

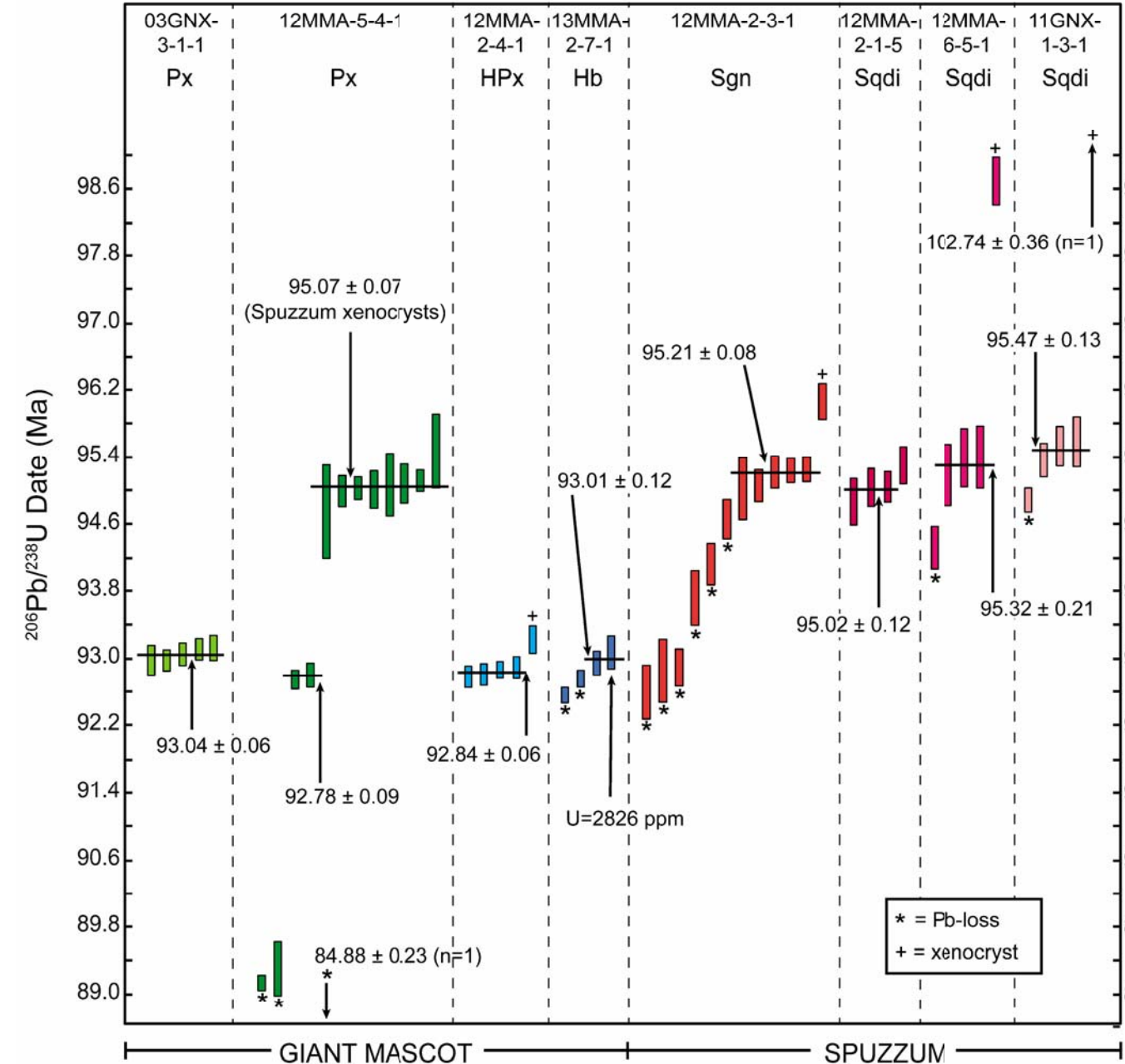
Giant Mascot Magmatic Ni-Cu-PGE Sulphide Deposit

The Giant Mascot Ni-Cu-PGE deposit remains British Columbia's only past-producing nickel mine (1958-1974) with 4.2 million metric tonnes of ore grading 0.77 wt% Ni and 0.34 wt% Cu, minor Co, Ag and Au, and unreported platinum group elements (PGE; Christopher and Robinson, 1975). The deposit belongs to an increasingly important class of under-explored, orthomagmatic Ni-Cu-PGE sulphide deposits located at convergent margins. These arc-related, ultramafic-mafic intrusions, which are known to host economic mineralization, generally have small footprints (~200 m² to 10 km²) and may exhibit crudely concentric lithological zoning. Ultramafic cumulates and associated gabbros characteristically contain hornblende and orthopyroxene. The occurrence of cumulus orthopyroxene in ultramafic rocks distinguishes these intrusions from those of Alaskan-type affinity in the supra-subduction zone environment. The geology and geochronology of Giant Mascot summarized herein is taken from recent work by Manor (2014); the geological map showing the major rock units is modified from original mapping by Aho (1954).

The Giant Mascot ultramafic intrusion forms an elliptical plug (~3 x 1.3 km) at the southeastern margin of the Coast Plutonic Complex, the locus of Late Jurassic to Paleogene arc magmatism in the northern Cordillera. The intrusion is hosted by the Upper Triassic Settler schist and Late Cretaceous Spuzzum pluton. Regional metamorphism (mid- to lower crust) reached upper amphibolite grade at ~91-86 Ma (Mitrovic, 2013). The Giant Mascot ultramafic rocks are remarkably fresh and comprise dunite, hornblende-bearing peridotite (harzburgite, hercynite) and pyroxenite (hornblende-bearing orthopyroxene, websterite), hornblende pyroxenite and hornblende with minor phlogopite and plagioclase, and accessory chromite, Fe-Ti oxides, apatite, zircon and rutile. Olivine-rich cumulates occupy the core of the crudely zoned intrusion and pegmatitic hornblende-hornblende gabbro forms a discontinuous rim. The sulphide ores mainly pyrrhotite, pentlandite and chalcopyrite exhibit unambiguous magmatic textures and are predominantly hosted in dunite, peridotite and pyroxenite.

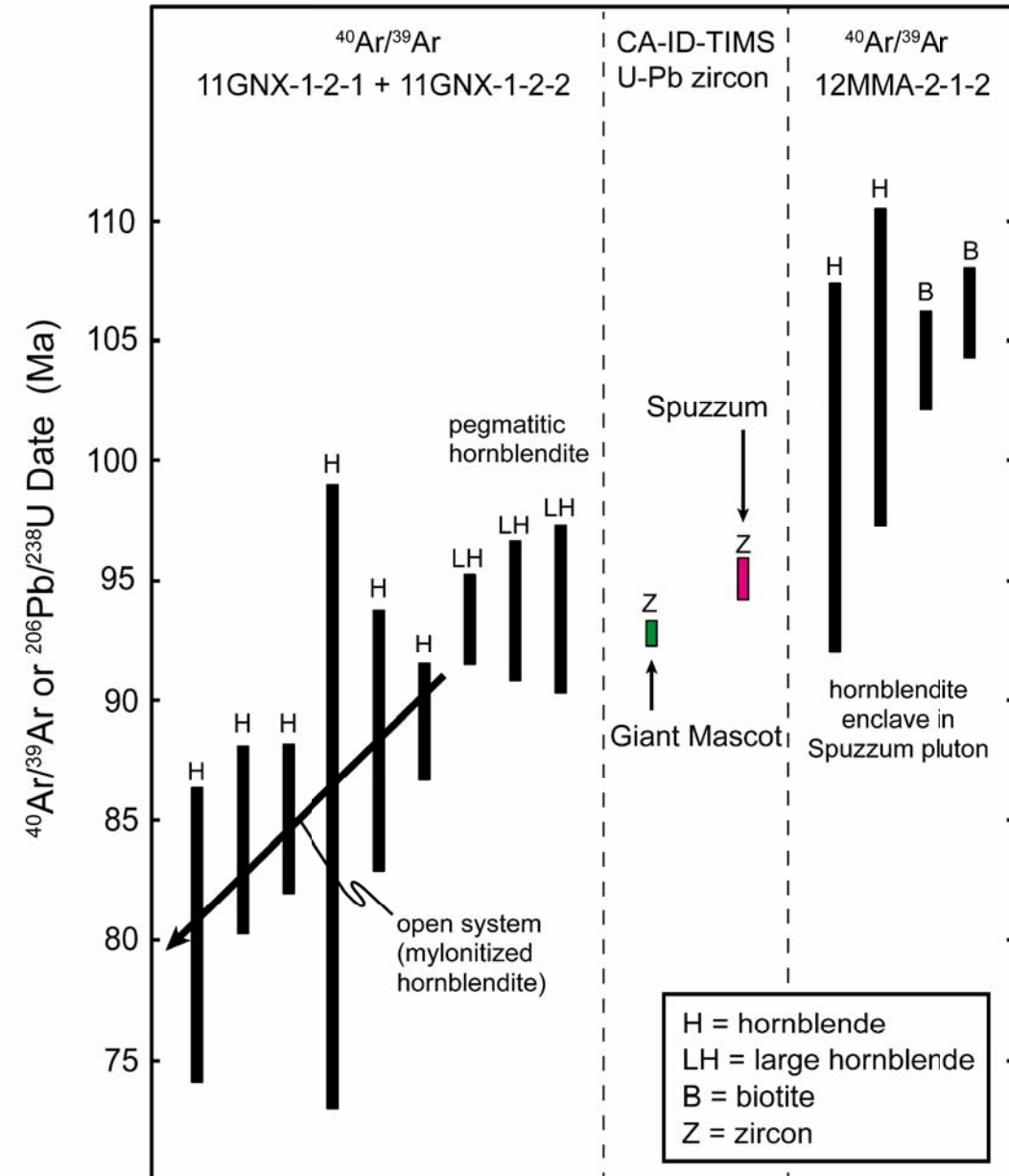
U-Pb zircon geochronology of pyroxenite and hornblende has yielded a Late Cretaceous age (ca. 93 Ma) for crystallization of the Giant Mascot intrusion, and a slightly older but statistically distinct age (ca. 95 Ma) for the host Spuzzum diorite, in agreement with observed contact relationships. ⁴⁰Ar/³⁹Ar dating of a mylonite cutting hornblende-hornblende gabbro at the rim of the ultramafic intrusion reveals open system loss of radiogenic argon starting shortly after consolidation (peak metamorphism ~91-86 Ma; Mitrovic, 2013). The new geochronological results indicate the timing of sulphide mineralization (ca. 93 Ma) and establish the Giant Mascot ores as the world's youngest known, orthomagmatic Ni-Cu-PGE deposit.

