the dome/cryptodome (Mercier-Langevin et al., 2007a). The unit 5.2b thickness is about 230m at surface and does not vary much at depth (Figs. 31 and 32). The contact between unit 5.2b and underlying unit 5.1b is slighly irregular, possibly reflecting paleo-topography on top of unit 5.1b. At depth, the unit 5.2b volcaniclastic deposits host the footwall alteration and the ore zone associated with the 20 North lens (Fig. 32). The 20 North lens was also formed, at least in part, by sub-seafloor replacement of the unit 5.2b uppermost part (Dubé et al., 2007b; Mercier-Langevin et al., 2007d).

Many volcanic textures and facies typical of subaqueous domes and cryptodomes are present in the rhyolite dome/cryptodome of subunit 5.2b-R. Outcrop PL-2000-029 (Stop 3-2) shows coherent and flow-banded, feldspar-phyric rhyolites of the upper part of the massive dome. Outcrop PL-2000-025 (Stop 3-3; Fig. 34), located west of

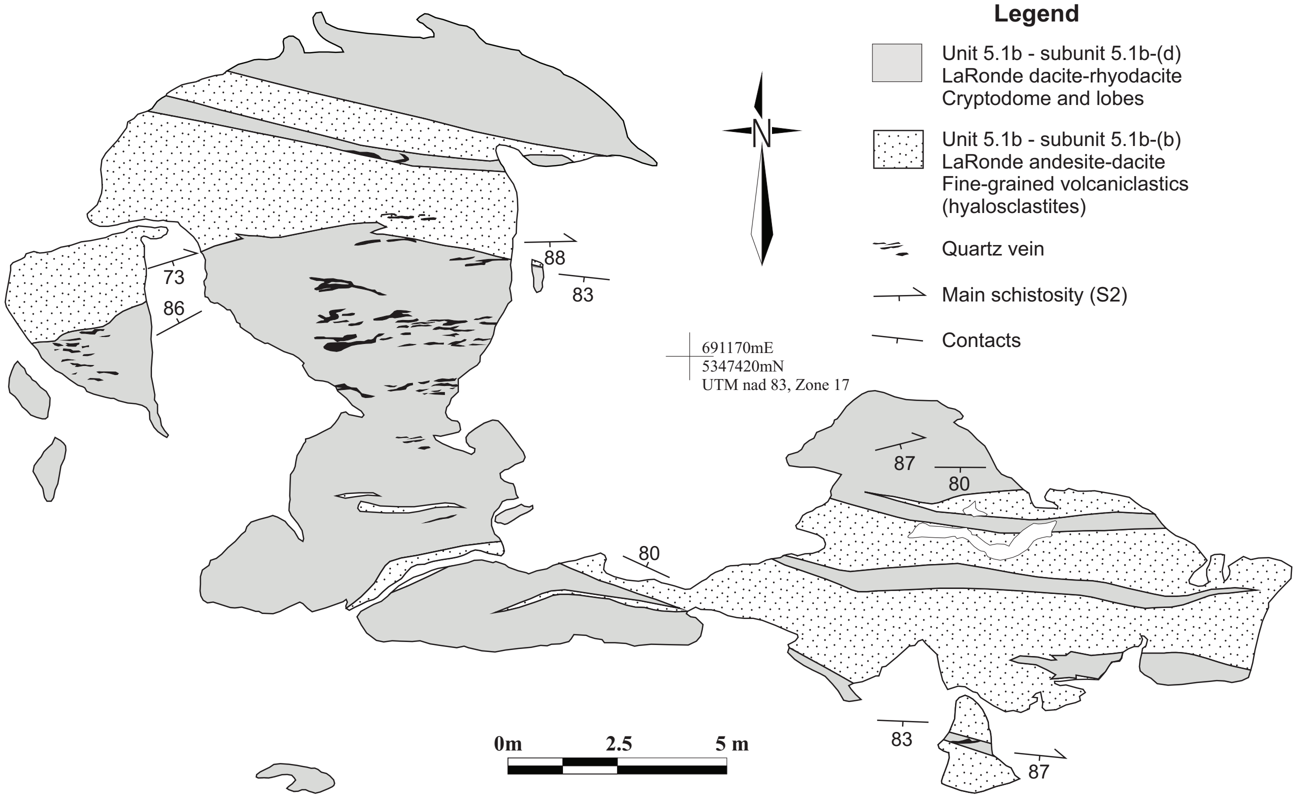


Figure 33. Volcanic facies associated with the subunits 5.1b-d (felsic lobes and cryptodomes) and 5.1b-b (andesitic volcaniclastic rocks). Modified from Mercier-Langevin (2005) and from Mercier-Langevin and Dubé (2010).

