Pantellerite-hosted rare earth element mineralization in southeast Labrador: The Foxtrot deposit

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1. Introduction

The Foxtrot rare earth element (REE) deposit is hosted by peralkaline volcanic rocks, primarily pantellerite and commendite flows and ash-flow tuffs, of the Fox Harbour Volcanic belt in southeast Labrador, near the coastal community of St Lewis (Fig. 1). Search Minerals personnel discovered the deposit in 2010 as a result of a REE exploration program in southeast Labrador. Exploration diamond drilling in late 2010, 2011, and early 2012, totalling 72 diamond-drill holes and 18,855 metres, outlined a Dy-Nd-Y-Tb deposit of 9.2 million tonnes indicated resource (cut-off 130 ppm Dy), grading 189 ppm Dy, 1442 ppm Nd and 1040 ppm Y, and, 5.2 million tonnes inferred resource, grading 176 ppm Dy, 1233 ppm Nd, and 974 ppm Y (Table 1; Srivastava et al., 2012, 2013). A smaller high-grade resource (HGC) was also defined (Table 1) and was the subject of a Preliminary Economic Assessment (Srivastava et al., 2013). The Foxtrot deposit and the Fox Harbour Volcanic belt have been the target of continued REE exploration and the subject of engineering and metallurgical studies (Srivastava et al., 2012, 2013; Search Minerals 2014, 2015b) to evaluate the possibility of developing a REE mine at Foxtrot and a REE processing plant in the St. Lewis area (Fig. 1).

Herein we outline the geology and mineralization of the Foxtrot REE deposit and develop a preliminary exploration model for REE mineralization in the Fox Harbour Volcanic belt and related belts in southeast Labrador.

2. Regional geological setting

Terranes in the eastern Grenville Province (Fig. 1) are distinguished on the basis of rock types, structures, ages, and metamorphic signatures, and are separated by major fault zones (Gower et al., 1987, 1988; Hanmer and Scott, 1990; Gower, 2010, 2012). The Foxtrot deposit is in the Fox Harbour Volcanic belt, which is part of the Fox Harbour domain. Single zircon U-Pb crystallization ages indicate that the peralkaline rocks and related mineralization at Foxtrot are 1.3 Ga (Haley, 2014). The Fox Harbour domain is bounded to the north by the Lake Melville terrane, to the west and southwest by the Mealy Mountains terrane, and to the south by the Pinware terrane (Fig. 1). Compilations of U-Pb zircon crystallization age data for rocks in southeastern Labrador indicate that the Lake Melville and Mealy Mountains terranes contain rocks older than 1.6 Ga and the Pinware terrane contains rocks with ages of 1.5 Ga (Gower, 2012).

The Lake Melville terrane contains the Alexis River anorthosite, biotite-bearing granite, granodiorite, and quartz diorite to diorite gneiss (Gower et al., 1987, 1988; Hanmer and Scott, 1990; Gower, 2010;). The Fox Harbour fault zone (Gower, 2012) separates the Lake Melville Terrane from the Fox Harbour domain. Near the Foxtrot deposit, terrane boundary interpretations (Gower, 2012) indicate that a thin sliver (5-6 km wide) of Mealy Mountains terrane occurs between the Lake Melville terrane to the north and the Pinware terrane to the south. Detailed mapping indicates that the Fox Harbour domain, is in the northern half (2-3 km wide) of the sliver and that the Deer Harbour domain is in the southern half.

Near the Foxtrot deposit, the Fox Harbour domain is bordered to the south by the Deer Harbour fault zone (Fig. 1). The Fox Harbour domain has been traced for 64 km; to the northwest it is cut off by a fault, to the east it disappears beneath the Labrador Sea. REE mineralization, peralkaline felsic and mafic volcanic rocks (Fox Harbour Volcanic suite) and an associated anorthositic gabbro distinguish this domain from adjacent domains and terranes. Feldspar porphyries and deformed augen gneisses also occur in this domain.

The Mealy Mountains terrane consists of mostly biotite granitic gneiss, potassium feldspar megacrystic granite gneiss, quartz diorite to dioritic gneisses, and pelitic to semipelitic sedimentary gneisses (Gower et al., 1987, 1988; Gower, 2010).

The Pinware terrane, in the St. Lewis Inlet area, consists of metamorphosed felsic to intermediate intrusions and older intercalated quartzofeldspathic supracrustal rocks. Intrusions consist mainly of granite, k-feldspar megacrystic granite, quartz monzonite, granodiorite, and supracrustal rocks consisting mainly of felsic volcanic rocks and arenitic sedimentary rocks (Gower, 2007, 2010). The Long Harbour fault zone (Gower, 2012) is interpreted to separate the Deer Harbour domain from the Pinware terrane to the south.