U-Pb Zircon Geochronology



U-Pb zircon geochronology results for chemical abrasion ID-TIMS dating of Giant Mascot ultramafic rocks and Spuzzum diorite. Each bar is an analysis of an individual zircon grain showing extent of error (2 standard deviations). Black horizontal lines indicate weighted mean ²⁰⁶Pb/²³⁸U crystallization ages for each sample. Rock unit codes correspond to those on the geology map.

⁴⁰Ar / ³⁹Ar Geochronology



Comparison of U-Pb zircon [chemical abrasion ID-TIMS] and ⁴⁰Ar/³⁹Ar (inverse isochron) dating results for Giant Mascot and Spuzzum intrusions. Each bar is an individual analysis showing extent of error (2 standard deviations). Hornblende inclusions occur in the Spuzzum pluton.

Base Map Information

Base map produced from digital TRM (Terrain Resource Inventory Management) 1:20 000 scale topographic database, British Columbia Ministry of Forests, Lands and Natural Resource Operations. North American Datum 1983 (NAD83). Universal Transverse Mercator Projection (Zone 10). Elevation in metres above mean sea level. Contour interval 20m.

Digital Cartography

G. T. Nixon
M. J. Manor
T. Barry

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Manor, M. J., Wall, C. J., Friedman, R. M., Gabites, J., Nixon, G. T., Scoates, J. S., and Ames, D. E., 2015. Geology, geochronology and Ni-Cu-PGE orebodies of the Giant Mascot ultramafic intrusion, Hope, southwestern British Columbia. British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Geoscience Map 2015-01, scale 1:10 000 (2 sheets).

Acknowledgments

We thank Wes Harmon, Alex Colyer and Lauren Harrison for help with mapping and sample collecting during 2012 and 2013 summer field seasons. The staff of Valley Helicopters in Hope are thanked for providing safe and efficient flights and Barrick Gold and Fraser Valley Dirt Riders Association for access to their property. McKay Edwards kindly provided detailed weather reports at the mine prior to the 2013 field season. Helpful comments by Jon Scoates and Alex Zagorevski, Geological Survey of Canada, improved the map presentation. Funding for this project is provided by Natural Resources Canada Targeted Geoscience Initiative 4 (TGI-4) Program administered by the Geological Survey of Canada and a Society of Economic Geologists Canada Foundation Student Research Grant awarded to Matthew Manor in 2013.



BC Geological Survey
GEOSCIENCE MAP 2015-01



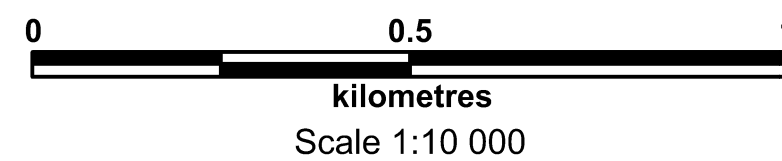
Geology, Geochronology and Ni-Cu-PGE Orebodies of the Giant Mascot Ultramafic Intrusion, Hope, Southwestern British Columbia

parts of NTS 092H/05 and 06

Sheet 1 of 2

M. J. Manor*, C. J. Wall*, R. M. Friedman*, J. Gabites*, G. T. Nixon**, J. S. Scoates*, and D. E. Ames***

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LEGEND

LATE CRETACEOUS

GIANT MASCOT ULTRAMAFIC SUITE (ca. 93 Ma)

- Hgb** Black and white mottled, medium- to coarse-grained hornblende gabbro with minor pyroxene (<15 vol %) and phlogopite (<5%); melanocratic varieties contain up to 75% stubby prismatic hornblende crystals.
- Hb** Black to grey-brown, medium-grained to pegmatitic hornblende and feldspathic hornblende: subhedral hornblende (90-98 vol %), minor pyroxene (<5%), rare phlogopite (<5%) and trace disseminated sulphide; forms a discontinuous pegmatitic zone up to 40m wide at the periphery of the ultramafic intrusion and also occurs in the pyroxenite.
- HPx** Black to dark green, medium- to coarse-grained hornblende pyroxenite (websterite and orthopyroxene), locally oikocrystic and feldspathic: anhedral-subhedral pyroxene (20-60 vol %) and hornblende (20-80%) with minor olivine (<5%) and trace sulphide; rare centimetre- to decimetre-scale modal layering.
- Px** Dark brownish green, medium-grained pyroxenite (websterite, olivine websterite and orthopyroxene), locally oikocrystic and feldspathic: subhedral pyroxene (55-90 vol %), olivine (5-35%), minor hornblende (<5%) and disseminated trace magnetite and sulphide.
- Pd** Dark brownish green, fine- to medium-grained, locally oikocrystic peridotite (hercynite and harzburgite): subhedral olivine (40-80%), pyroxene (30-60%), minor hornblende (<10%), net-textured sulphide (pyrrhotite, pentlandite and chalcopyrite, 2-25%) and trace chromian spinel.
- Dn** Dark green to yellow-brown, fine- to medium-grained, equigranular dunite: subhedral olivine (90-95%) and minor interstitial pyroxene (5-10%) with accessory chromian spinel and trace disseminated sulphide.

SPUZZUM PLUTON (ca. 95 Ma)

- Sqdi** Pale grey, medium-grained hornblende-biotite diorite and quartz diorite: subhedral plagioclase (An50-55; 40-60%), pyroxene (10-35%), biotite (5-20%), hornblende (5-15%) and accessory magnetite and ilmenite, and trace disseminated sulphides; entrains sparse ultramafic xenoliths and locally exhibits a moderate to strong foliation.
- Shgn** Pale grey to pinkish grey, medium-grained, biotite-hornblende gabbro, diorite and minor nortite: subhedral calcic plagioclase (An50-70; 45-75 vol %), pyroxene (15-35%), hornblende (<5%), biotite (<5%), quartz (0-15%), Fe-Ti oxides (ilmenite and magnetite<2%) and trace disseminated sulphides; weak to moderate foliation.
- Sgn** Pale grey to pinkish grey, medium-grained gabbro, diorite and minor nortite: subhedral calcic plagioclase (An50-70; 45-75 vol %), pyroxene (15-35%), hornblende (<5%), biotite (<5%), quartz (0-15%), Fe-Ti oxides (ilmenite and magnetite<2%) and trace disseminated sulphides; weak to moderate foliation.
- Sgng** Garnetiferous gabbro, diorite adjacent to small raft of Settler Schist in the western part of Zofka Ridge.

UPPER TRIASSIC

SETTLER SCHIST

- Ss** Dark grey, finely to coarsely crystalline, metasedimentary schist containing garnet, staurolite, kyanite, biotite, plagioclase and quartz, minor graphite and trace pyrite.

MAP SYMBOLS

- Geological contact, defined
- Geological contact, approximate
- Geological contact, inferred
- Modal layering, inclined
- Dike (hornblende or hornblende gabbro), inclined, vertical
- Foliation or schistosity, inclined
- Foliation or schistosity, inclined, vertical (Aho, 1954)
- Foliation induced by shearing, inclined
- Foliation induced by shearing, inclined, vertical (Aho, 1954)
- U-Pb zircon date (Ma, 2 sigma; determined by R. M. Friedman)
- 40Ar/39Ar date (Ma, H, hornblende; L, large crystal; B, biotite; X, xenolith; inverse isochron dates determined by J. Gabites)
- Tunnel and adit
- Orebody (projected to surface)
- Outcrop examined
- Outcrop too small to show at map scale
- Flooded land (swamp)
- Stream or river
- Contour (100m)
- Contour (20m)
- Road (dirt)

References

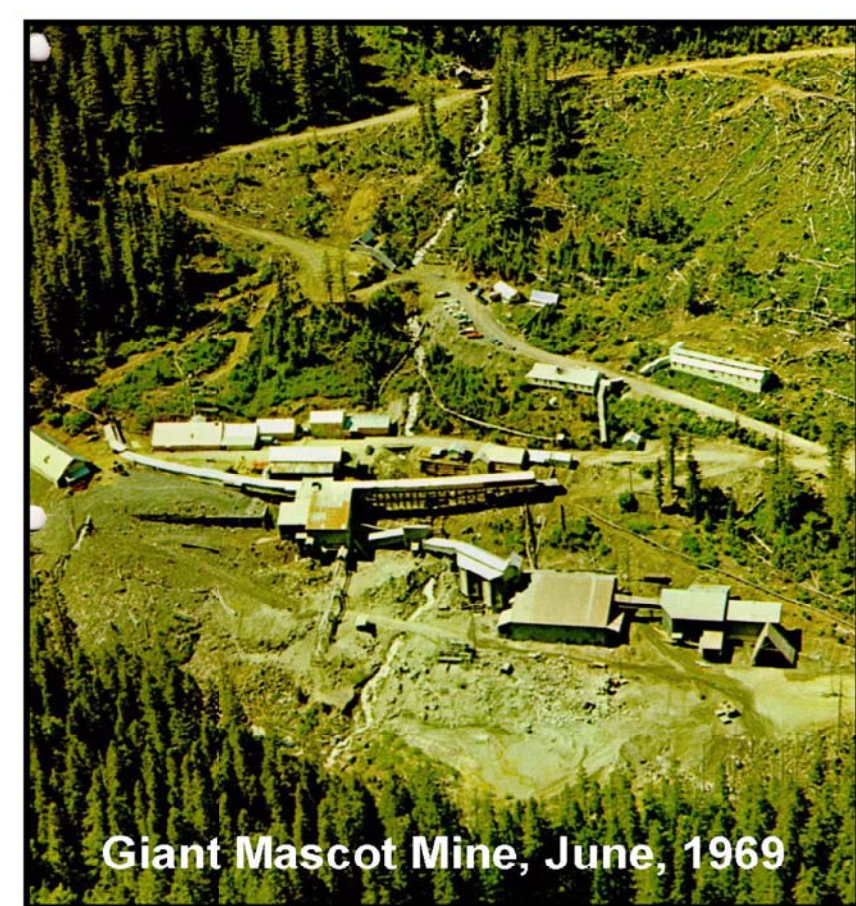
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Semi-massive sulphides in peridotite, Pride of Emory orebody.