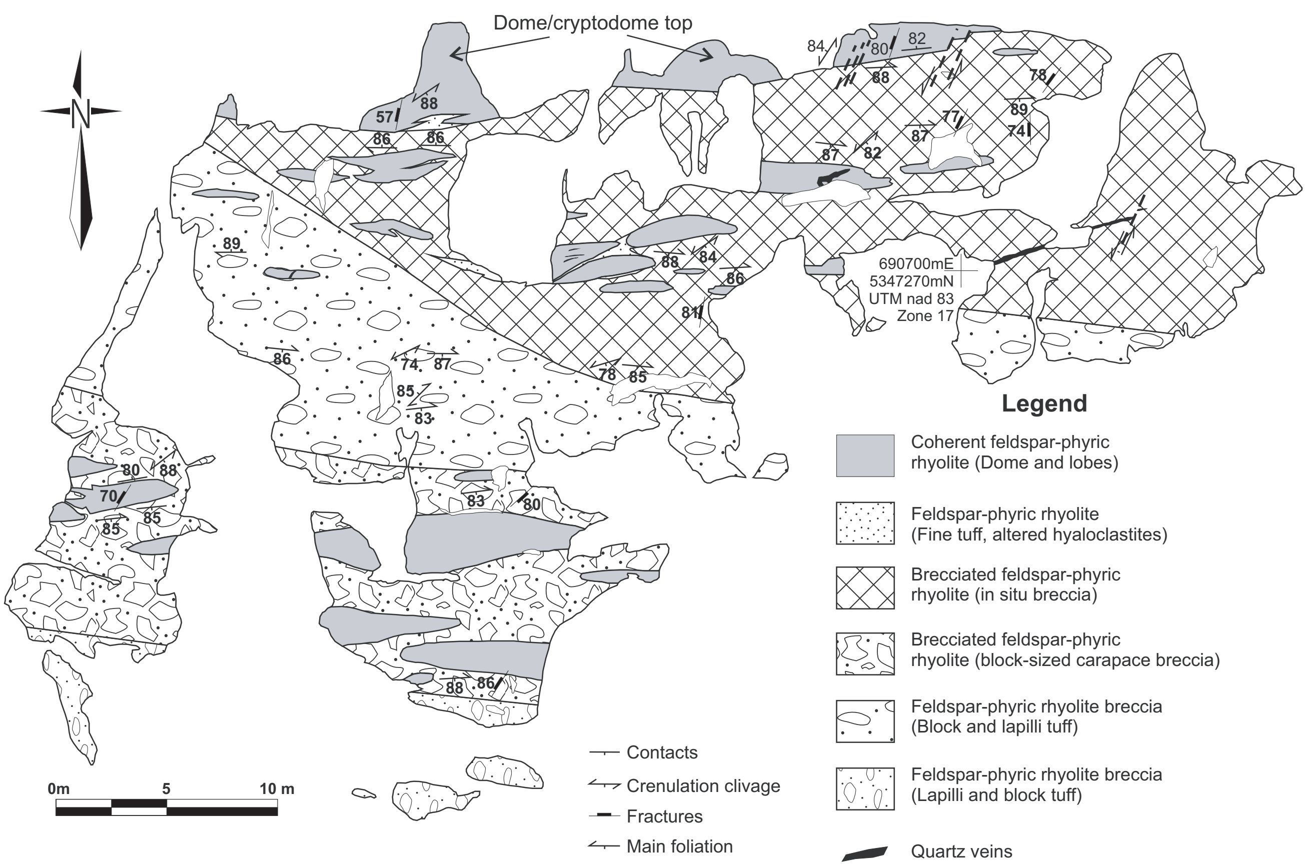


Figure 34. Volcanic facies associated with the rhyolite dome/cryptodome of subunit 5.2b-R. Fp=feldspar. Modified from Mercier-Langevin (2005) and from Mercier-Langevin and Dubé (2010).