Mapping and exploration south of the Long Harbour fault zone indicate that peralkaline volcanic and intrusive rocks

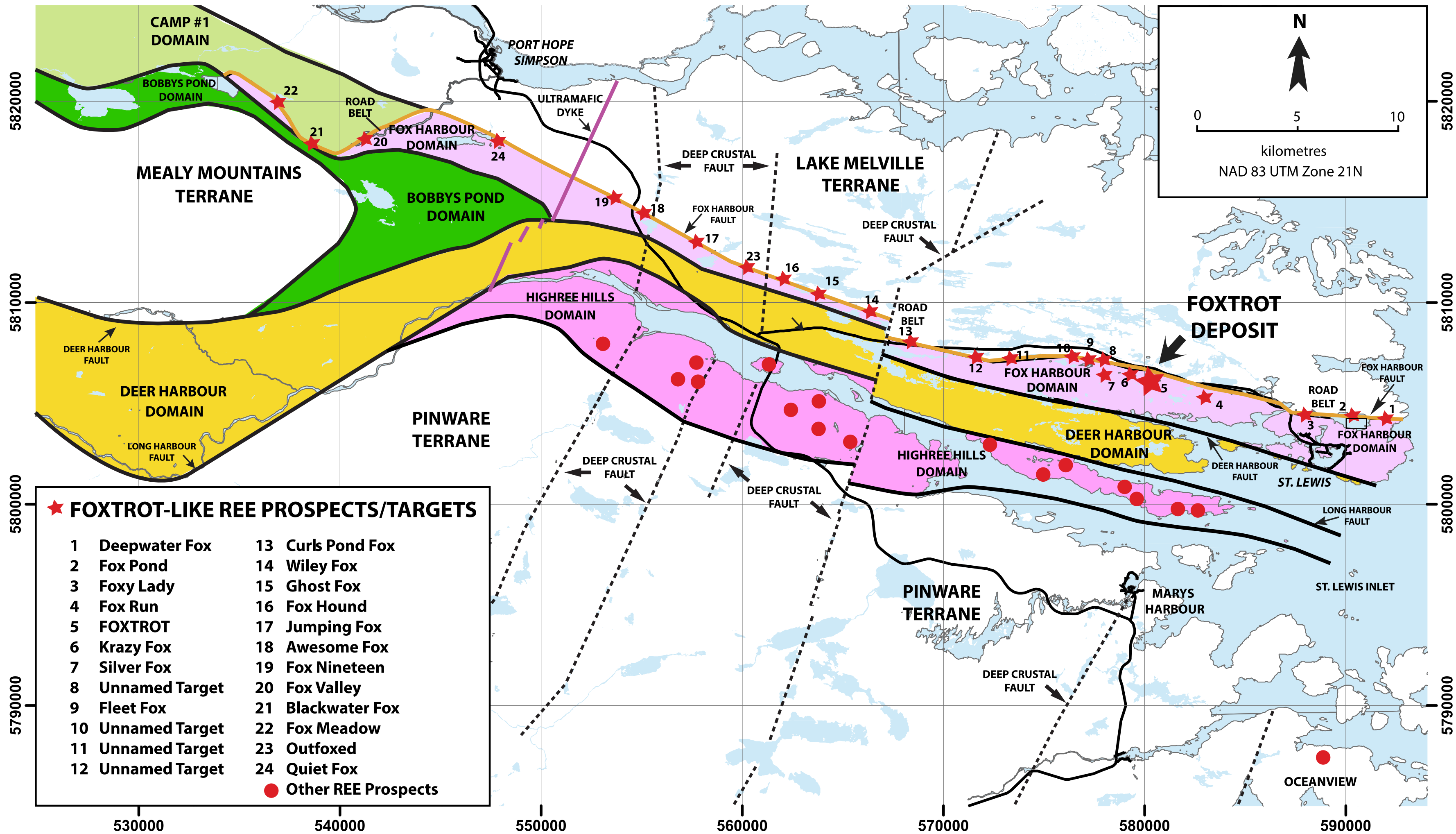

Fig. 1. Rare earth element prospects and targets in the Port Hope Simpson – St. Lewis area, southeast Labrador. Terrane boundaries are modified from Gower (2012). The Fox Harbour Volcanic belt, host to the Foxtrot REE mineralization is in the Fox Harbour domain; the pale brown line corresponds to a marker horizon and is referred to as the Road belt. The HighREE Hills domain also hosts REE mineralization. All domain names are informal.

Table 1. Foxtrot resource (September, 2012).

	Foxtrot Resource		**Foxtrot HGC**	
	Foxtrot Inferred	Foxtrot Indicated	HGC Inferred	HGC Indicated
	5,165,000 (tonnes)	9,229,000 (tonnes)	660,000 (tonnes)	3,423,000 (tonnes)
Y	974	1,040	1,199	1,238
Zr	10,064	9,619	11,716	11,779
Nb	538	626	676	691
La	1,426	1,646	1,894	1,931
Ce	2,881	3,337	3,861	3,945
Pr	330	384	443	455
Nd	1,233	1,442	1,658	1,711
Sm	228	262	302	312
Eu	11.0	13.0	15.0	16.0
Gd	183	205	238	245
Tb	30.0	33.0	38.0	39.0
Dy	176	189	219	228
Ho	34.0	37.0	43.0	44.0
Er	98	103	121	125
Tm	14.0	15.0	17.0	18.0
Yb	91	92	108	111
Lu	14.0	14.0	16.0	16.0
LREE	6,098	7,071	8,158	8,354
HREE	651	701	815	842
HREE + Y	1,625	1,741	2,014	2,080
TREE	6,749	7,772	8,973	9,196
TREE + Y	7,723	8,812	10,172	10,434
%TREE	0.67%	0.78%	0.90%	0.92%
%TREE + Y	0.77%	0.88%	1.02%	1.04%
%HREE	8.43%	9.02%	9.08%	9.16%
%HREE + Y	21.04%	19.76%	19.80%	19.93%