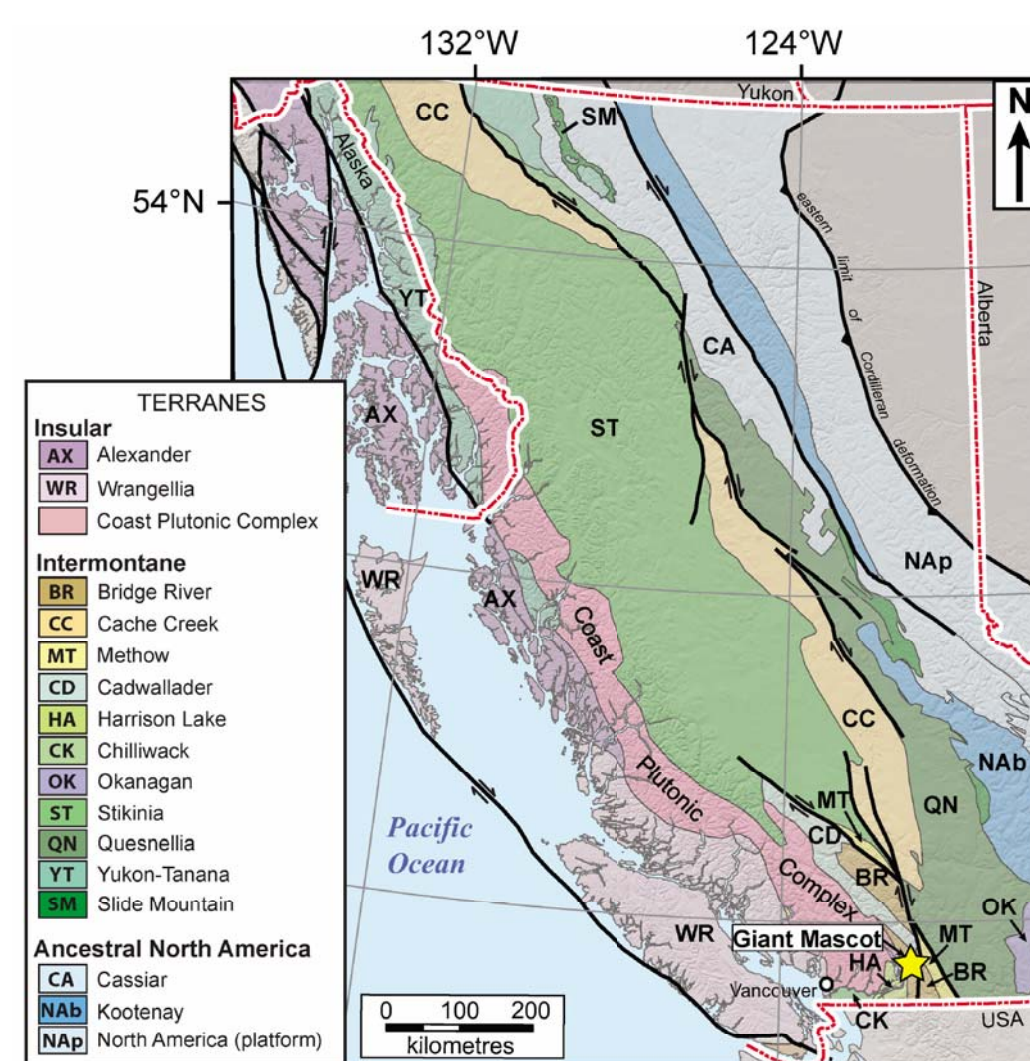
Mineralized pyroxenite exhibiting partially disrupted, weak modal layering. Hammer handle is 50 cm long.



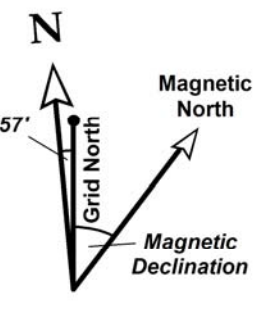
Giant Mascot Mine, June, 1969



Thin mylonite zone (extreme right) cutting pegmatitic hornblende-hornblende gabbro.



Tectonostratigraphic terranes and major faults of British Columbia and southeastern Alaska showing location of Giant Mascot (modified from Colpron and Nelson, 2011).