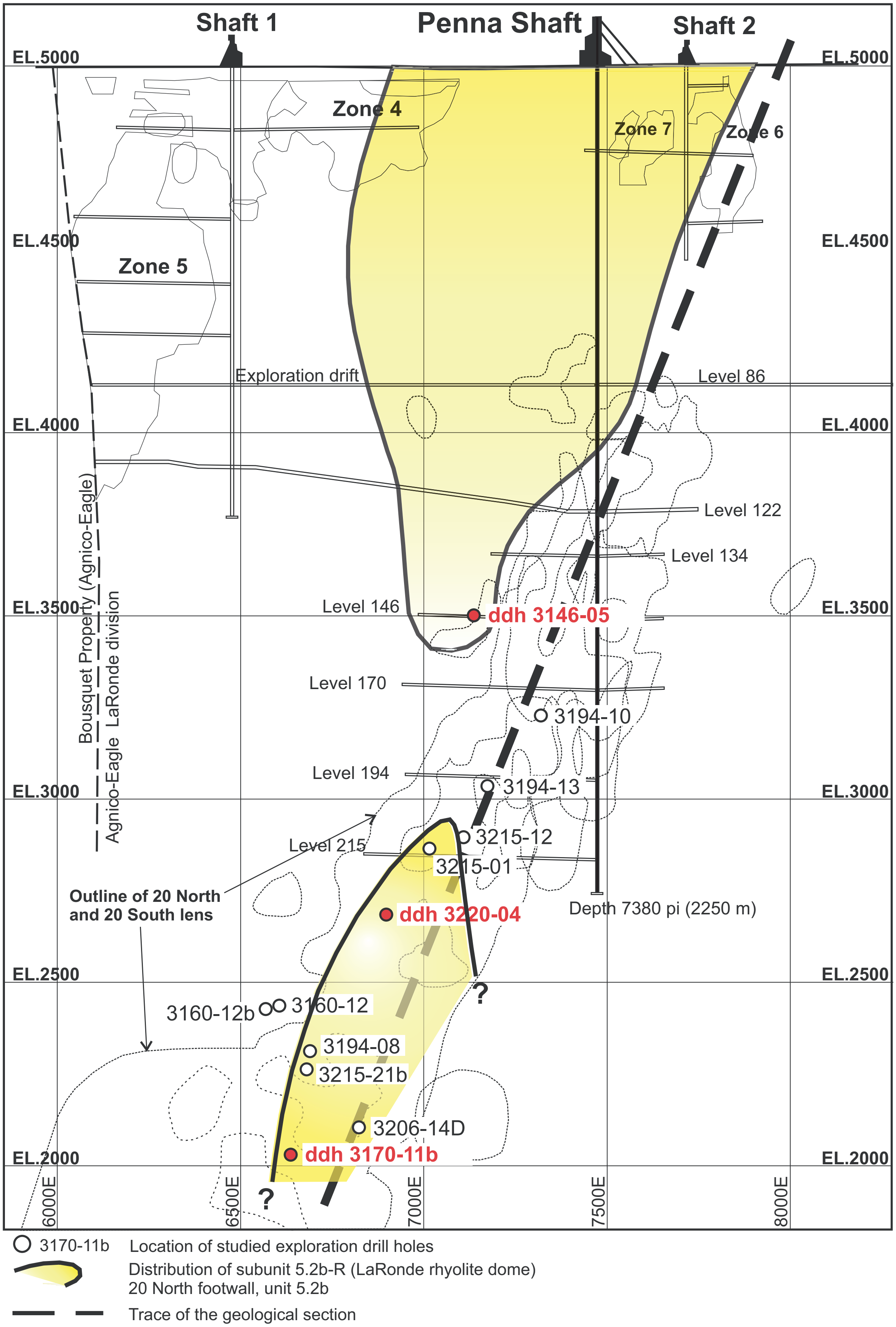


Figure 35. Distribution of the two domes/cryptodomes of sub-unit 5.2b-R observed in longitudinal section. Piercing points of drill holes 3146-05, 3220-04 and 3170-11b are shown in red. From Mercier-Langevin (2005) and Mercier-Langevin et al. (2007a).

Stop 3-2, shows a carapace breccia cut by flow-banded lobes and overlain by a flow breccia. Perlitic fractures are locally present in some breccia fragments.

The composite longitudinal view of the LaRonde Penna deposit on Figure 35 shows the trace of the ore lenses and the distribution at depth of the subunit 5.2b-R dome/cryptodome seen on surface. A large part of this dome has been eroded. A second dome has partially been traced at greater depth (Fig. 35). This second dome is at the same stratigraphic position than the one seen at surface and it has the same geochemical signature. It has been mapped using drill holes and lithogeochemistry as intense hydrothermal alteration in this part of the deposit precluded preservation of primary textures.

The volcanic facies that characterize the subunit 5.2b-R domes/cryptodomes are typical of rhyolite flow-dome complexes (e.g., Gibson et al., 1999) rather than pyroclastic deposits. This implies that the LaRonde Penna deposit was formed close to a felsic volcanic vent, in a « proximal » environment, likely characterized by the presence of synvolcanic faults that may have helped hydrothermal fluid upflow .

Stop 3-4: Unit 5.3 feldspar and quartz-phyric rhyolite (hangingwall cryptodome)

Coordinates

UTM nad 83, zone 17, 690 675 m E, 5 347 220 m N

Stop description

The unit 5.3 (feldspar- and quartz-phyric rhyolite) that forms part of the 20 North lens hanging wall (Fig. 32) are exposed on surface west of the LaRonde Penna mine headframe (Fig. 31). This unit thickens west of LaRonde Penna and hosts part of the mineralization at Bousquet 2-Dumagami. This unit is a key marker in the camp and is also present in the hanging wall of the Westwood deposit, 5 km west of LaRonde Penna (Fig. 29). Unique petrographic and geochemical features differentiate this unit from the other units of the Bousquet Formation, including blue-quartz phenocrysts, very high SiO_2 and low TiO_2 contents.

Drill core observations – hydrothermal alterations and mineralization

These “stops” will allow for the observation of the main alteration and mineralization assemblages associated with the 20 North and 20 South lenses in the upper and lower levels of the mine along two drill holes that cut most of the upper member of the Bousquet Formation (see Figs. 32, 35 and 36 for location). As described by Dubé et al. (2007b) and Mercier-Langevin et al. (2007d), there is a major zonation in the alteration and ore styles at LaRonde Penna. In the upper part of the mine, the 20 North lens comprises a transposed pyrite-chalcopyrite (Au-Cu) stockwork (20N Au zone) overlain by a pyrite-sphalerite-galena-chalcopyrite-pyrrhotite (Zn-Ag-Pb) massive sulphide lens (20N Zn zone). As previously mentioned, the later was formed, at least in part, by replacement of footwall rhyodacitic autoclastic deposits of unit 5.2b. The 20 North lens (20N Au and 20N Zn zones) are underlain by a large, semi-conformable alteration zone that comprises a proximal quartz-Mn-garnet-biotite-sericite alteration assemblage (“low-sulphidation style alteration”). The 20N Zn zone tapers with depth in the mine and gives way to the 20N Au zone. At depth in the mine, the 20N Au zone consists of semimassive sulphides (Au-rich pyrite and chalcopyrite) enclosed by a large aluminous alteration (“high-sulphidation style alteration”) halo on the margin of a large rhyolitic dome or cryptodome. The synvolcanic hydrothermal alteration now corresponds to mappable upper greenschist-lower amphibolite grade metamorphic assemblages (Dubé et al., 2007b).

ddh 3146-05 – Upper levels of the mine

Zones 6 and 7 horizons at depth: The ddh 3146-05 cuts the Zones 6 and 7 horizons, which are only weakly mineralized in this part of the deposit. There is however a significant alteration envelope associated with the sulphides. Felsic and mafic rocks of the lowermost part of the Bousquet Formation upper member are strongly sericitized in this section.

Proximal footwall alteration: This segment of drill core will show the quartz-Mn-garnet-biotite-sericite alteration assemblage typical of the 20 North lens footwall in the upper levels of the mine. The size and abundance of Mn-garnet gradually increase towards the 20 North lens, illustrating the intensification of the K and Mn alteration towards the ore zone.

Immediate footwall alteration: A thin (< 10m-wide) zone of intense quartz-sericite alteration is present in the immediate footwall of the 20N Au zone, especially in the eastern part of the lens (see Fig. 36). Small amounts of disseminated pyrite are often associated with this intensely leached zone that is commonly strongly foliated.

