

MINERAL COMMODITIES OF
NEWFOUNDLAND AND LABRADOR

RARE-EARTH ELEMENTS

(Including Y, Zr, Nb, Be)



Mineral Commodities of Newfoundland and Labrador

Rare-Earth Elements

Foreword

This is the sixth in a series of summary publications covering the principal mineral commodities of the Province. Its purpose is to act as a source of initial information for explorationists and to provide a bridge to the detailed repository of information contained in the maps and reports of the provincial and federal geological surveys, as well as in numerous exploration-assessment reports. The information contained in this series is accessible via the internet at the Geological Survey of Newfoundland and Labrador web site <http://www.nr.gov.nl.ca/nr/mines/Geoscience/index.html>

Other Publications in the Series

Zinc and Lead. (Number 1, revised 2008)

Nickel (Number 2, revised 2008)

Copper (Number 3, revised 2007)

Gold (Number 4, revised 2005)

Uranium (Number 5, 2009)

Rare-Earth Elements (Number 6, 2011)

Additional Sources of Information

Further information is available in the publications of the geological surveys of Newfoundland and Labrador, and Canada. The Geological Survey of Newfoundland and Labrador also holds a considerable inventory of exploration-assessment files available for onsite inspection at its St. John's headquarters and for download via the Department of Natural Resources web site: <http://www.nr.gov.nl.ca/nr/mines/Geoscience/index.html>. Descriptions of individual mineral occurrences are available through the provincial Mineral Occurrence Database System (MODS), which is accessible via the Department of Natural Resources web site. Up-to-date overviews of mining developments and exploration activity targeting rare-earth elements are available on-line at <http://www.nr.gov.nl.ca/nr/mines/Geoscience/index.html>

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Compiled by A. Kerr and H. Rafuse, 2011.

Front Cover: Pink eudialyte, Red Wine Intrusive Suite, Red Wine Mountains, Labrador.

Introduction

The *rare-earth elements* (REE) include the 14 natural *lanthanide elements*, i.e., lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and lutetium (Lu). The REEs are divided into *light REE* (La to Sm) and *heavy REE* (Gd to Lu). Europium may be included with either group, but has distinctly different characteristics from all other REE. Yttrium (Y) is commonly included with the REE as it is chemically similar to heavy REE, and scandium (Sc) is also included within the group. The REE generally occur in common rocks at concentrations of a few parts per million (ppm), aside from La, Ce and Y, for which concentrations above 100 ppm are not unusual; the crustal abundances of these elements resemble those of base metals such as Cu and Pb. The REE are commonly associated with other elements grouped under the general term ‘rare metals’; these include Zr, Hf, Nb, Ta, and Be.

The REE and associated metals have long been used as pigments in glass and ceramics, and their catalytic properties are important to the petroleum industry. They are vital in the high-tech manufacturing sector, where they are used in high-strength magnets, flat-screen TVs, lasers, miniature batteries, superconductors, energy-efficient lighting, and nanotechnology applications. Some REE are important in ‘green revolution’ products, e.g., wind turbines contain large amounts of neodymium or dysprosium in lightweight magnets, as do hybrid gas-electric vehicles. The amounts of these metals consumed have risen sharply, and demand has increased dramatically since 2000. However, the markets for REE and associated metals are small compared to those for base-metals.

The supplies and markets for REE and associated elements have also changed significantly since the early 1980s. China became an important global supplier in the 1990s, and now accounts for about 95% of global production. Rare-earth element supplies from China were limited by the imposition of export controls in 2008; this development, coupled with increased demand, led to significant commodity price

increases, and exploration interest in deposits outside China.

The economic forecasts for REE and associated metals are varied, but some sources predict annual demand growth rates of 8 to 11% between 2010 and 2020. The heavy REE are of particular interest, and are considered strategic by many countries due to lack of substitutes in specialized technology applications. Deposits of REE and associated metals are widely distributed, and significant undeveloped deposits exist in Saudi Arabia, Russia, Greenland, Australia and Canada; one of the two largest Canadian examples is located in Labrador, at Strange Lake.

Historical Review

Over 50 years ago, Be- and Zr-bearing minerals were first discovered in Labrador by Leslie Mann, John Michelin and Joe Brummer. These deposits received limited evaluation in the 1960s, but saw little systematic work until 2009. In 1979, the Strange Lake deposit was discovered by the Iron Ore Company of Canada. This Zr–Nb–Y–REE deposit is one of the largest of its kind in the world. Several mining and processing options were investigated, but development proved difficult due to the remote location, metallurgical challenges and poor market conditions. At the time, Zr, Y and Nb were the main commodities of interest, and the REE held little value.