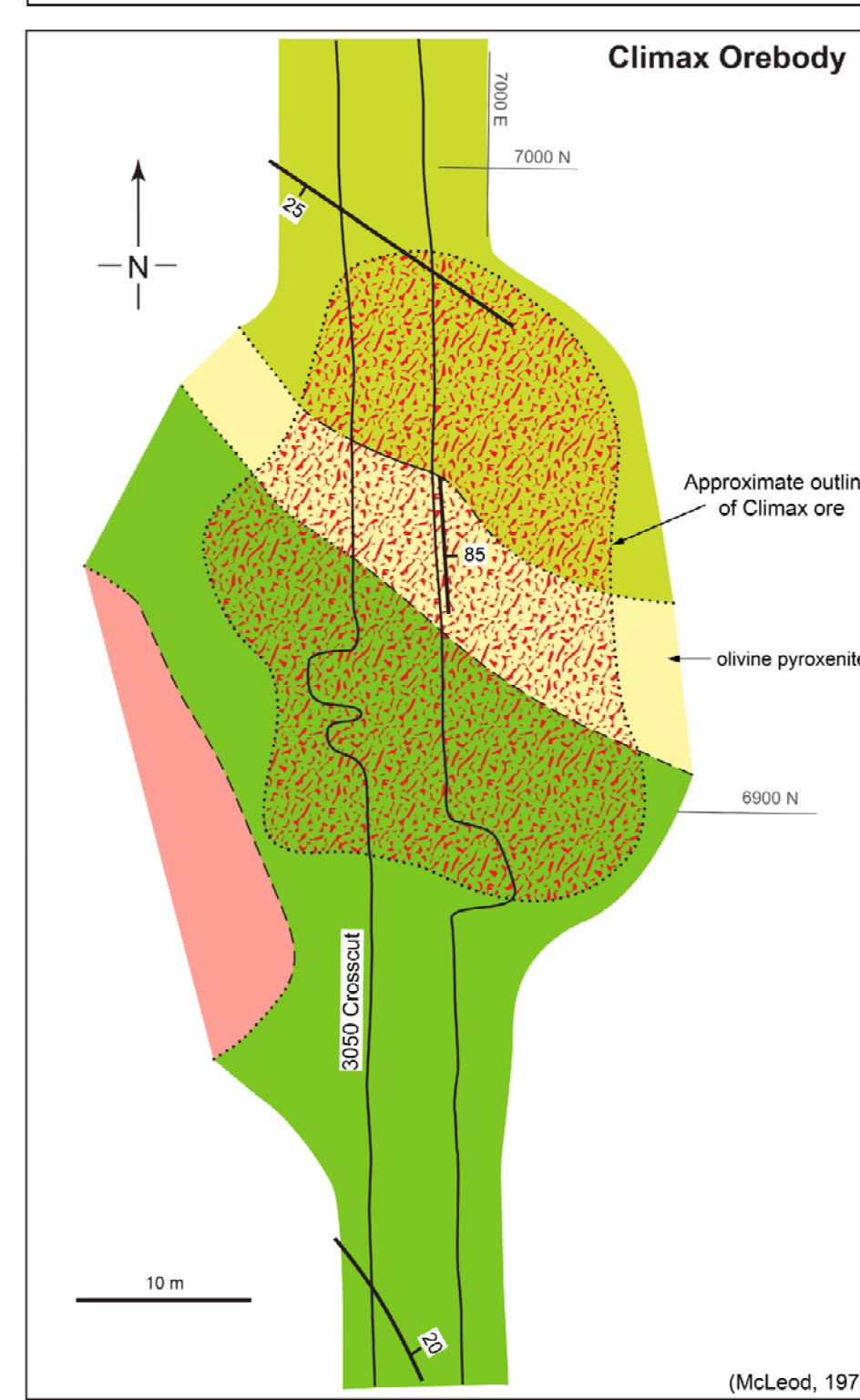
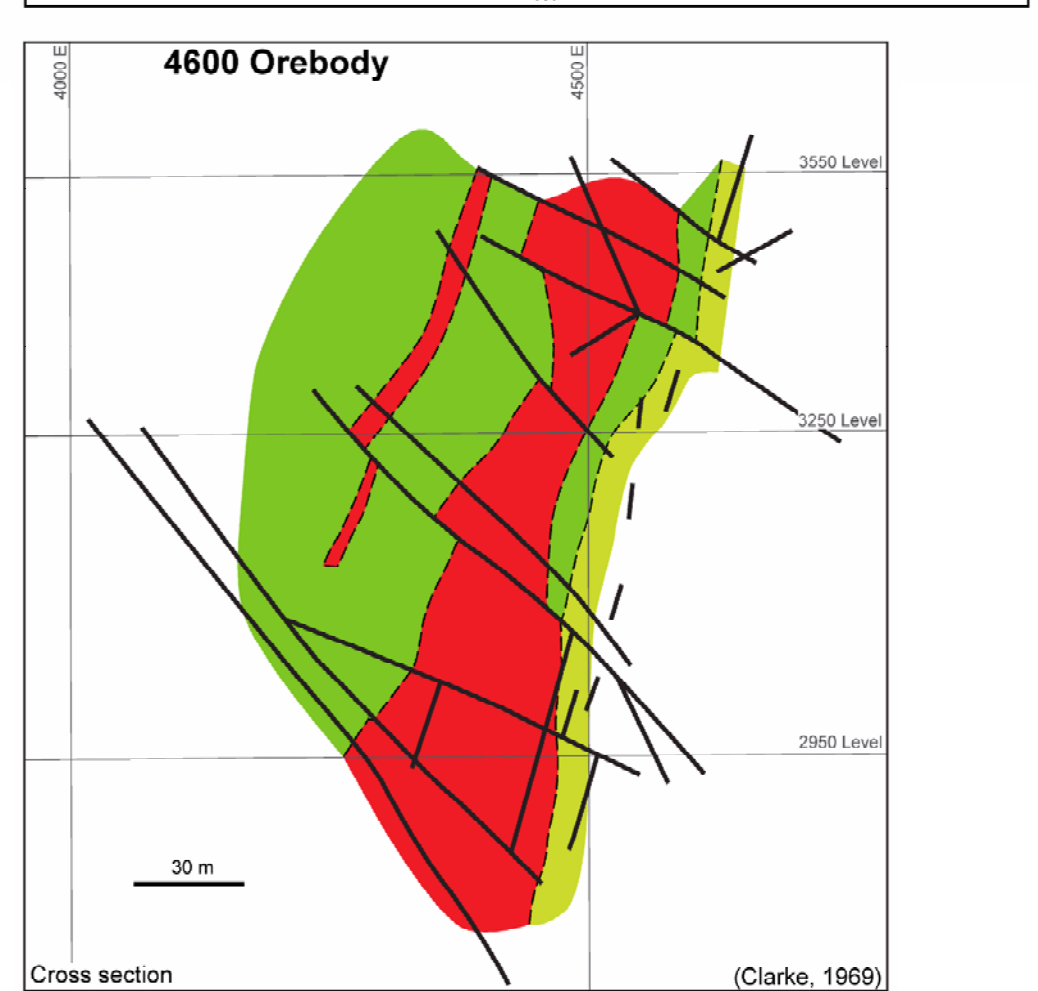
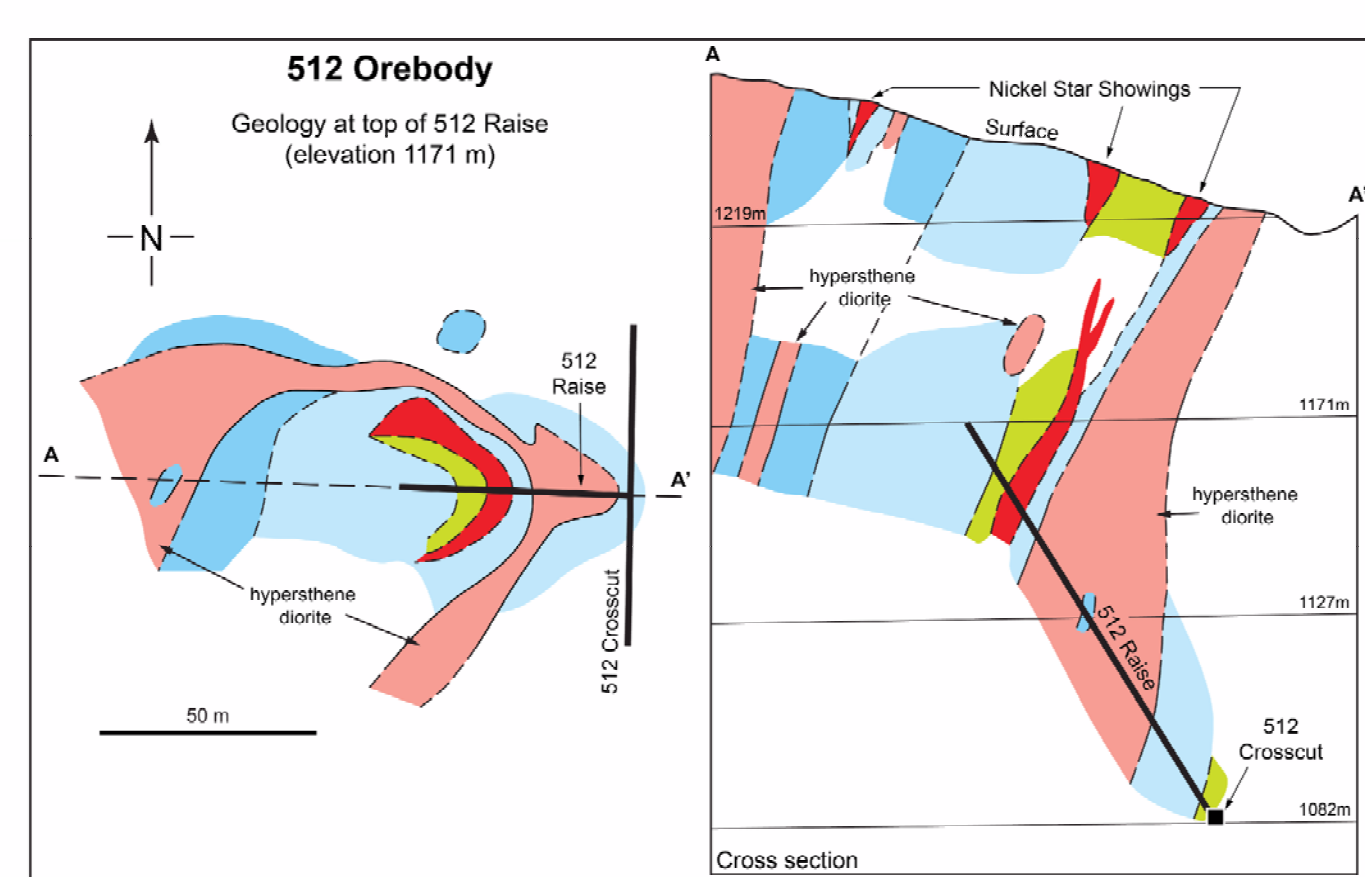
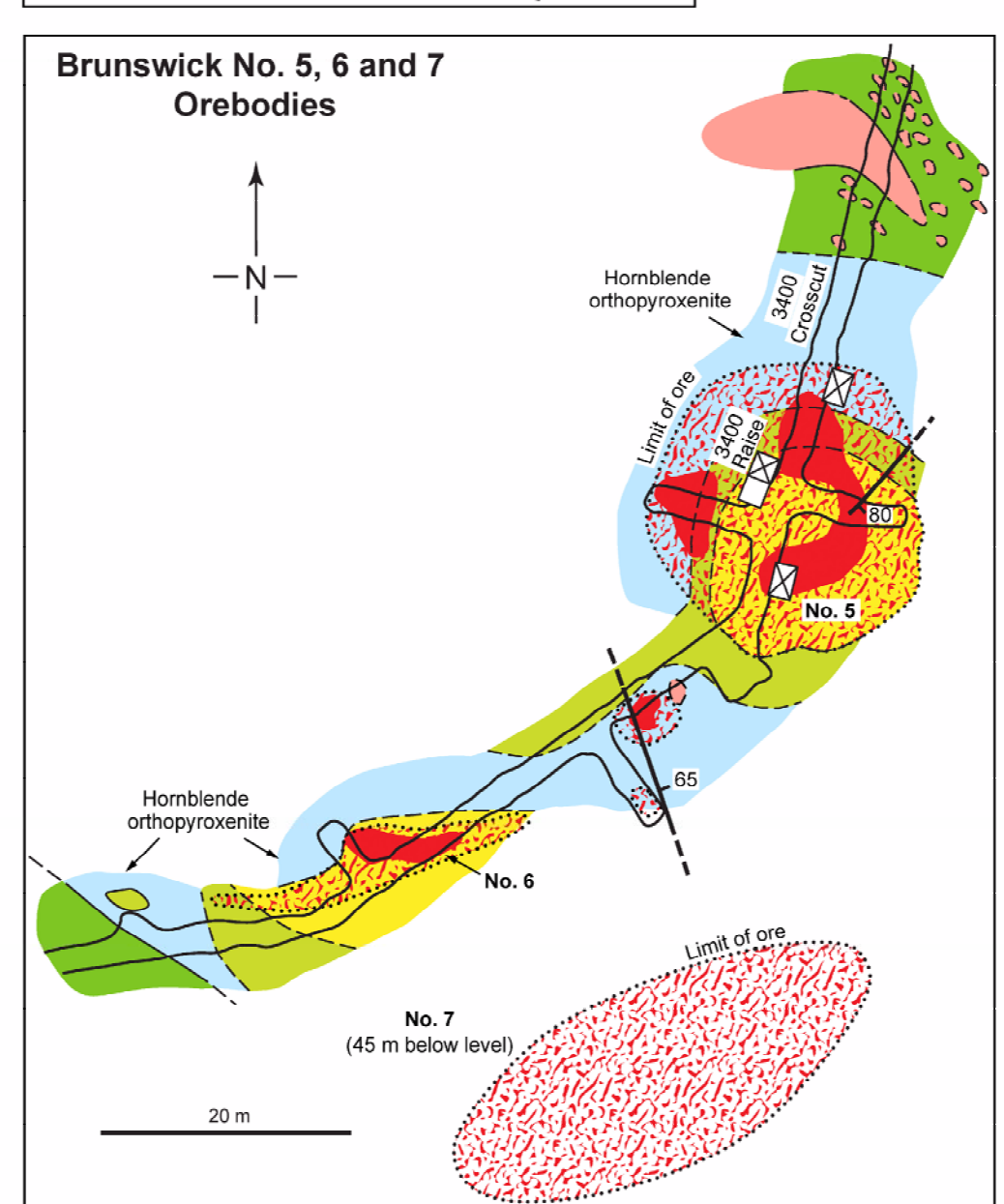
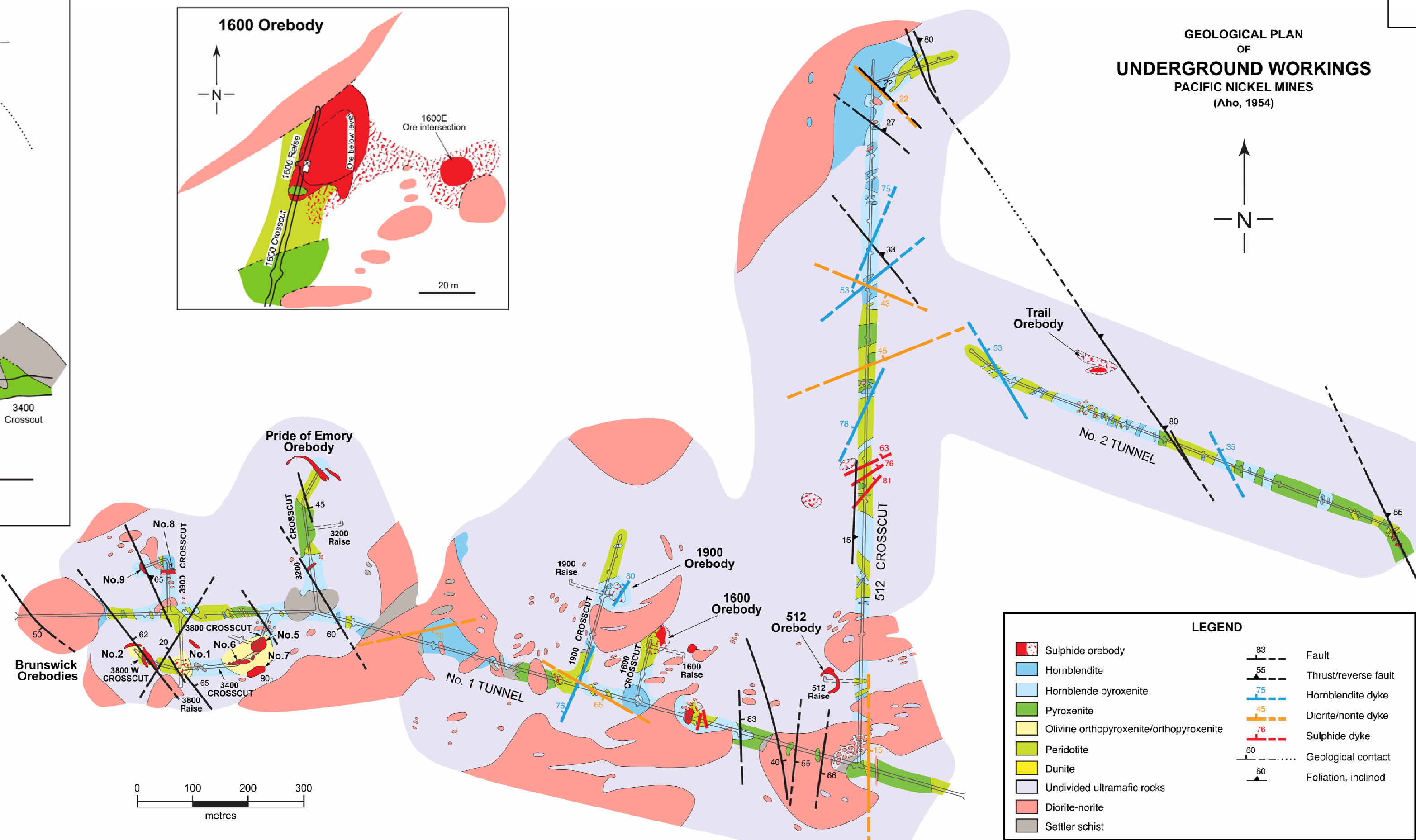
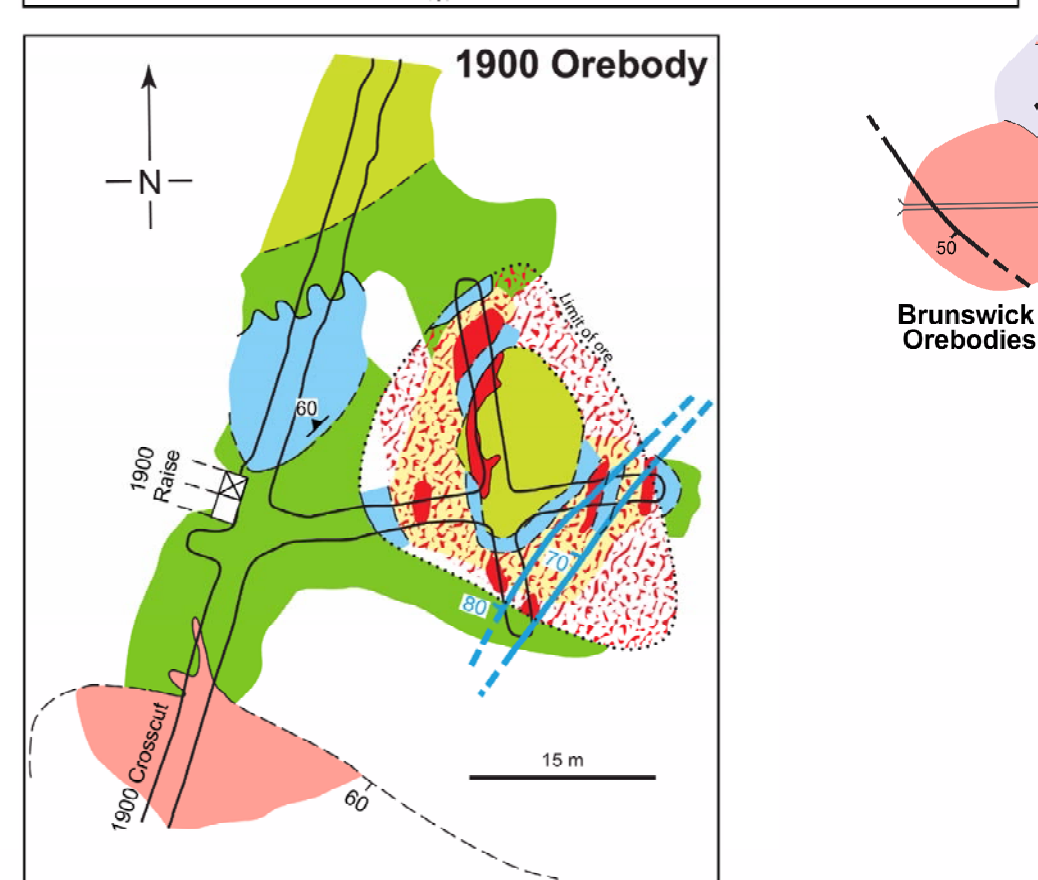
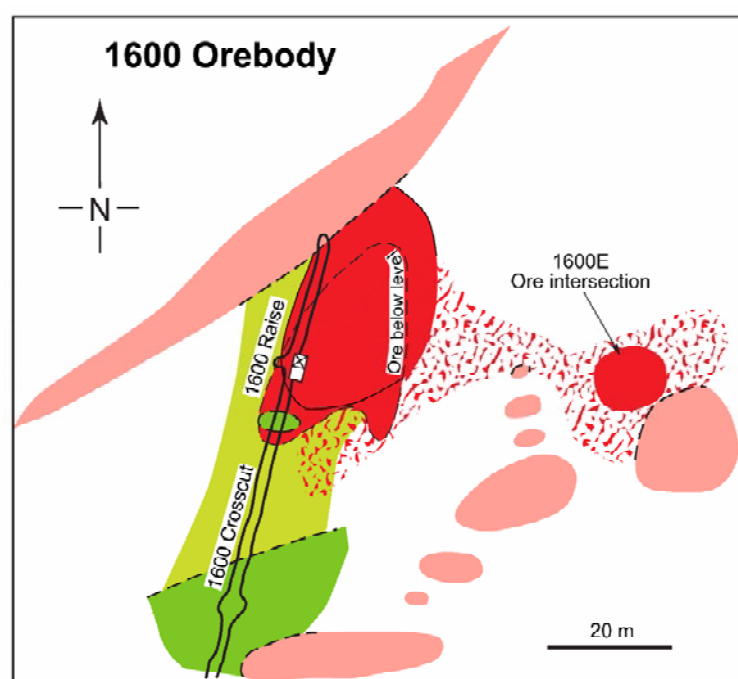
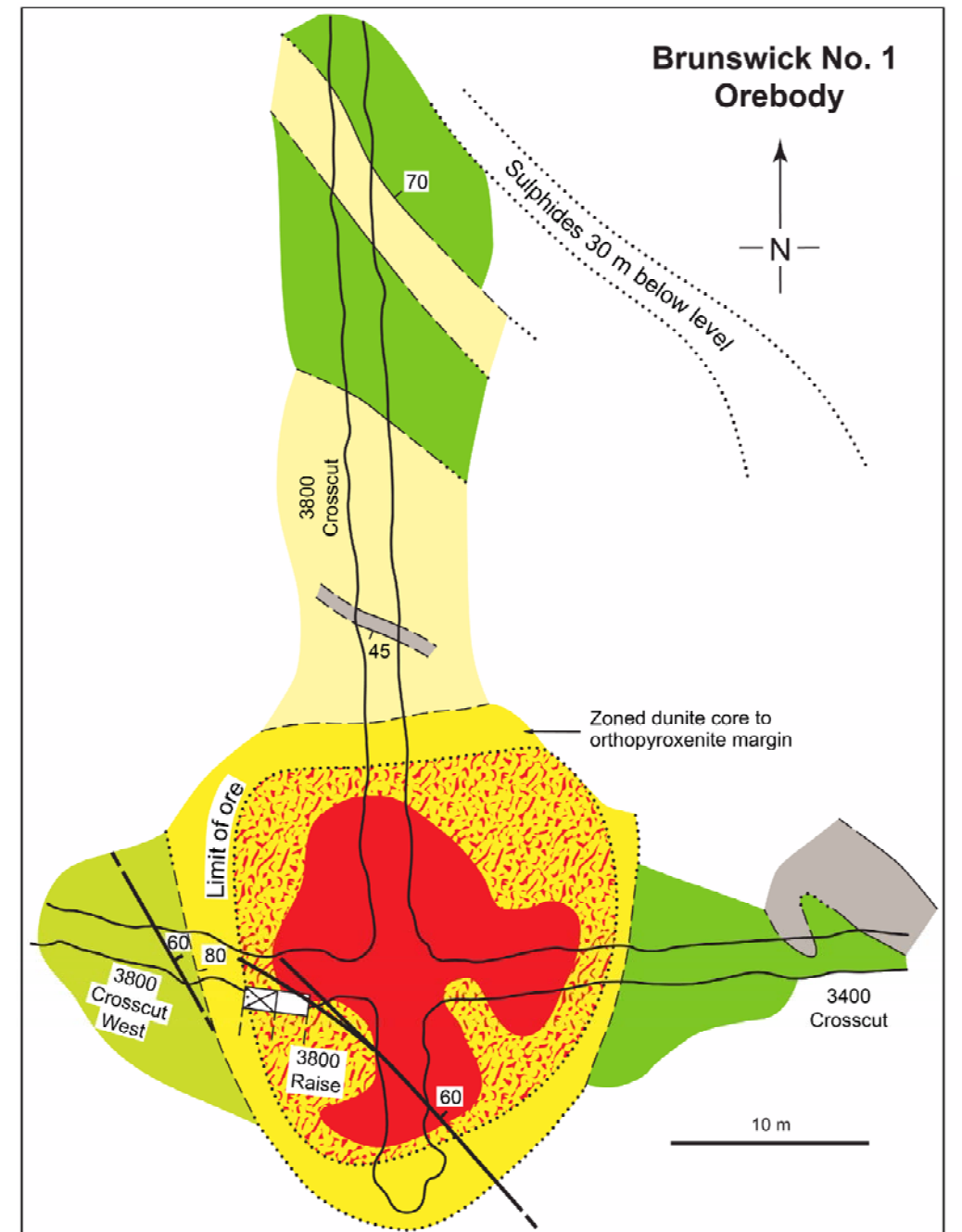
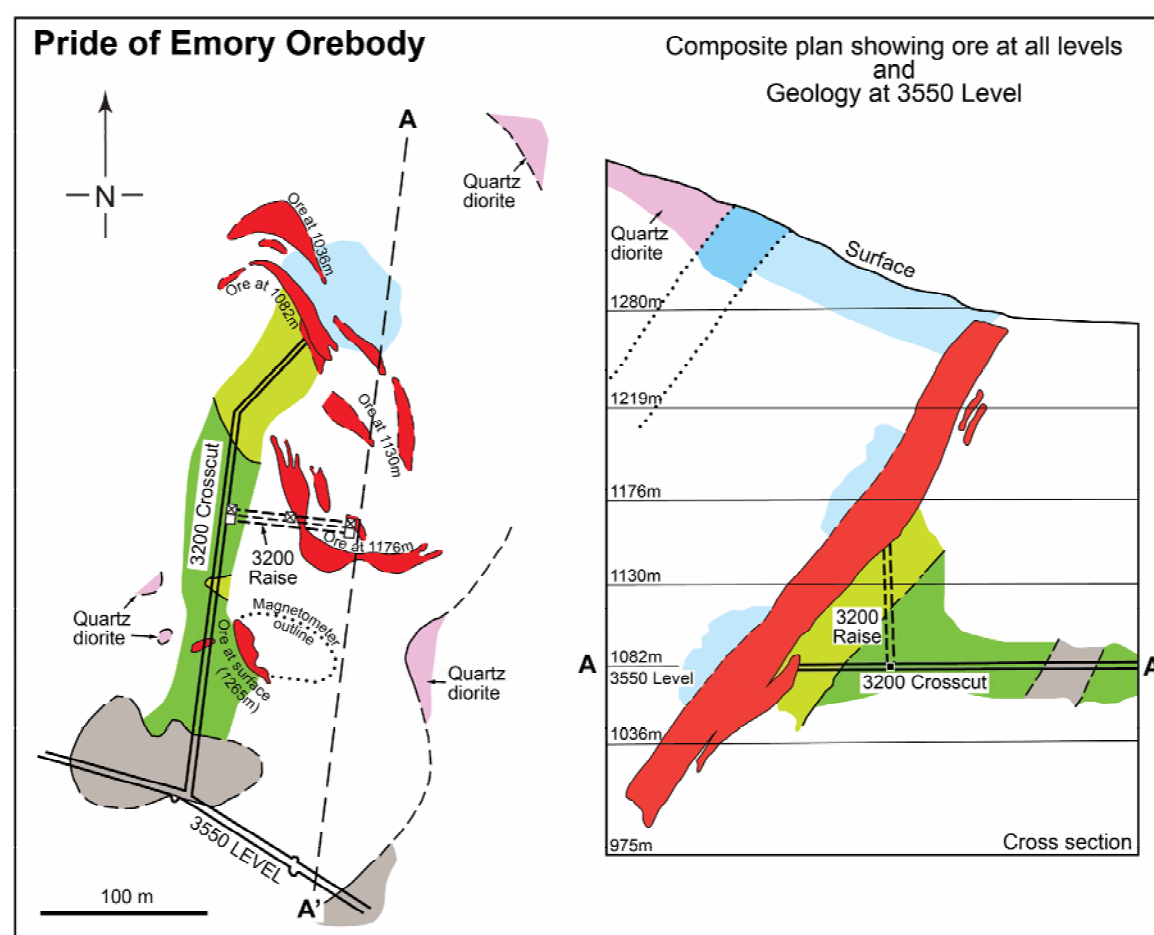
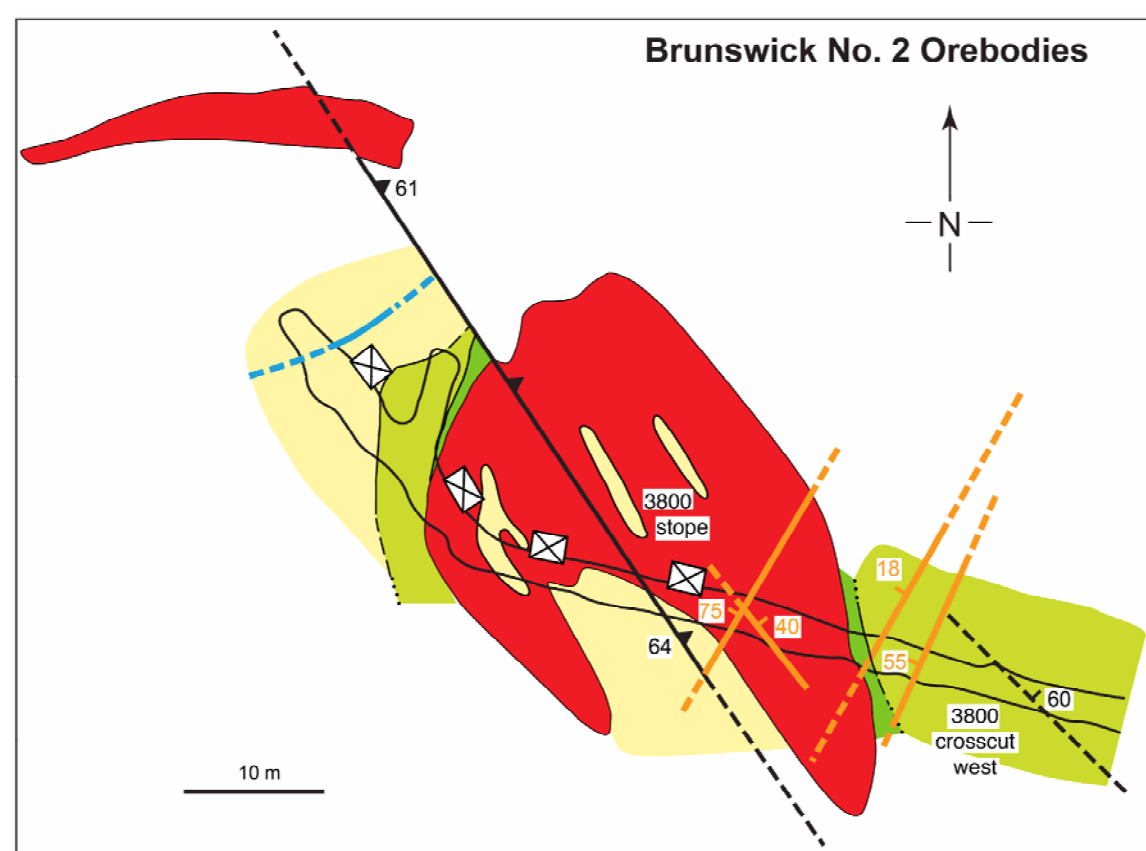
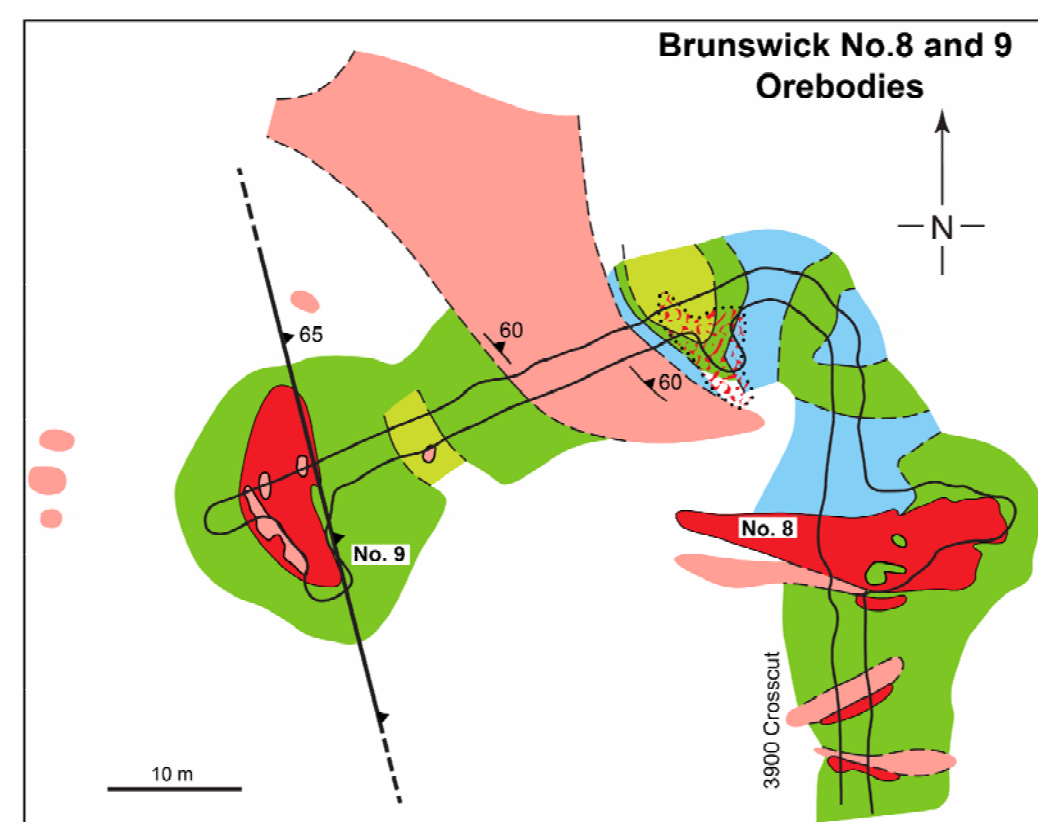