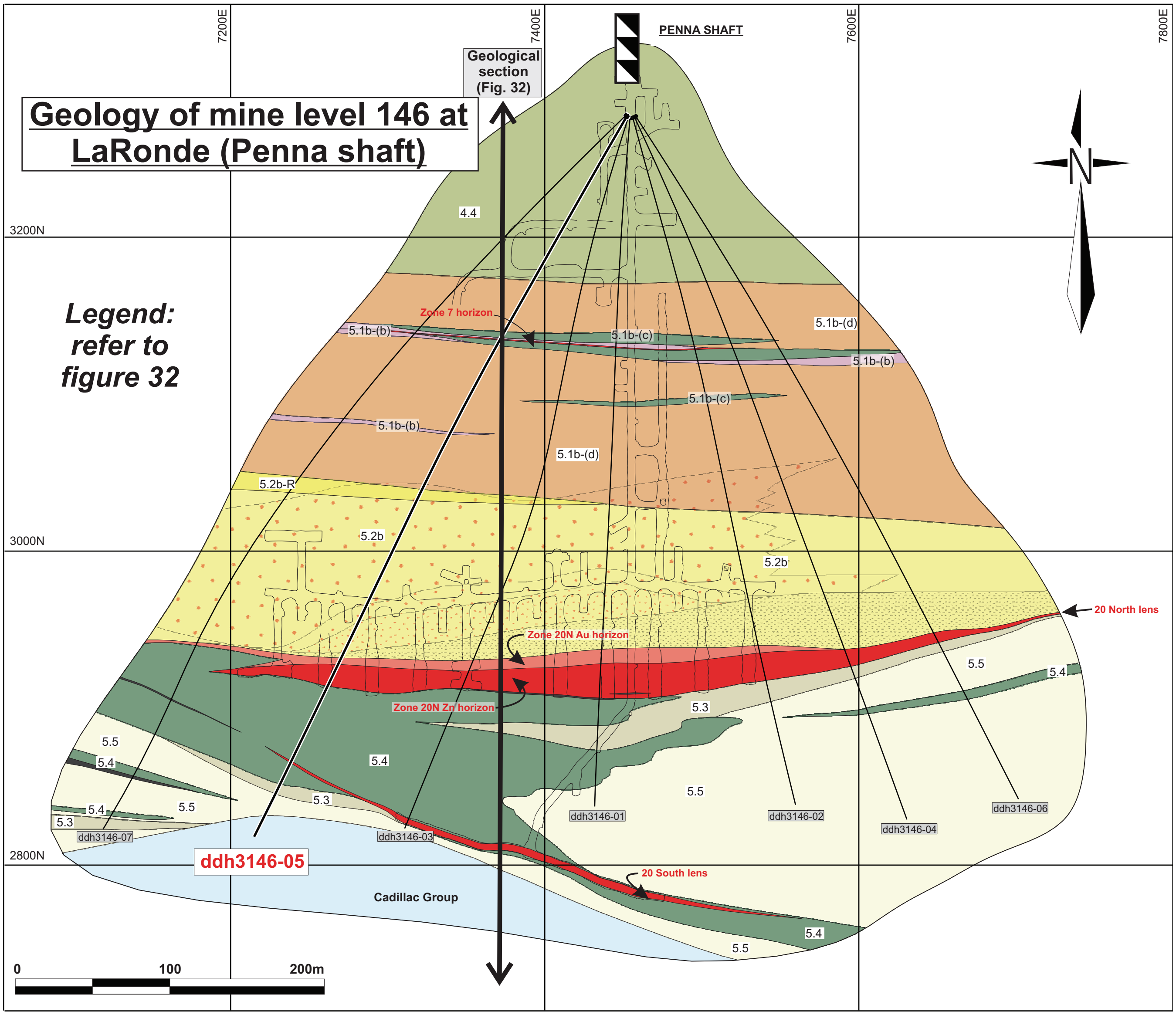


Figure 36. Distribution of principal geological units and subunits observed at mine level 146 (depth of 1460 metres) at the LaRonde Penna mine and location of drill hole 3146-05. This map was compiled from underground drift and stope mapping and from the observation and sampling of horizontal drill holes combined with the compilation of exploration and production data from Agnico-Eagle mines Ltd. Modified from Agnico-Eagle mines Ltd. and from Mercier-Langevin (2005) and Dubé et al. (2007b).

20 North lens – 20N Au zone: The 20N Au reported values of 3.3 g/t Au, 80 g/t Ag, 0.66% Cu and 1.27% Zn over 11.4 m in ddh 3146-05. The mineralization consists of 30 to 70% granoblastic pyrite with trace amounts of chalcopyrite and sphalerite. The sulphides are disseminated, in small accumulations or in irregular veinlets that are generally transposed and boudinaged into the main foliation. The sulphides are hosted in strongly sericitized felsic volcaniclastic rocks of unit 5.2b (Fig. 37).

20 North lens – 20N Zn zone: The 20N Zn zone is well mineralized in this part of the deposit (0.9 g/t Au, 121.4 g/t Ag, 0.08% Cu and 10.4% Zn over 16.4m). The 20N Zn zone sits directly on top of the 20N Au zone. It consists of massive (75-100%) pyrite-sphalerite sulphides with traces of galena and siliceous clasts of gangue material. Pyrite is abundant and granoblastic whereas sphalerite is less abundant and forms a matrix to pyrite. The banding seen in the massive sulphides is due to the main stage of deformation.

Hanging wall geology and alteration: Three main units are present in the 20 North lens hanging wall (Fig. 37), which is also the 20 South lens footwall, the 20 South lens being located higher in the stratigraphy than the 20 North lens (see Figs. 32 and 36). These units are: the Feldspar and quartz-phyric rhyolite (unit 5.3), the Basaltic andesite (unit 5.4) and the Upper felsic unit (unit 5.5). Their characteristics are discussed in detail in Mercier-Langevin et al. (2007b) and are only briefly presented here.