Note:	All amounts parts per million (ppm). 10,000 ppm = 1% = 10 kg/tonne.
REE	Rare Earth Elements: La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu (Lanthanide Series).
TREE	Total Rare Earth Elements: Add La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu.
LREE	Light Rare Earth Elements: Add La, Ce, Pr, Nd, Sm.
HREE	Heavy Rare Earth Elements: Add Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu.
Y	Y not included in HREE due to relatively low value compared to most Lanthanide series HREE.
%HREE+Y	%(HREE+Y)/(TREE+Y).
%HREE	%(HREE/ TREE).
HGC	Subset of mineral resource within a contiguous volume; estimated inside preliminary pit shell.

and related REE mineralization (e.g., Search Minerals 2010a, 2010b) also occur in an area interpreted to be Pinware terrane (Gower, 2012). These rocks and spatially associated non-peralkaline supracrustal rocks have been grouped into the HighREE Hills domain (Fig. 1). The HighREE Hills domain contains peralkaline volcanic and subvolcanic rocks and related pegmatite- and vein-hosted REE mineralization. Several REE prospects have been discovered in the HighREE Hills (see Search Minerals 2010a, 2010b).

3. Fox Harbour Volcanic belt

The Fox Harbour Volcanic belt is about 64 km-long and ranges in width from <50 m in the northwest to 3 km in the east. Units strike westerly to northwesterly, parallel to bounding faults, and dip steeply northward. The belt contains one (in the northwest) to three (in the east) sub-belts of bimodal rocks with mainly REE-bearing felsic peralkaline flows and ash-flow tuffs and mafic to ultramafic volcanic and related subvolcanic units. Feldspar augen gneisses and porphyritic units, including crystal tuffs in the eastern portion of the belt, predominantly occur between the three sub-belts. Sedimentary supracrustal units, including quartzite and locally derived volcaniclastic rocks sourced by felsic (commonly peralkaline) and mafic units, are locally abundant.

The three bimodal sub-belts (Road belt, Magnetite belt and South belt) have been the focus of REE exploration. The Road belt, is on the northern boundary of the Fox Harbour Volcanic belt, and can be traced throughout its full length, but the Magnetite and South belts have only been observed in the eastern 30 km. The mineralized units within the sub-belts, predominantly pantellerite (a peralkaline rhyolite with high Fe and low Al contents) and commendite (similar to pantellerite but with less Fe and more Al), outcrop poorly and commonly occur in bogs or water-filled topographic lows. These units exhibit relatively high radiometric (anomalous U and Th values) and relatively high magnetic (anomalous concentrations of magnetite) signatures that, when combined, are excellent indicators of REE mineralization. Airborne and ground-based radiometric-magnetic surveys clearly outline the three mineralized belts (Srivastava et al., 2012, 2013).

High-grade mineralization, characterized by Dy from 100–300 ppm, is predominantly hosted by fine-grained, layered to massive, pantellerite. Lower grade mineralization, characterized by Dy from 20–100ppm, is predominantly hosted by fine-grained, mostly massive commendite. Mineralized units are commonly interbedded with mafic volcanic units, quartzite, and locally derived volcanogenic sedimentary rocks.

Most of the REE mineralization occurs in allanite and fergusonite; minor amounts of REE occur in chevkinite, monazite, bastnasite and zircon (Srivastava et al., 2012, 2013). Most of the light REE (i.e., La to Sm) in the mineralization occurs in allanite, whereas most of the heavy REE (i.e., Eu to Lu) and Y occurs in both fergusonite and allanite (Srivastava et al., 2012, 2013).

The Road belt commonly consists of non-peralkaline porphyritic feldspar-bearing units, mafic volcanic rocks, non-peralkaline felsic volcanic units, commendite, and pantellerite. A medium-grained anorthositic gabbro, with minor amounts of gabbro, always occurs north (i.e., within 25 m) of Road belt volcanic units on the southern side of the Fox Harbour fault zone. Mineralized units commonly range from 1 to 10 m thick. The Road belt hosts several significant REE prospects with high-grade REE mineralization including the Fox Pond, Fox Valley, Fox Meadow, and Deepwater Fox prospects (Fig. 1; Search Minerals, 2012, 2013, 2015a). High-grade plus medium-grade mineralization at some of these prospects ranges from 10 to 30 m thick.

The Magnetite belt commonly consists of pantellerite, commendite, non-peralkaline rhyolite, and mafic to ultramafic volcanic and related subvolcanic units. Mineralized units commonly range from 5 to 20 m thick. This belt hosts the Foxtrot deposit and additional REE prospects (e.g., Silver Fox and Fox Run; Fig. 1). Mineralization is up to 100m thick (commendites plus pantellerites) at the Foxtrot deposit; high-grade mineralization is up to 25 m thick but usually averages 10 to 14 m.