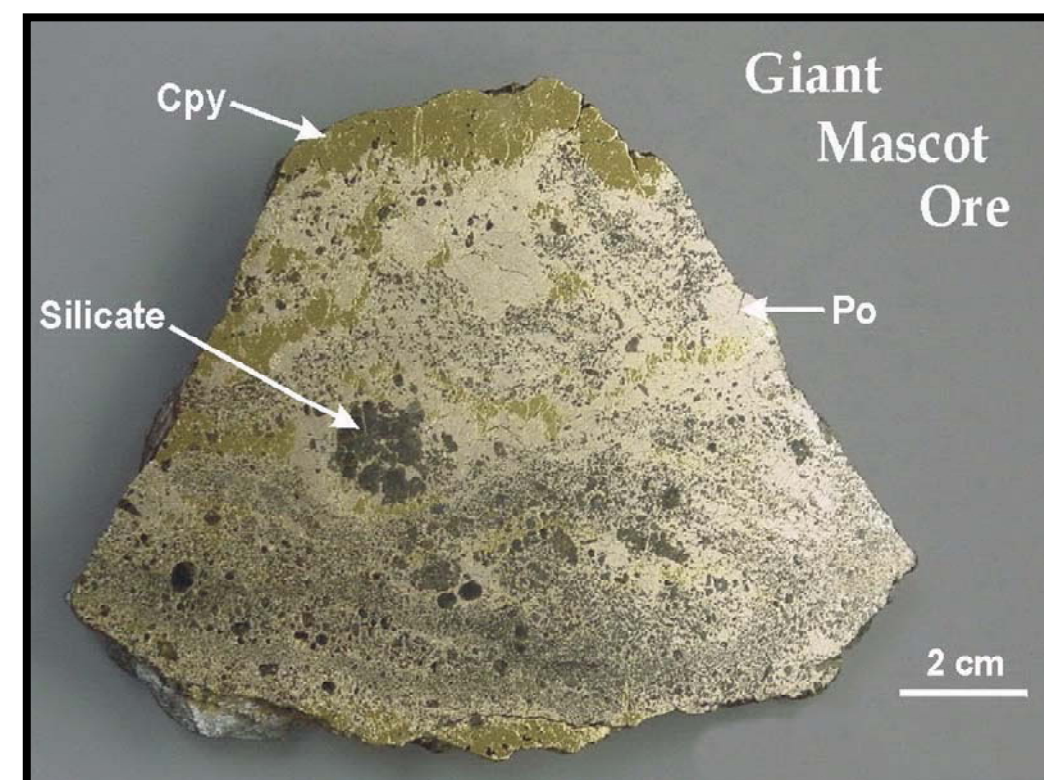
TABLE 2 Orebody statistics for the Giant Mascot Ni-Cu-PGE deposit