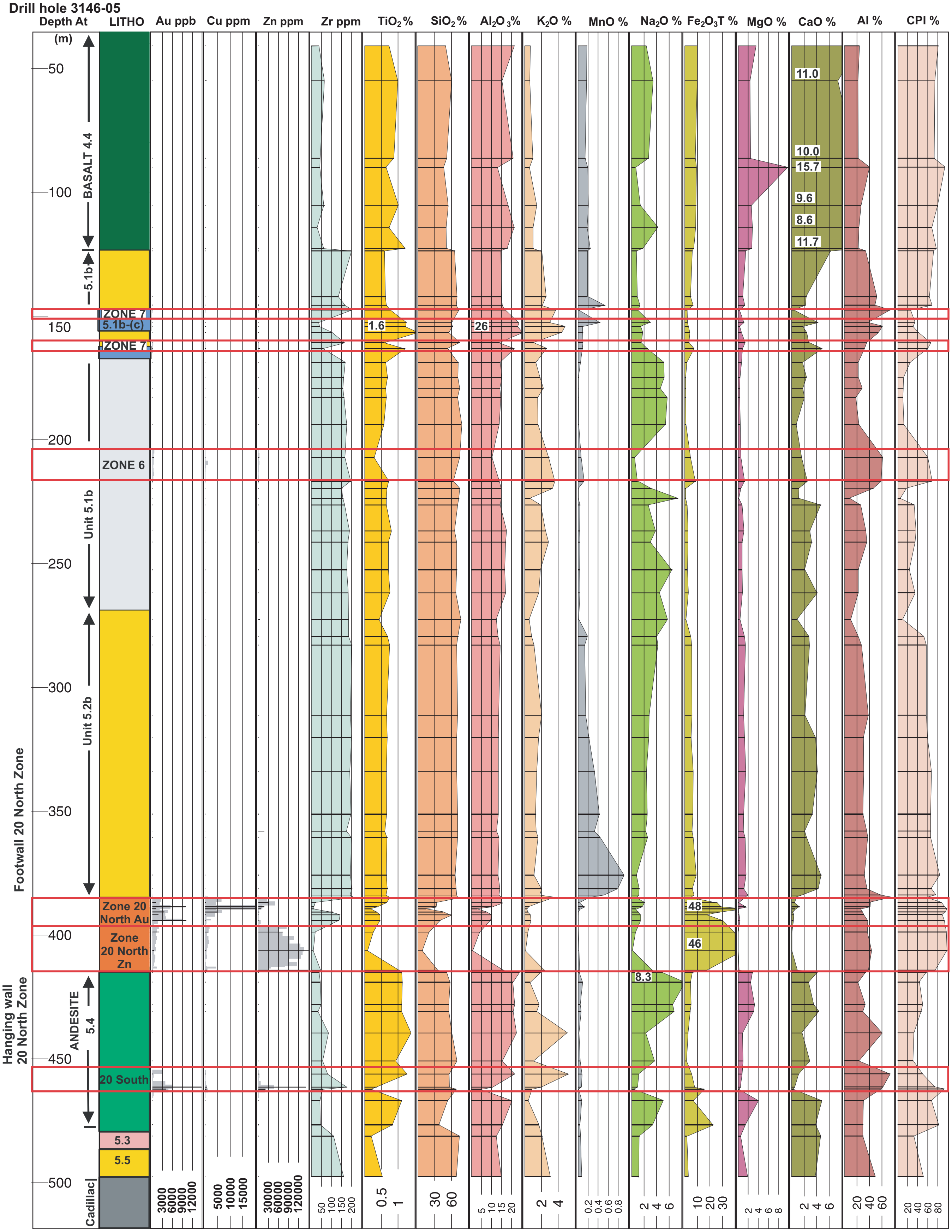


Figure 37. Geochemical profile of drill hole 3146-05 showing the compositional variations related with the hydrothermal alteration in the 20 North lens footwall at intermediate depth in the mine. From Dubé et al. (2007b).

Feldspar and quartz-phyric rhyolite (unit 5.3): This calc-alkaline unit emplaced on top of unit 5.2b and is mostly restricted to the immediate LaRonde Penna and Bousquet 2 – Dumagami deposit area (Mercier-Langevin et al., 2007a, b). At LaRonde Penna, it comprises a part of the 20 North lens stratigraphic hanging wall and a part of the 20 South lens stratigraphic footwall (Figs. 32 and 36). Locally, it is intercalated with the upper felsic unit (unit 5.5). It locally contains fragments of the underlying unit 5.2b and fragments of the host unit 5.5. The feldspar- and quartz-phyric rhyolite has an irregular distribution and it is largely hosted by the upper felsic unit (5.5), suggesting that it was, at least in part, emplaced as an intrusive body (cryptodome) associated with compositionally similar sills and dykes centered in the LaRonde Penna mine area (Mercier-Langevin et al., 2007a). This unit was sampled for U-Pb geochronology and yielded a crystallization age of 2697.8 ±1 Ma (Mercier-Langevin et al., 2007a).

Basaltic andesite (unit 5.4): This unit forms an important part of the 20 North lens hanging wall and hosts part of the 20 South lens (Fig. 36). Its geochemistry is distinct from the other units of the upper member of the Bousquet Formation (57% SiO_2, 1.1 TiO_2 and 50 ppm Zr; Mercier-Langevin et al., 2007b). It comprises a massive sill-dyke complex and a few narrow glomeroporphyritic sills that are only very locally developed. The sill and dyke complex is characterized by a major feldspar-phyric facies and by a fine-grained amygdaloidal facies that defines the uppermost part of the unit. The basaltic andesite is thicker at depth in the mine and is spatially related to the ore lenses (20 North and 20 South), especially in the upper levels. It cuts through the feldspar and quartz-phyric rhyolite (unit 5.3) and the upper felsic unit (unit 5.5) as shown on figures 32 and 36. The contacts between the basaltic andesite and the felsic rocks are sharp and the basaltic andesite locally contains small felsic fragments. In the deeper parts of the mine, it is present only in the footwall of the 20 South lens. The complex distribution, crosscutting relationship with enclosing felsic rocks, and the textures of this unit confirm an intrusive origin (Mercier-Langevin et al., 2007a). It is mostly discordant to, and entirely enclosed within, the upper felsic unit (unit 5.5). The concentration of amygdules in the fine-grained matrix in the uppermost part of the complex is interpreted to reflect segregation of volatiles and the formation of a chilled margin on top of the shallow intrusive complex, as it is commonly the case in hypabyssal sills.