Lower grade REE mineralization is commonly found in the South belt. This sub-belt commonly consists predominantly of commendite, minor mafic and pantelleritic units, feldspar-bearing porphyry and locally abundant volcanogenic sedimentary rocks. Mineralization is commonly 10 to 50 m thick.

4. Foxtrot deposit

The Foxtrot deposit is about 8 km west of St. Lewis and 0.5 km south of Highway 513 in the Magnetite sub-belt of the Fox Harbour Volcanic belt (Figs. 1-3). Near the Foxtrot deposit, the Magnetite belt consists of, from north to south: 1) commendite; 2) pantellerite with interlayered non-peralkaline rhyolite; and 3) a mafic to ultramafic unit with interlayered non-peralkaline rhyolite. Minor units of locally derived volcanogenic sedimentary rocks, mafic volcanic rocks and related subvolcanic units, and pegmatites occur throughout this sequence. Augen/porphyritic gneiss borders the mineralized units to the north, and a mafic unit, forming a predominant ridge, occurs to the south. Table 2 lists representative REE, Nb, Y, and Zr data for the major units at the deposit.

The commenditic mineralization, which is approximately 50 m thick, consists of individual units of fine-grained, commonly <1 to 2 m thick, massive to poorly layered commendite. These commendites commonly contain trace to minor magnetite, exhibit radioactivity 3-5 times higher than background levels, and contain lower amounts of REE (e.g., 20–60 ppm Dy) and other incompatible elements (Table 2) relative to other mineralized units. Zirconium values commonly range from 800 to 5000 ppm.

The pantelleritic mineralization, up to 30 m thick, consists of individual units of fine-grained, commonly <1 to 5 m thick, poorly to well-layered pantellerite. These pantellerites contain up to 10% magnetite and local amphibole and pyroxene;