Strange Lake became Exempt Mineral Land (EML) in 1998, and has remained so. Exploration resumed in adjacent Québec in 2008, and another deposit of similar type has now been defined west of the border.

Recent geophysical and geochemical surveys in Labrador and Québec have revealed magnetic features and geochemical anomalies suggesting the presence of several other potentially fertile igneous complexes. REE–Zr–Y–Nb mineralization is also known in Newfoundland, notably in the Fortune Bay area, where it was discovered in the 1980s. Felsic igneous rocks with ‘peralkaline’ compositions, considered favourable for this style of mineralization, are widespread on the island, but remain unexplored. The mineral beryl ($\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$) occurs in pegmatites in several areas of Newfoundland; although beryl is commonly more important as a gemstone than as a source of beryllium, these occurrences are also summarized in this report.

“Rare earth elements are increasingly important in high-technology applications and in the quest for ‘green energy’. They are indispensable to the modern world”

Geological Attributes of Rare-earth Element and Rare-metal Deposits

There are several types of primary REE and rare-metal deposits, and a wide range of secondary deposits derived by erosion and/or weathering of primary sources. The most important types in terms of resources are associated with carbonatites and peralkaline igneous suites. With the exception of beryl-bearing pegmatites, all occurrences in the province belong to the second group. Peralkaline igneous rocks are defined by high contents of alkali elements relative to alumina, such that molecular $(\text{Na}_2\text{O}+\text{K}_2\text{O})$ exceeds molecular Al_2O_3 . Under such circumstances, Na-rich mafic amphiboles and pyroxenes (e.g., aegirine, arfvedsonite and rebeckite) become the dominant mafic minerals, rather than common Fe–Mg silicates. In silica-deficient (undersaturated) peralkaline rocks of mafic composition, common feldspars may be replaced or augmented by ‘feldspathoid’ minerals such as nepheline, sodalite, leucite or cancrinite. Peralkaline magmas favour the concentration of REE and associated elements by fractionation. Mineralization is associated with both silica-saturated and undersaturated peralkaline suites, and the geometry and associations of individual deposits vary widely. The high concentrations of these elements in residual peralkaline magmas leads to the formation of a wide range of uncommon silicate and oxide minerals (Table 1), and individual deposits tend to be mineralogically unique.

Rare-earth elements and rare-metal deposits in peralkaline suites define two end-member-types that are respectively dominated by magmatic and metasomatic–hydrothermal processes, but many deposits exhibit evidence for both processes. In magmatic examples, the ore minerals are dispersed as essential components of igneous rocks, notably in pegmatites and aplites, and hydrothermal alteration is limited. The host rocks may be either of plutonic or vol-

Table 1. Examples of unusual minerals that occur in rare-metal deposits, and their generalized chemical formulae. Modified after Richardson and Birkett (1996). Minerals indicated in red are present in Strange Lake