Upper felsic unit (unit 5.5): This unit comprises rhyodacitic to rhyolitic volcanic rocks. Its composition is similar to that of units 5.1b, 5.2b and 5.3. It consists of thick deposits of fine- to coarse-grained autoclastic material associated with small lobes and thin intervals of crystal tuffs. The upper felsic unit is similar to the rhyodacite-rhyolite flow-breccia deposits of unit 5.2. In outcrop, some isolated fragments of feldspar and quartz-phyric rhyolite (unit 5.3) are locally present within the upper felsic unit.

<u>20 North lens hanging wall alteration:</u> The unit 5.4 basaltic andesite forms the hanging wall of the 20 North lens in ddh 3146-05 (Figs. 36 and 37) and commonly hosts a discordant alteration zone (Dubé et al., 2007b). This hanging wall alteration is concentrated along zones of intense brittle fracturing in the immediate hanging wall of the basaltic andesite where veins and veinlets (now strongly transposed in the main foliation) of pyrrhotite and pyrite are formed in association with an assemblage of pinkish quartz-biotite-titanite-albite alteration of varying intensity (Dubé et al., 2007b). It commonly gradually decreases in intensity higher in the stratigraphy up to the 20 South lens footwall where it gets more intensely developed again.

<u>20 South lens footwall geology and alteration:</u> This segment of ddh 3146-05 shows the fine-grained and amygdular facies of the basaltic andesite (unit 5.4) close to the 20 South lens in the upper part of the upper member of the Bousquet Formation. The 20 South lens footwall alteration developed within unit 5.4 and is similar to the 20 North lens hangingwall alteration, except for the common occurrence of green micas (Cr-phengite; Dubé et al., 2007b).

<u>20 South lens:</u> The 20 South lens consists of massive sulphides in the upper levels of the mine that gradually become semimassive (transposed veins, veinlets and disseminations) at depth in the mine. On level 146 (1460m depth; Fig. 36), it consists of highly transposed veins and veinlets of massive pyrite with minor amounts of sphalerite, pyrrhotite and chalcopyrite (4.83 g/t Au, 27 g/t Ag, 0.07% Cu and 2.4% Zn over 4.5m). The sulphides are hosted in a strongly sericitized and schistose part of unit 5.4 basaltic andesite. This part of the 20 South lens was probably formed by replacement as discordant stringers zones now transposed by the main foliation. However, the 20 South lens was also formed on the seafloor as evidenced by the presence of argillites within the massive sulphides in the uppermost levels of the mine (Mercier-Langevin et al., 2007a).

<u>20 South lens hanging wall alteration:</u> The alteration in the hanging wall of the 20 South lens in ddh 3146-05 is similar to the alteration seen in the hanging wall of the 20 North lens in many places where the basaltic andesite is present. It consists of a dense pyrrhotite-pyrite vein stockwork associated with the pinkish quartz-biotite-titanite-rutile-albite alteration assemblage described previously. Green micas are locally as well.

20 South lens hanging wall geology: This section will allow for the observation of the two felsic units (unit 5.3 and unit 5.5) present in the hanging wall of the 20 North lens as well as in the footwall and hanging wall of the 20 South lens (see Figs. 32 and 36). Both these units have been briefly described above. In ddh 3146-05, the units 5.3 (feldspar and quartz-phyric rhyolite) and 5.5 (upper felsic unit) are slightly to moderately sericitized. The feldspar and quartz-phyric rhyolite is relatively easy to recognize due to the presence of 5-10 vol.%, 1-2mm blue quartz phenocrysts.

Contact between the Bousquet Formation and the sedimentary rocks of the Cadillac Group: The final section of ddh 3146-05 (Fig. 37) shows the contact between the volcanic rocks of the Bousquet Formation and the sedimentary rocks (greywackes) of the Cadillac Group. The Cadillac Group consists of a turbiditic sequence younger than 2687 Ma (Davis, 2002, and references therein). The greywackes of the Cadillac Group have been dated by U-Pb geochronology at <2689 Ma at LaRonde Penna (Mercier-Langevin et al., 2007a). This age, and the age of the underlying volcanic rocks of the Bousquet Formation indicate that there is a ~8-10 m.y. gap between the youngest volcanic event and the oldest sedimentary rocks. The contact between the volcanic and sedimentary rocks is not exposed at surface in the LaRonde Penna mine area but it has been intersected in many drill holes (e.g., ddh 3146-05). Regionally this contact has been interpreted both as a major deformation corridor (Dumagami Fault of Tourigny et al., 1988, 1989, 1993; Marquis et al., 1990) and as a conformable contact (Valliant and Hutchinson, 1982; Stone, 1990). In the LaRonde Penna mine area, the contact is slightly discordant (i.e., erosional) to subconcordant as illustrated in section (Fig. 32) and in plan view (Fig. 36). A thin horizon (<20 cm) of semimassive to massive pyrrhotite and pyrite is commonly present at or near the contact between the volcanic and sedimentary rocks. This sulphide-rich interval at, or close to, the contact between the BRG volcanic sequence and the Cadillac Group sedimentary rocks may result from the interaction between late hydrothermal fluids and seawater during a period of non-deposition (Dubé et al., 2004; 2007b; Lafrance et al., 2005; Mercier-Langevin et al., 2004; 2007a; Mercier-Langevin, 2005). The exact nature of this sulphide-bearing horizon is still under investigation.

ddh 3220-04 – Lower levels of the mine (aluminous alteration)

Parts of ddh 3220-04 will be laid out to allow for the observation of the aluminous alteration assemblage associated with the 20 North lens at LaRonde Penna in the lower levels of the mine, and for a comparison with the observations made in ddh 3146-05 that cuts the ore and its alteration zones higher in the mine. The aluminous alteration at LaRonde Penna has been described in Dubé et al. (2007b). The drill hole 3220-04 shows very good examples of the aluminous assemblages and the zonations towards the ore.