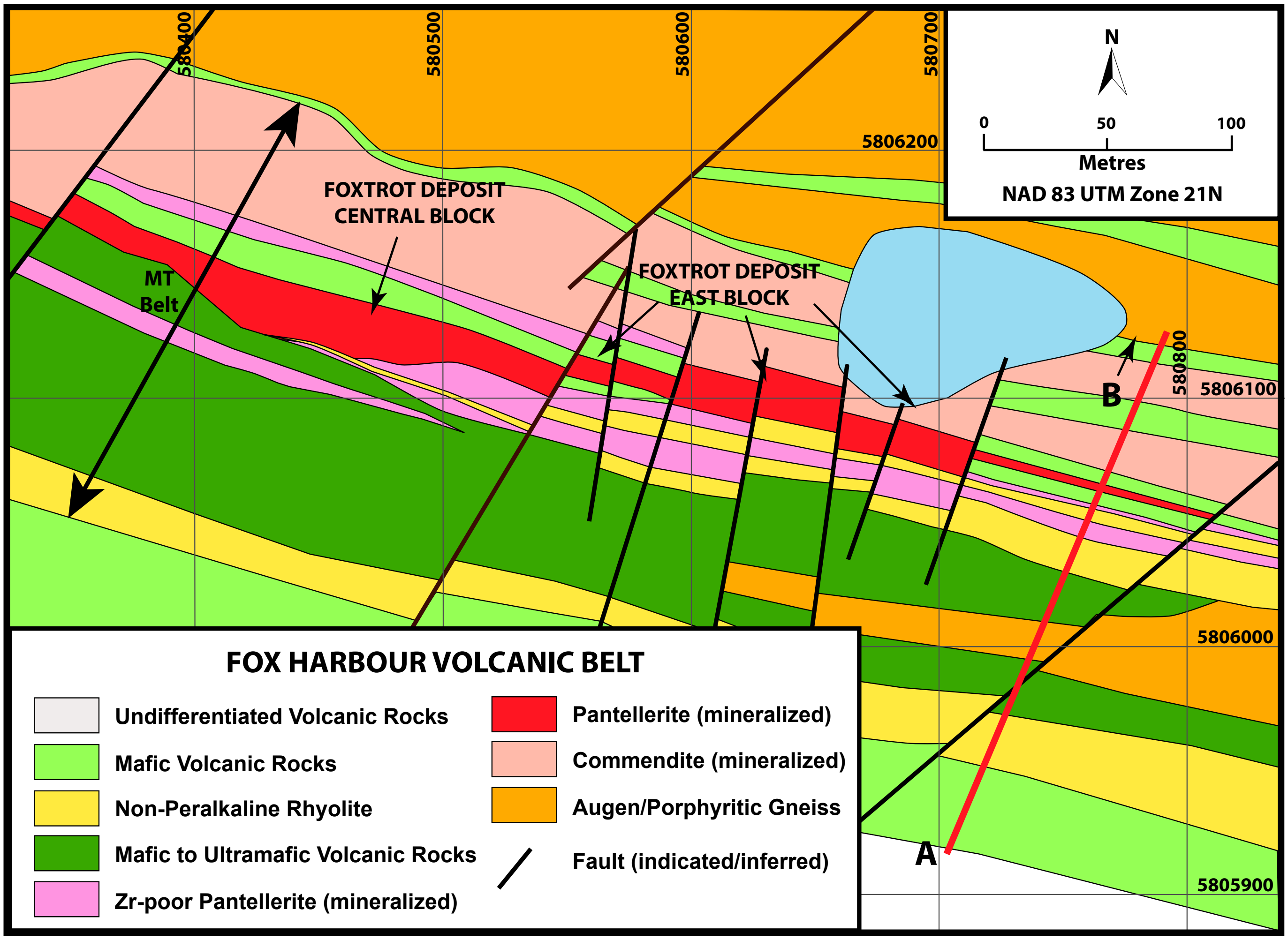

Fig. 2. Geology of the Foxtrot deposit based on 25 metre spacing ground magnetic survey, detailed mapping, channeling, core logging, and chemical analysis. Section A-B illustrated in Figure 3.

magnetite is mostly fine grained but may occur as porphyritic grains up to 4 mm across. They exhibit radioactivity from 5 to 40 times background. Layering in the units, observed as darker and lighter bands, is commonly defined by varying contents of magnetite. These units are relatively highly mineralized and contain potentially economic concentrations of REE (e.g., 60–300 ppm Dy) and other incompatible elements (Table 2). Differences in average Zr values subdivide the pantellerites into two mappable units: Zr-poor Pantellerite (5000–10,000 ppm Zr) and Pantellerite (10,000–15,000 ppm Zr); Zr-enriched pantellerite (>15,000 ppm Zr) is also observed but is commonly <1 m thick and is not depicted in Figures 2 or 3. The mineral resource at Foxtrot essentially encompasses the pantelleritic units. However, the high-grade core (Table 1), which is the main focus of development plans (Srivastava et al., 2013), includes mostly pantellerites with over 10,000 ppm Zr.

Mafic volcanic and locally derived sedimentary units, commonly <0.5 m thick, separate many mineralized units. Thicker mafic units, up to 10 m thick, occur in the commenditic unit and near the contact between the commenditic and pantelleritic units. Mafic units commonly contain <300 ppm Zr and <10 ppm Dy.

Locally derived sedimentary rocks consist of thin (<20 cm) quartzite layers interbedded with thin (<30 cm) mafic and felsic bands. Felsic bands consist of non-peralkaline rhyolite, commendite, low Zr pantellerite, or a mix of mafic and felsic volcanic rocks.

Ultramafic units up to 90 m thick contain epidote-bearing fragments and appear layered. Zirconium and Dy values are commonly <100 ppm and <4 ppm respectively. These units mostly occur to the south of the pantelleritic mineralization.

Several units of non-peralkaline rhyolite, <1 to 8 m thick, occur within the mineralized zones, particularly in the eastern part of the deposit (Figs. 2, 3). They are commonly associated with low-Zr pantellerite, mafic rocks, and locally derived sedimentary rocks. Non-peralkaline rhyolite contains low Zr values (300–600 ppm), low Dy values (<12 ppm) and low mafic mineral concentrations (commonly <5%).

Detailed geological mapping, a 25 m-spaced detailed ground magnetometer survey (Srivastava et al., 2013), radiometric prospecting, and 12 channels, cut throughout the mineralized zone, were used to compile the surface geology of the deposit