Orebody	Location in mineralized trend	Dimensions (m)			Orebody shape	Orientation of orebody (x-tonnes)	Grade (wt%)			Mineralization type**	Orebody type	Host rocks**	
		Length	Width	Vertical height			Ni	Cu	Ni/Cu				
Pride of Emory	West	45.7	18.3	268.8	pipe-like lens	53/320	639	1.46	0.38	3.84	M	unzoned	dunite to orthopyroxene
Brunswick 1	West	33.5	18.3	160.1	pipe-like lens	75/340	112	1.1	0.35	3.14	M	zoned	dunite core to harzburgite to barren orthopyroxene
Brunswick 2	West	54.9	21.3	251.5	lenticular	58/330	517	1.4	0.6	2.33	M-NT	unzoned	harzburgite
Brunswick 2A	West	33.5	21.3	106.7	lenticular	72/320	263	0.98	0.35	2.8	M-NT	unzoned	harzburgite
Brunswick 2B	West	21.3	19.8	91.5	lenticular	77/315	119	0.56	0.27	2.07	M-NT	unzoned	harzburgite
Brunswick 5	West	36.6	21.3	182.9	elliptical pipe	77/330	371	1.49	0.5	2.96	M	zoned	dunite core to harzburgite to orthopyroxene to barren orthopyroxene
Brunswick 6	West	4.6	18.3	75.2	lenticular	unknown	unknown	unknown	unknown	unknown	M	zoned	dunite to peridotite
Brunswick 7	West	27.4	15.2	61.0	lenticular	68/330	21	2.37	0.75	3.16	M	unzoned	orthopyroxene
Brunswick 8	West	6.1	15.2	53.4	pipe-like lens	79/020	11	1.75	0.61	2.86	M	unzoned	orthopyroxene
Brunswick 9	West	6.1	12.2	61.0	pipe-like lens	unknown	unknown	unknown	unknown	unknown	M	unzoned	orthopyroxene
Brunswick 10	West	21.3	16.8	61.0	unknown	75/330	35	0.74	0.35	2.11	M	unknown	orthopyroxene
2663	West	15.2	18.3	99.1	pipe	68/320	93	0.86	0.32	2.69	D	zoned	peridotite core to barren pyroxene
6800	West	15.2	15.2	91.5	tabular	56/290	43	0.66	0.24	2.75	D	unknown	pyroxene
600	West	30.5	13.7	91.5	tabular	66/310	75	1.42	0.42	3.04	M	unknown	peridotite
4600	East	76.2	30.5	196.0	elliptical pipe	82/315	730	1.35	0.73	1.8	M at contact	zoned	pyroxene to peridotite: Ol-barren core to Cl-rich rim
4400	East	12.2	15.2	45.7	pipe	76/310	25	0.51	0.22	2.31	D	unknown	peridotite to pyroxene
4300	East	27.4	12.2	68.6	lenticular	61/310	56	0.91	0.51	1.78	D	zoned	Hb pyroxene
2200	East	15.2	15.2	238.7	pipe	75/330	122	0.68	0.38	1.79	D	unknown	peridotite to barren pyroxene
1900	East	15.2	24.4	91.5	pipe	63/300	41	0.86	0.45	1.91	D	zoned	Hb peridotite core to pyroxene to discontinuous Hb pyroxene
1800	East	15.2	24.4	45.7	pipe	60/120	36	0.53	0.23	2.3	D	zoned	peridotite to pyroxene
1700	East	3.7	3.7	15.2	pipe	1	2	0.51	0.22	2.31	D	unknown	dunite
1600	East	51.8	27.4	129.9	lenticular	66/320	196	0.97	0.34	2.85	M	zoned	dunite core to barren Hb peridotite
1400	East	15.2	15.2	142.7	pipe	65/310	46	0.71	0.32	2.21	D	unknown	peridotite to pyroxene
512	East	9.1	15.2	68.6	pipe and lenticular dykes	75/225	25	1.08	0.41	2.63	D	zoned	barren core to Cl pyroxene shell to Hb pyroxene and hornblende
Portal zone	East	8.1	9.1	15.2	pipe	2154	0.25	0.11	2.27	D	unknown	peridotite to Hb pyroxene	
2000	East	6.1	9.1	15.2	pipe	80/315	3	1.33	0.33	4.03	D	NT	unknown
1500	East	61.0	21.3	344.5	elliptical pipe	58/330	608	1.37	0.45	3.04	M-NT	unzoned	Hb peridotite and Hb pyroxene
Chinaman	East	27.4	30.5	194.5	elliptical pipe	68/300	341	0.73	0.3	2.43	D	zoned	Hb pyroxene to barren peridotite core
Climax	East	15.2	27.4	182.3	cylindrical pipe	63/330	191	0.78	0.36	2.16	D	zoned	peridotite to pyroxene