Distal footwall alteration: The first exposed segment of drill core shows the distal footwall alteration to the 20 North lens at depth in the mine. The quartz-Mn-garnet-biotite-sericite assemblage is dominant in this part of the stratigraphy and is developed in the unit 5.2b rhyodacite-rhyolite (Fig. 38).

Intermediate to proximal footwall alteration: The proximal alteration in ddh 3220-04 consists of an assemblage of quartz-staurolite-muscovite-Mn-garnet-biotite present in the footwall of the 20 North lens. The staurolite is fractured-controlled and becomes more common and abundant whereas the Mn-garnet is gradually disappearing.

Immediate footwall alteration: The immediate footwall alteration assemblage consists of varying amounts of quartz, muscovite, pyrite, paragonite and aluminosilicates (prograde andalusite and kyanite and retrograde pyrophyllite). Pyrite is granoblastic, disseminated or in bands and veins. Despite the presence of significant amounts of sulphides, the background gold values are only very weakly anomalous.

20 North lens at depth in the mine: This section of ddh 3220-04 shows the ore zone (20 North lens at depth in the mine). The mineralization is mostly made of transposed stringers and semimassive to locally massive, recristallized pyrite with minor amounts of interstitial chalcopyrite. The gangue is composed of abundant andalusite and kyanite porphyroblasts with varying amounts of quartz and sericite±paragonite. Two mineralized corridors were intersected in ddh 3220-04: 709.1 to 715.9m – 6.6 g/t Au over 6.8m, and 718.9 to 732.8m – 6.3 g/t Au over 13.9m. These two mineralized intervals are separated by a thin, low grade zone (<1 g/t Au) that is strongly altered.

20 North lens at depth in the mine – 20N Zn zone: The 20N Zn zone that was very well developed in the upper levels of the mine gradually tapers with depth in the mine. This segment shows what remains of this zone at depth. The Zn zone in this part of the deposit consists of “diffuse” bands of sphalerite in strongly altered rocks (aluminous alteration). This intersection reported 0.05 g/t Au and 6.2% Zn over 4.8m.

20 North lens hanging wall alteration: The hanging wall alteration assemblage in ddh 3220-04 consists of quartz, sericite and pyrite. This alteration assemblage is developed in the upper felsic unit (unit 5.5; Fig. 38). Some aluminosilicates are present locally but rapidly disappear higher in the stratigraphy, away from the ore zone. As seen in ddh 3146-05, alteration related to the 20 North lens extent into the hanging wall. However, in ddh 3220-04, the hanging wall consists of felsic rocks of unit 5.5. The alteration is therefore dominated by sericite and quartz.