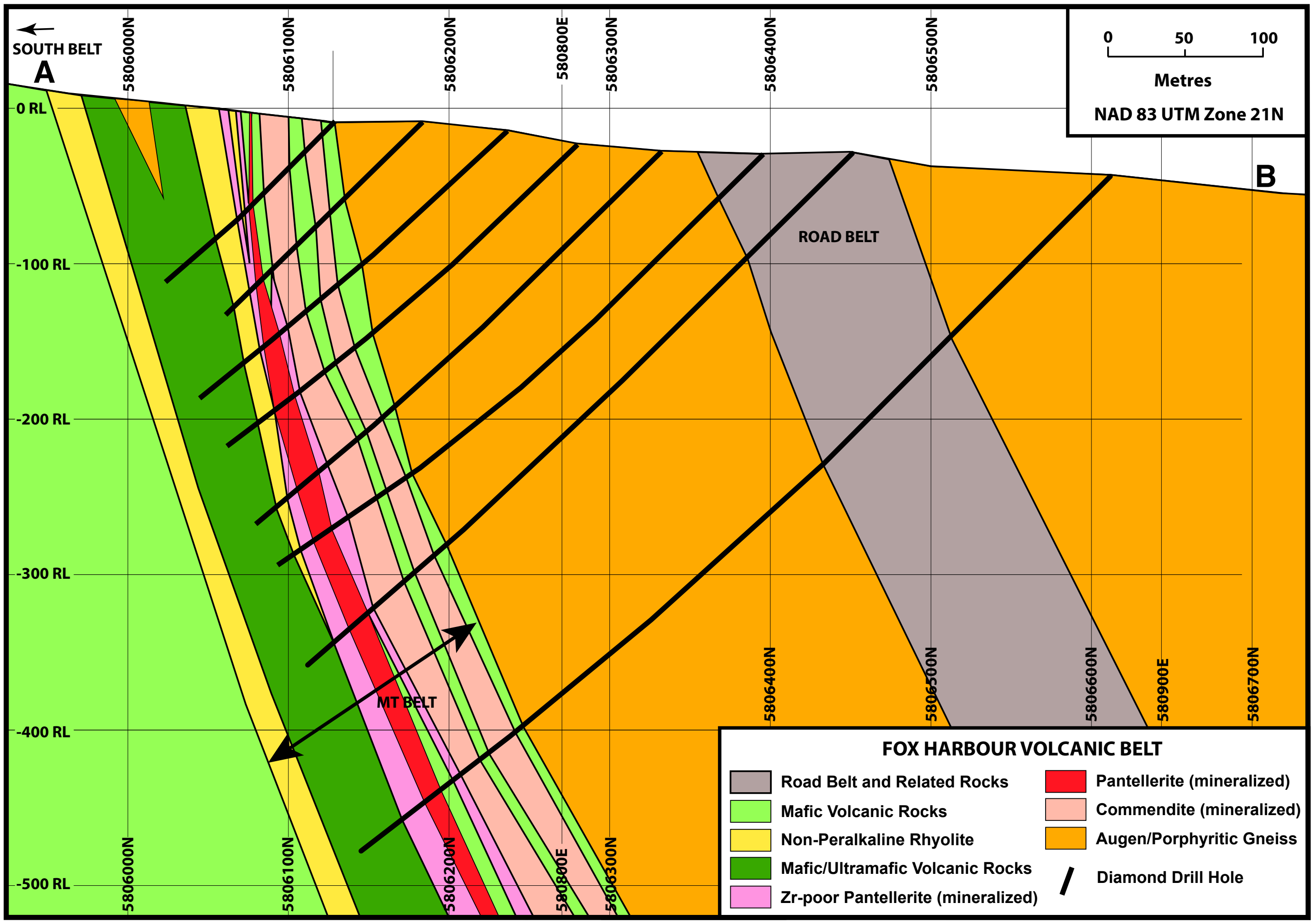

Fig. 3. Foxtrot deposit in NNE-SSW cross-section. View to the northwest along line A-B (Fig. 2); no vertical exaggeration. Drillholes are perpendicular to the general strike of the volcanic stratigraphy (Fig. 2), whereas the thickest and highest grade portion of the deposit plunges to the NE. This results in a thin zone of high-grade mineralization at surface that thickens at depth. Road belt, MT belt (Magnetite belt) and South belt (300m south of A) contain REE mineralized peralkaline volcanic rocks.

(Fig. 2). Faults, defined by the geology, magnetic survey offsets, and topographic lineaments, divide the deposit into two major blocks, the Central block and the East block. The observed faults are northerly to northeasterly striking and steeply dipping, with up to 15 m observed horizontal offset and an unknown amount of vertical offset.

The vertical movement on the faults appears to have been partly responsible for changes along strike in the thickness of units, including the mineralization, and the presence or absence of specific units. Change in the thickness of mineralization is observed across the western boundary of the Central block and across the eastern boundary of the East block (Fig. 2). Non-peralkaline rhyolite is prominent in the East block, where it commonly occurs as two units, and very minor in the Central block, where it occurs as one thinner unit or is absent. Similar changes in thicknesses and absence or presence of specific units also occurs across smaller faults in the East block and may also occur in the Central block, but corroborating data are lacking.

5. Discussion

The peralkaline mineralized units and spatially associated mafic-ultramafic, non-peralkaline rhyolite and locally derived sedimentary units of the Foxtrot deposit are interpreted to represent a subaerial bimodal sequence of volcanic and related volcanogenic sedimentary rocks and subvolcanic intrusions (e.g., Marshall et al., 2009). The probable mantle derivation of the peralkaline and mafic to ultramafic rocks, the subaerial setting, the occurrence on 1.5 to 1.6 Ga continental crust and the occurrence of these units in a narrow belt over a strike-length of at least a 64 km are consistent with a continental rift setting. Possible modern analogues would include Pantelleria (e.g., Civetta et al., 1998) and the East African Rift (e.g., Marshall et al., 2009).

Peralkaline volcanic and intrusive rocks of similar age to the Fox Harbour Volcanic belt are also found in central and northern Labrador (Miller et al., 1996; Gower, 2012). These include REE mineralized peralkaline volcanic rocks, mainly pantellerite (Nuiklavik Volcanic suite; Miller, 1993), REE mineralized peralkaline intrusive rocks, granites-syenites

Table 2. Representative content of REE, Nb, Y and Zr in major rock units, Foxtrot deposit.