Modified after Christopher and Robinson (1975). * Orientation of pipe and tabular orebodies given as plunge/trend and dip/strike, respectively (right-hand rule); pipe-like orebodies are assumed where orebody shapes are not designated. ** M, massive/semi-massive; NT, not-textured; D, disseminated. *** Ol, olivine; Hb, hornblende.



Small-scale folds within layered sulphides (pyrrhotite, pentlandite and chalcopyrite) and olivine-rich peridotite grading downward into dunite with net-textured to disseminated sulphides. Sample was collected at the contact between barren dunite and barren peridotite where sulphide layers are steeply dipping (Pride of Emory orebody, sample 179-E-708; Aho, 1956).



Massive sulphide containing 2.55 wt% Ni and 3.78 wt% Cu with rounded silicate (ultramafic) clasts (Po, pyrrhotite; Cpy, chalcopyrite; 3550 Level adit area, sample RHP01-076; photo by R. H. Pinsent).

BC Geological Survey
GEOSCIENCE MAP 2015-01

Geology, Geochronology and Ni-Cu-PGE Orebodies of the Giant Mascot Ultramafic Intrusion, Hope, Southwestern British Columbia

parts of NTS 092H/05 and 06

Sheet 2 of 2

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*PCIGR, University of British Columbia **BC Geological Survey ***Geological Survey of Canada

TABLE 1. Giant Mascot mine and exploration history

Date	Activity	Owner
1923	Nickel showings first discovered at Pride of Emory by Carl Zofka	
1927-1933	Surface exploration	B.C. Nickel Co.
1933	Underground development began	B.C. Nickel Mines Ltd.
1937	3550 (No. 1 tunnel) and 3275 (No. 2 or Chinaman tunnel) developed	
	1.2 Mt of ore mined at 1.38% Ni and 0.50% Cu	
	Property closed down - all drill core lost	
1938-1952	Exploration programs resumed	Pacific Nickel Mines Ltd.
1951	Pulse survey conducted by Newmont Exploration Co.	
1952	Electromagnetic and magnetometer surveys conducted by McArthur Geophysics	
	Pacific Nickel Mines Ltd. and Newmont Mining Corp. of Canada merge	Western Nickel Mines Ltd.
	2600 (main haulage), 2950, and 3250 levels developed; levels connected with internal inclined shaft	
1958	Mining began	
	July 1958: Closed due to market conditions	
1959	Newmont Mining Corp. sold property interest to Giant Mascot Mines Ltd.	
	Giant Mascot Mines Ltd. opened mine as salvage operation	
	Giant Mascot Mines Ltd. purchased Pacific Nickel Mines Ltd. and gained full control	Giant Mascot Mines Ltd.
1961	November: mine closed due to collapse of a Brunswick stope	
1968	August: mine closed due to mill burning down	
1970	Mine production	
1988-1994	4.2 Mt of ore mined at 0.77% Ni, 0.34% Cu, minor Co, Ag, Au	Mascot Gold Mines Ltd.
1980	Ownership of mine transferred to Mascot Gold Mines Ltd.	
1986	Exploration programs resumed with a focus on Au and PGE mineralization	
1988	Mascot Gold Mines Ltd. was acquired by International Corona Corp.	International Corona Corp.
1992	Homestake Canada Ltd. acquired International Corona Corp.	Homestake Canada Ltd.
	Began reclamation of the Giant Mascot Mine, sealed portals, groomed dumps, and seeded tailings	
2001	Filled a glory hole exposing the Pride of Emory and Brunswick deposits	
2001	December: Final acquisition of Homestake Canada Ltd. by Barrick Gold Corp.	Barrick Gold Corp.
2001-present	Reclamation of the Giant Mascot Mine by Barrick Gold Corp.	