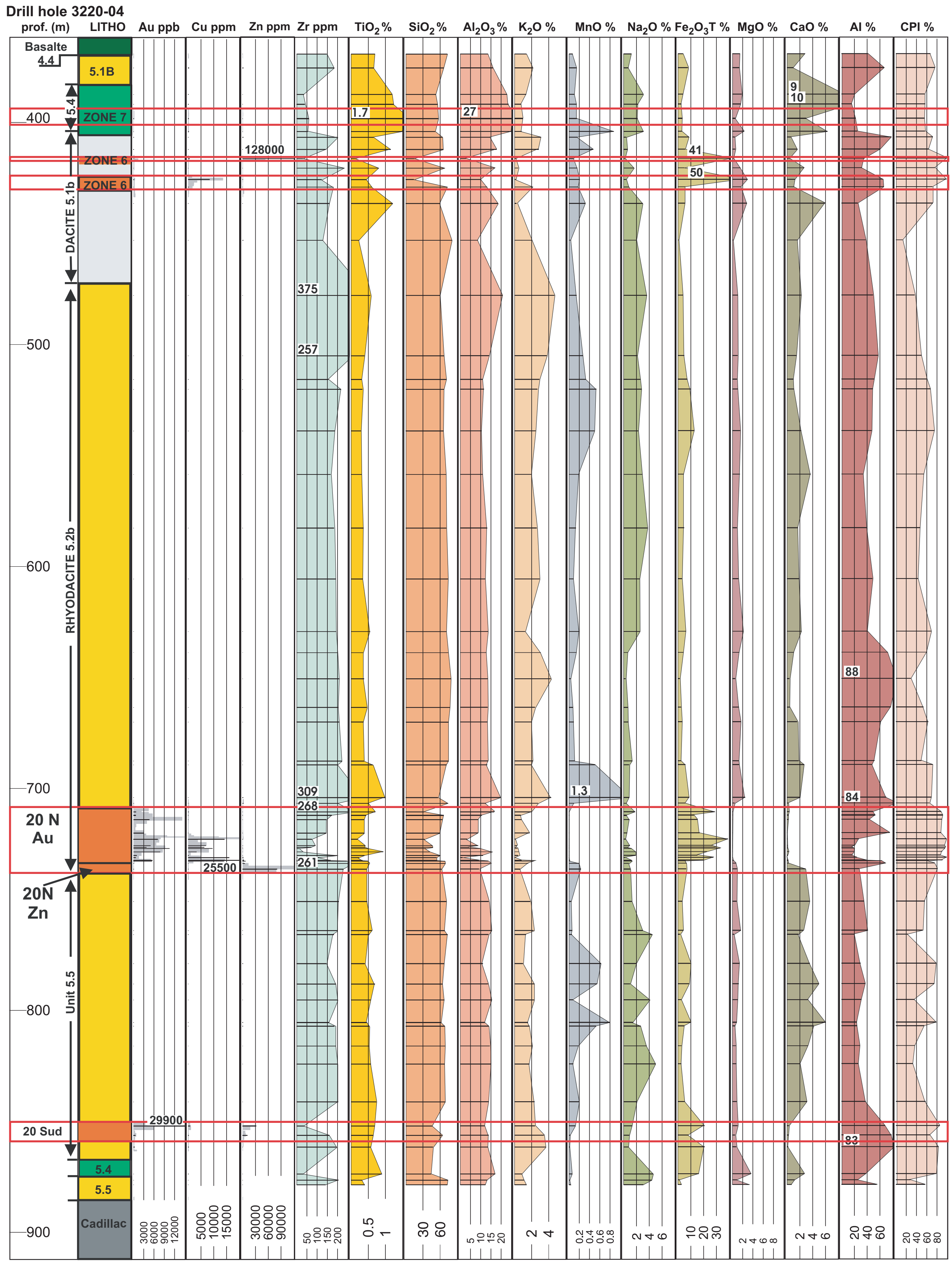


Figure 38. Geochemical profile of drill hole 3220-04 showing the compositional variations related with the hydrothermal aluminous alteration in the 20 North lens footwall at depth in the mine. From Dubé et al. (2007b).

Distal hangingwall alteration: Away from the 20 North lens, the aluminous alteration gradually disappears and gives way to the quartz-Mn-garnet-sericite-biotite assemblage typical of the footwall alteration higher in the mine.

20 South lens extension at depth in the mine: The 20 South lens is still present at great depth in the mine. It is associated with aluminous alteration, although much less intense than around the 20 North lens. In ddh 3220-04, the 20 South lens reported values of 8 g/t Au and 1.3% Zn over 3.4m. It consists of transposed centimetre to decimetre-wide bands and veins of massive pyrite with some sphalerite and chalcopyrite and disseminated pyrite in schistose, strongly sericitized felsic rocks (unit 5.5; Fig. 38).

ddh 3170-11b – very intense aluminous and silicic alteration

Only a couple of core box of ddh 3170-11b will be laid out to allow for observation of a very intense aluminous and siliceous alteration at LaRonde. The exposed section shows the extension at depth of the 20 North lens where the ore consists of semimassive sulphides that are hosted in strongly silicified (acid-leached) felsic rocks (unit 5.2b).

Summary and conclusions – Day 3

Despite the superposition of late tectonic and metamorphic events, the primary geological characteristics of the LaRonde Penna Au-rich volcanogenic massive sulphide deposit are sufficiently well preserved to allow detailed description and reconstruction of the primary setting of mineralization, as shown during the visit. Active volcanism within the relatively restricted setting of the LaRonde Penna deposit and rapid burial of the host sequence likely contributed to the large size of the massive sulphide lenses, with the deposits growing partly by sub-seafloor replacement of the permeable footwall breccias (Dubé et al., 2007b, Mercier-Langevin et al., 2007a). The hydrothermal activity is characterized by different styles of alteration assemblages and mineralization along strike and is thought to be related to variable contributions of magmatic volatiles and convective hydrothermal circulation of seawater within a single, protracted system. The aluminous alteration at LaRonde Penna is interpreted to be the metamorphic equivalent of an advanced argillic alteration and has many similarities with metamorphosed high-sulphidation systems, and particularly with a class of Au-rich VMS characterized by aluminous alteration (Dubé et al., 2007b). Strong permeability contrasts resulted from autoclastic, flow breccia deposits being cut by and buried by less permeable felsic domes or cryptodomes and intermediate to mafic sills and dykes. The emplacement of a relatively impermeable feldspar and quartz-phyric rhyolite cryptodome above the 20 North lens enhanced sub-seafloor replacement of the footwall felsic breccia by the ore. A shallowly emplaced mafic sill and dyke complex above the 20 North lens also helped to focus hydrothermal fluids through fractures into the overlying 20 South lens (Mercier-Langevin et al., 2007a).

The formation of the LaRonde Penna deposit at ca. 2698 Ma corresponds to a particularly fertile episode of Au-rich VMS formation in the BRG. The host rocks of the deposit are among the youngest dated units in the BRG, suggesting a possible correlation between the petrogenetic evolution of this volcanic assemblage and the enrichment of Au in the VMS (see Mercier-Langevin et al., 2007b). Deformation and metamorphism greatly modified the primary hydrothermal assemblages and the alteration but were not responsible for the introduction of the bulk of the Au, as previously proposed for other deposits of the district. The early, synvolcanic introduction of Au is supported by a number of observations from the ore and alteration zones, as discussed in Dubé et al. (2007b) and Mercier-Langevin et al. (2007c, d), as well as a number of other features of the mine stratigraphy presented in this study. These include: (1) the presence of Au-rich clasts in some volcanic breccias near Zone 6, (2) stacking of discrete Au-rich lenses within the volcanic succession, with little or no Au mineralization between the lenses, (3) the preserved primary distribution of Au and Cu in the highly strained lenses along synvolcanic faults, and (4) the correlation of different volcanic facies and alteration assemblages with Au enrichment.

The ore lenses of the Archean LaRonde Penna deposit are associated with transitional to calc-alkaline felsic volcanic rocks. This type of felsic rocks traditionally has been considered to be of limited prospectivity. The LaRonde Penna study suggests that Archean transitional to calc-alkaline felsic rocks and the inferred geodynamic setting in which they were produced could be related to the elevated Au content of the associated VMS deposits and therefore represent favourable exploration targets for polymetalic ore deposits (Mercier-Langevin et al., 2007a).

At LaRonde Penna, the presence of sulphide lenses characterized by Au-rich portions and base-metal rich portions (e.g., 20 North lens) demonstrates that a volcanogenic massive sulphide system can generate mineralization styles that gradually evolve (spatially and temporally) from neutral (Au-Cu-Zn-Ag-Pb ore), to transitional, to «acidic» (advanced argillic alteration and Au ± Cu-rich ore) fluid conditions in response to the evolving local geological context. The study illustrates that diverse styles of Au-rich VMS can coexist within the same deposit (Dubé et al., 2007b).

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