	Unmineralized Units		**Mineralized Felsic Volcanic Rocks**			
	NPR	Mafic	Commendite	Low Zr	Pantellerite	High Zr
	FTC-11-08	FTC-11-12	FTC-12-02	FTC-11-12	FTC-11-12	FTC-15-07A
From (m)	16.00	19.70	5.43	0.16	6.87	5.9
To (m)	16.90	20.85	6.23	0.42	7.88	6.05
Interval (m)	0.90	1.15	0.80	0.26	1.01	0.15
Y	51	17	135	620	1260	1428
Zr	404	67	1746	7028	11560	16600
Nb	32	6	87	767	832	621
La	70	6	142	1150	2160	1770
Ce	163	13	299	2350	4260	4180
Pr	18	2	37	269	481	488
Nd	62	9	142	1020	1810	1880
Sm	11	3	27	182	329	356
Eu	0.5	0.9	4.2	10.2	16.3	17.8
Gd	9	3	24	145	245	267
Tb	1.5	0.1	4.3	21.5	38.7	44
Dy	9	4	28	116	234	268
Ho	1.7	0.1	5.8	22.5	43.3	49.9
Er	5	2	17	62	127	144
Tm	0.8	0.3	2.5	9.0	18.4	20.5
Yb	5	2	16	56	113	126
Lu	0.9	0.3	2.4	8.2	17.1	18.1
LREE	324	33	647	4971	9040	8674
HREE	34	12	104	451	853	955
HREE + Y	85	29	239	1071	2113	2383
TREE	358	45	751	5422	9893	9629
TREE + Y	409	62	886	6042	11153	11057
%TREE	0.04%	0.00%	0.08%	0.54%	0.99%	0.96%
%TREE + Y	0.04%	0.01%	0.09%	0.60%	1.12%	1.11%
% HREE	9.42%	27.24%	13.80%	8.31%	8.62%	9.92%
%HREE + Y	20.73%	47.28%	26.94%	17.72%	18.94%	21.55%

Note:	All amounts parts per million (ppm). 10,000 ppm = 1% = 10 kg/tonne.
REE	Rare Earth Elements: La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu (Lanthanide Series).
TREE	Total Rare Earth Elements: Add La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu.
LREE	Light Rare Earth Elements: Add La, Ce, Pr, Nd, Sm.
HREE	Heavy Rare Earth Elements: Add Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu.
Y	Y not included in HREE due to relatively low value compared to most Lanthanide series HREE.
%HREE+Y	%(HREE+Y)/(TREE+Y).
%HREE	%(HREE/ TREE).
NPR	Non-peralkaline Rhyolite.
Low Zr	Zr-poor Pantellerite.
High Zr	Zr-enriched Pantellerite.
Mafic	Mafic to Ultramafic Volcanic Unit.

(Strange Lake; Miller, 1996, Miller et al., 1996; Two Tom Lake syenite; Miller, 1987, 1988), and undersaturated syenites (Red Wine suite; Miller, 1987, 1988). In all these examples, peralkaline rocks, hosting the REE mineralization represent low-volume late differentiates of high-level (crustal) magma chambers. For intrusions the mineralization occurs in late pegmatites, vein systems, or small-volume intrusions at or near the top of the source magma chamber. In the volcanic settings the mineralization occurs as vent filling or near-vent magma flows and/or ash-flow tuffs (Miller, 1993).

Mineralized pantellerites, containing extreme concentrations of REE and other incompatible elements (e.g., Zr, Nb, Y; Table 2), are very rare and must represent extreme differentiation of peralkaline or near peralkaline magma in crustal magma chambers. The 1.3 Ga (Haley, 2014) Foxtrot deposit occurs on 1.5 to 1.6 Ga continental crust (Gower, 2012). The mineralized pantellerite at Foxtrot, using a strike length of 400 m, average width of 20 m and known depth of 500 m (Figs. 2, 3) gives a volume of pantellerite of less than 0.01 km^3. Such small volumes of pantelleritic magma, occurring in a continuous unit, must occur within or near the source vent. Widespread dispersal of this volume of mineralized pantellerite from other vents would result in very thin units, perhaps represented by less than 1 m-thick units throughout the Fox Harbour Volcanic belt.

6. Conclusion

The exploration program at the Foxtrot deposit reveals the relationship between peralkaline volcanic rocks, vent or near-vent locations, and significant REE mineralization. The deposit is being used as a model for further exploration in the Fox Harbour Volcanic belt.

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References cited

Civetta, L., D'Antonio, M., Orsi, G., and Tilton, G.R., 1998. The geochemistry of volcanic rocks from Pantelleria Island, Sicily channel: petrogenesis and characteristics of the mantle source region. Journal of Petrology, 39, 1453-1491.

Gower, C.F., 2007. Protolith recognition of metamorphosed volcanic/volcaniclastic rocks, with special reference to the Grenville Province in southeast Labrador. In Current Research. Newfoundland and Labrador Department of Natural Resources, Geological Survey, Report 07-1, 11-23.

Gower, C.F., 2010. Geology of the St. Lewis River area (NTS sheets 03D/04 and 05; 13A/01, 02, 07 and 08), southeastern Labrador. Geological Survey, Mines Branch, Department of Natural Resources, Government of Newfoundland and Labrador, Map 2010-24, Open File LAB/1566.

Gower, C.F., 2012. The Grenville Province of southeast Labrador and adjacent Quebec. Geological Association of Canada – Mineralogical Association of Canada, Joint Annual Meeting, St. John's, Field Trip Guidebook – B6, 140 pp.