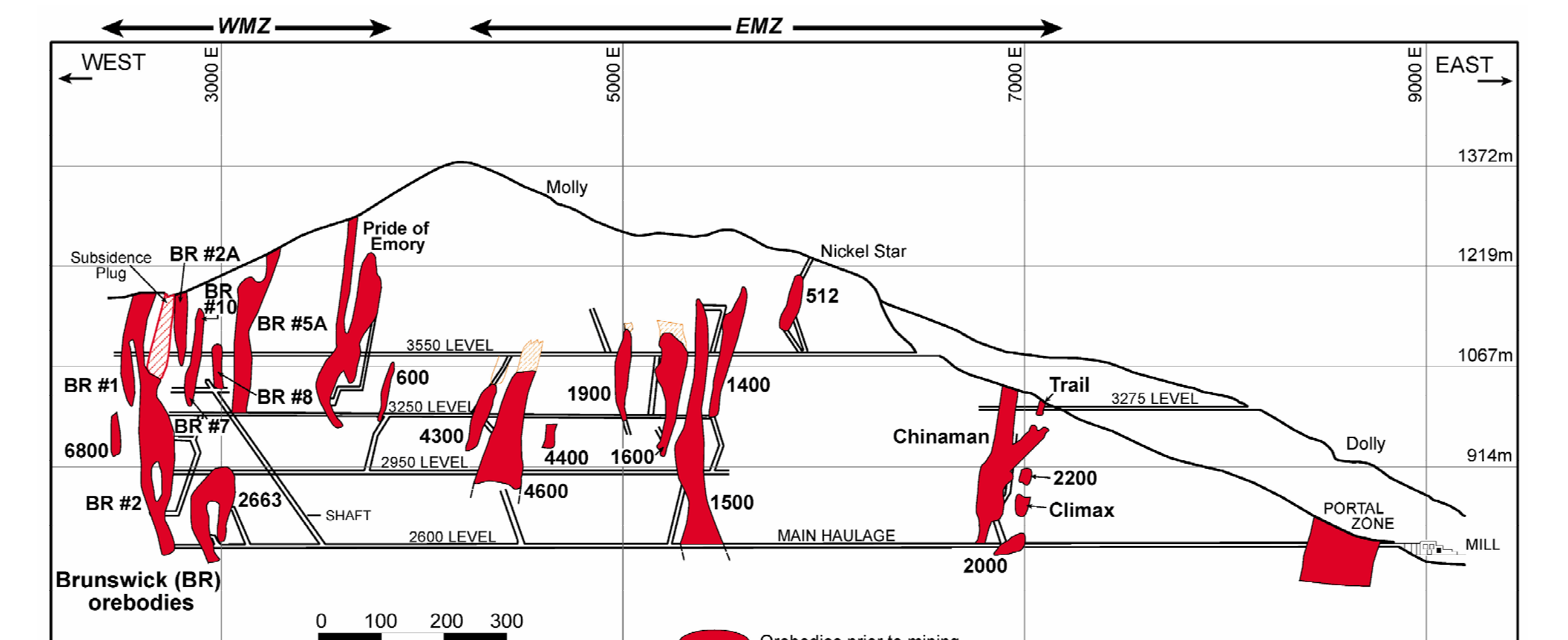
Giant Mascot Ni-Cu-PGE Orebodies

The Giant Mascot orebodies were discovered in 1923 by Carl Zofka at the Pride of Emory showing. Underground development and mining began in the 1930s and continued intermittently under various operators until mine closure in 1974 (Table 1, and Pinsent, 2002). Statistics for 28 orebodies are given in Table 2, and detailed plans and sections of selected orebodies are reproduced from Aho (1954, 1956), Clarke (1969), and McLeod (1975).

The main mineralized zone trends N76°W through Zofka Ridge. Sulphide ore zones have steep attitudes and form pipe-like, lenticular and tabular bodies measuring 4-76 m in length, 4-31 m in width and 15-345 m in vertical extent. The orebodies are classified as zoned or unzoned based primarily on ore textures. Zoned ore shoots are concentrically zoned, predominantly pipe-like bodies with a core of massive or semi-massive ore surrounded by a shell of disseminated to net-textured sulphide (e.g. Brunswick No. 1, 5 and 512). Massive and semi-massive mineralization containing up to 50 vol% crystals of olivine and/or orthopyroxene occurs in unzoned orebodies that are lenticular or pipe-like in shape (e.g., Brunswick No. 2, 8 and 9). The cores of both types of orebody are intimately associated with dunite, olivine-rich peridotite or less commonly orthopyroxene, and locally contain rounded to irregular inclusions of ultramafic wallrocks and nonitic schlieren. In addition to the textural variation of sulphides, zoned orebodies commonly exhibit an outward zonation from olivine-rich to olivine-poor host rocks. Unzoned massive orebodies may exhibit layered sulphides at their margins with rare, small-scale folds that formed while the cumulates were still mobile (e.g., Pride of Emory). Contacts between orebodies or their ultramafic host rocks and barren wallrocks are sharp to gradational over several centimetres, and are accompanied by distinct textural and mineralogical differences (Aho, 1956).

The highest Ni grades (~5 wt%) are associated with dunite-hosted ore (e.g., Brunswick No. 5 and 6; Aho, 1956). Overall, the sulphide ores have high tenors (3-14 wt% Ni, 0.1-17.1 wt% Cu, 84 ppb to 5 g/t total PGE; recalculated to 100 wt% sulphide). Iridium-group PGE contents distinguish two magma types in the western mineralized zone (WMZ) and eastern mineralized zone (EMZ). Platinum-group minerals are predominantly bismuthotellurides (monchete, merenskyite, palladian melonite) and minor arsenide (sperrylite), derived via exsolution from base metal sulphides during cooling (Manor et al., 2014; Manor 2014).

The geometry, internal features and contact relationships of the ore-bearing structures are consistent with them representing magmatic conduits, a possibility originally recognized by Aho (1956). Certain orebodies are cored by virtually barren pyroxene (e.g., 1900), potentially indicative of multiple injection; others have arcuate shapes indicating that they may have formed by wedging out of injected crystal-rich magma in blind conduits, or possibly through partial collapse and infilling of channelways by wallrock cumulates that were poorly consolidated (e.g., 512). These narrow conduits, formed under dynamic conditions, pose a significant challenge to exploration, yet the presence of PGE-enriched, high tenor sulphides underscores the potential for economic Ni-Cu-PGE deposits in convergent margin environments.



Longitudinal west-east section of the Giant Mascot sulphide deposit distinguishing orebodies of the western mineralized zone (WMZ) from those of the eastern mineralized zone (EMZ). Section extends from the Brunswick (BR) orebodies in the west to the Portal Zone and mill in the east. Note the two topographic profiles in the east (modified after Clarke, 1969; Christopher and Robinson, 1975).

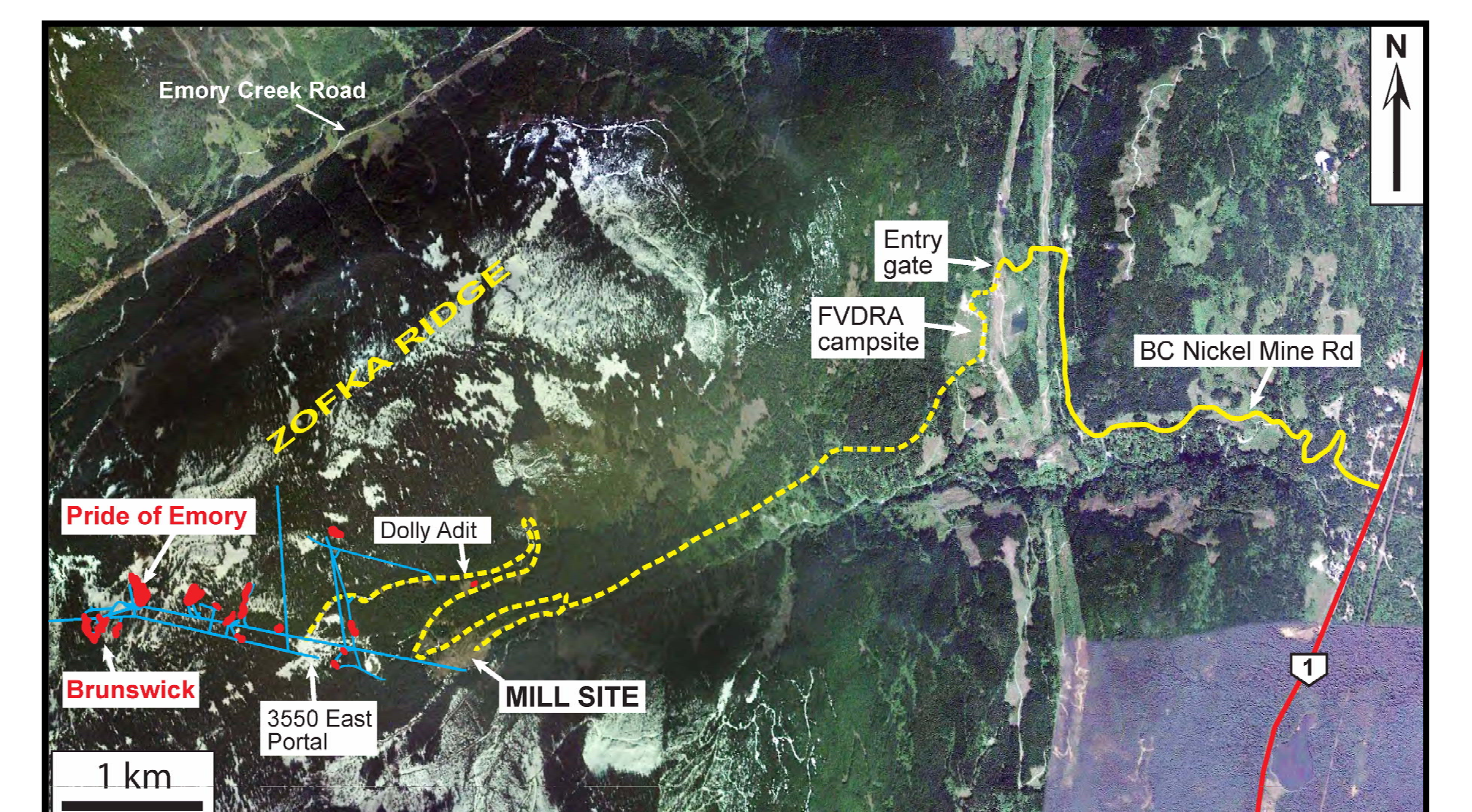


Image of Giant Mascot mine showing major orebodies and tunnels (projected to surface), and access roads (solid) and trails (dashed) to the mine site (FVDR, Fraser Valley Dirt Rider's Association; Google Earth, 2010; after Manor, 2014).