Gower, C.F., Neuland, S., Newman, M., and Smyth, J., 1987. Geology of the Port Hope-Simpson map region, Grenville Province, eastern Labrador. In Current Research. Newfoundland Department of Mines, Mineral Development Division, Report 87-1, 183-199.

Gower, C.F., van Nostrand, T., and Smyth, J., 1988. Geology of the St. Lewis River map region, Grenville Province, eastern Labrador. In Current Research. Newfoundland Department of Mines, Mineral Development Division, Report 88-1, 59-73.

Haley, J.T., 2014. 1.3 Ga bimodal volcanism in southeastern Labrador: Fox Harbour. Unpublished M.Sc. thesis, Memorial University of Newfoundland, St. John's, Canada, 204p.

Hanmer, S., and Scott, D.J., 1990. Structural observations in the Gilbert River Belt, Grenville Province, southeastern Labrador. In Current Research, Part C. Geologic Survey of Canada, Paper 90-1C, 1-11.

Marshall, A.S., Macdonald, R., Rogers, N.W., Fitton, J.G., Tindle, A.G., Nejbert, K., and Hinton, R.W., 2009. Fractionation of peralkaline silicic magmas: the Greater Olkaria, Volcanic Complex, Kenya Rift Valley. Journal of Petrology, 50, 323-359.

Miller, R.R., 1987. The relationship between Mann-type Nb-Be mineralization and felsic peralkaline intrusives, Letitia Lake Project, Labrador. Newfoundland and Labrador Department of Mines and Energy, Mineral Development Division, Report 87-1, 83-91.

Miller, R.R., 1988. Yttrium (Y) and other rare metals (Be, Nb, REE, Ta, Zr) in Labrador. Newfoundland and Labrador Department of Mines and Energy, Mineral Development Division, Report 88-1, 229-245.

Miller, R.R., 1993. Rare-metal mineralization in the Nuiklavik volcanic rocks of the Flowers River Igneous Suite. Newfoundland and Labrador Department of Mines and Energy, Mineral Development Division, Report 89-1, 363-371.

Miller, R.R., 1996. Structural and textural evolution of the Strange Lake peralkaline rare-element (NYF) granitic pegmatite, Quebec-Labrador. Canadian Mineralogist 34, 349-371.

Miller, R.R., Heaman, L.M. and Birkett, T.C., 1996. U-Pb zircon age of the Strange Lake peralkaline complex: implications for Mesoproterozoic peralkaline magmatism in north-central Labrador. Precambrian Research, 81, 67-82.

Search Minerals Inc., 2010a. Search Minerals Inc. discovers heavy rare earth element mineralization in the Port Hope Simpson REE District, Labrador. <http://searchminerals.mediaroom.com/index.php?s=26366&item=81769>. accessed Oct. 19, 2015

Search Minerals Inc., 2010b. Search Minerals Inc. discovers four new heavy REE showings in Port Hope Simpson REE District, Labrador. <http://searchminerals.mediaroom.com/index.php?s=26366&item=81760>. accessed Oct. 19, 2015.

Search Minerals Inc., 2012. Search Minerals discovers two further REE-Zr-Y-Nb prospects in the Port Hope Simpson REE District, SE Labrador. <http://searchminerals.mediaroom.com/index.php?s=26366&item=125025>. accessed Oct. 19, 2015.

Search Minerals Inc., 2013. Search Minerals announces ten new Foxtrot-like REE prospects in 64 km-long mineralized belt in SE Labrador. <http://searchminerals.mediaroom.com/index.php?s=26366&item=137194>. accessed Oct. 19, 2015

Search Minerals Inc., 2014. Search Minerals announces metallurgical breakthrough for rare earth recovery. <http://searchminerals.mediaroom.com/index.php?s=26366&item=137204>. accessed Oct. 19, 2015.

Search Minerals Inc., 2015a. Search Minerals announces "Critical REE" discovery in the Port Hope Simpson REE District. <http://searchminerals.mediaroom.com/index.php?s=26366&item=137243>. accessed Oct. 19, 2015.

Search Minerals Inc., 2015b. Search Minerals announces successful scale up of proprietary metallurgical process to produce 98.9% purity rare earth oxide product. <http://searchminerals.mediaroom.com/index.php?s=26366&item=137244>. accessed Oct. 19, 2015.

Srivastava, R.M., Gauthier, J., Cox, J.J., and Krutzelmann, H., 2012. Technical report on the Foxtrot Project in Labrador, Newfoundland and Labrador, Canada. Technical Report NI 43-101, Search Minerals Inc., Vancouver, Canada, 174p. <http://www.searchminerals.ca/i/pdf/reports/RPA-Foxtrot-July2012.pdf>. accessed Sept. 25, 2015.

Srivastava, R.M., Gauthier, J., Cox, J.J., and Krutzelmann, H., 2013. Technical report on the Foxtrot Project in Labrador, Newfoundland and Labrador, Canada. Technical Report NI 43-101, Search Minerals Inc., Toronto, Canada, 203p. <http://www.searchminerals.ca/i/pdf/reports/RPA-Foxtrot-May2013.PDF>. accessed Sept. 25, 2015.