Mineral name	Formula
Silicates	
allanite-(Ce)	$(\text{Ce,Ca})_2(\text{Al, Fe}^{3+})_3(\text{SiO}_4)_3(\text{OH})$
aenigmatite	$\text{Na}_2\text{Fe}^{2+}_5\text{TiSi}_6\text{O}_{20}$
armstrongite	$\text{CaZrSi}_6\text{O}_{15}\cdot 3\text{H}_2\text{O}$
astrophyllite	$(\text{K,Na})_3\text{Fe}^{2+}_7\text{Ti}(\text{Si}_8\text{O}_{24})(\text{O,OH,F})_7$
barylite	$\text{BaBe}_2\text{Si}_2\text{O}_7$
catapleiite	$\text{CaZrSi}_3\text{O}_9\cdot 2\text{H}_2\text{O}$
dalyite	$\text{K}_2\text{ZrSi}_6\text{O}_{15}$
elpidite	$\text{Na}_2\text{ZrSi}_6\text{O}_{15}\cdot 3\text{H}_2\text{O}$
eucolite	$(\text{Ca,Na,Ce})_5(\text{Fe}^{2+}, \text{Mn,Y})\text{ZrSi}_8\text{O}_{22}(\text{OH,Cl})_2$
eudialyte	$\text{Na}_4(\text{Ca,Ce})_2(\text{Fe}^{2+}, \text{Mn,Y})\text{ZrSi}_8\text{O}_{22}(\text{OH,Cl})_2$
eudidymite	$\text{NaBeSi}_3\text{O}_7(\text{OH})$
gadolinite (Ca-rich)	$\text{Be}_2(\text{Ca,REE,Fe})_3\text{Si}_2\text{O}_{10}$
gittinsite	$\text{CaZrSi}_2\text{O}_7$
kainosite	$\text{Ca}_2(\text{Y,Ce})_2\text{Si}_4\text{O}_{12}(\text{CO}_3)\cdot \text{H}_2\text{O}$
leifite	$\text{Na}_2(\text{Si,Al,Be})_7(\text{O,OH,F})_{14}$
milarite	$\text{K}_2\text{Ca}_4\text{Al}_2\text{Be}_4\text{Si}_{24}\text{O}_{60}\cdot \text{H}_2\text{O}$
mosandrite (rinkite)	$(\text{Na,Ca,Ce})_3\text{Ti}(\text{SiO}_4)_2\text{F}$
narsarsukite	$\text{Na}_2(\text{TiFe}^{3+})\text{Si}_4(\text{O,F})_{11}$
niobophyllite	$(\text{K,Na})_3(\text{Fe}^{2+}, \text{Mn})_6(\text{NbTi})_2\text{Si}_8(\text{O,OH,F})_{31}$
thorite	$(\text{Th,Fe,Y,P,Ca})\text{SiO}_4$
titanite	CaTiSiO_5
vlasovite	$\text{Na}_2\text{ZrSi}_4\text{O}_{11}$
zircon	ZrSiO_4
Oxides	
baddelyite	ZrO_2
betafite	$(\text{Ca,U})_2(\text{Ti,Nb,Ta})_2\text{O}_6(\text{OH})$
fergusonite	YNbO_4
perovskite	$(\text{Ca,Na,Fe}^{2+}, \text{Ce,Sr})(\text{Ti,Nb})\text{O}_3$
pyrochlore	$(\text{Na,Ca})_2\text{Nb}_2\text{O}_6(\text{OH,F})$
uraninite	UO_2
Carbonates/fluorides	
bastnaesite-(Ce)	$(\text{Ca,Lu})(\text{CO}_3)\text{F}$
gagarinite-(Y)	$\text{NaCaY}(\text{F,Cl})_6$
Phosphates	
britholite	$(\text{Ca,Ce,Y})_5(\text{SiO}_4)_3(\text{PO}_4)_3(\text{OH,F})$
monazite-(Ce)	$(\text{La,Ce,Nd,Th})\text{PO}_4$
xenotime	YPO_4

canic origin, although the former are more common. In metasomatic–hydrothermal examples, mineralization is superimposed on pre-existing rock units (which may be of peralkaline affinity) reflecting the transfer of metals in magmatic

“The economic forecasts for REE and rare-metals are varied, but some predict annual demand growth rates of 8 to 11% to 2020”

hydrothermal fluids to form replacement zones or vein systems. In such deposits, hydrothermal alteration is more widespread. Both

processes operate together and a complex continuum of mineralization styles may occur. However, the REE and related metals are all incompatible trace elements that are concentrated by magmatic fractionation in peralkaline magmas, and this process appears to be fundamental to deposit genesis.

Rare-earth elements and rare-metal deposits may include a wide variety of uncommon minerals in addition to better-known minerals such as zircon, allanite, titanite, monazite and xenotime. Table 1 lists the names and formulae of some of these minerals. The mineralogy of these deposits is a critical factor in their economic evaluation, as some REE-bearing minerals are highly resistant to chemical solvent extraction processes. In many cases, custom-process design is required to successfully extract the desired commodities from ore, and from each other.

In contrast, beryl-bearing granitic pegmatites are associated with magmatic suites of peraluminous affinity (*i.e.*, those in which alumina remains following crystallization of feldspars). Examples in Newfoundland are associated with peraluminous granites, likely derived by partial melting of metasedimentary rocks during high-grade metamorphism.

Mineralization in Labrador

Rare-earth element and rare-metal mineralization in Labrador (Figure 1) is associated with ‘anorogenic’ high-level intrusions of peralkaline felsic rocks and their extrusive equivalents. The host rocks to mineralization are

Mesoproterozoic, ranging from ~ 1330 Ma (Letitia Lake and Red Wine Mountains areas) to ~ 1270 Ma (Flowers River) to ~ 1240 Ma (Strange Lake). These peralkaline igneous suites developed in the terminal stages of a major magmatic event, which led to the emplacement of large Mesoproterozoic anorthosite–granite batholiths across Labrador (Figures 1 and 2). The Letitia Lake and Red Wine Mountains areas were subsequently affected by *ca.* 1000 Ma deformation and metamorphism. Most examples are considered to fall broadly into the magmatic end-member type, although metasomatic–hydrothermal mineralization may be important at Letitia Lake.

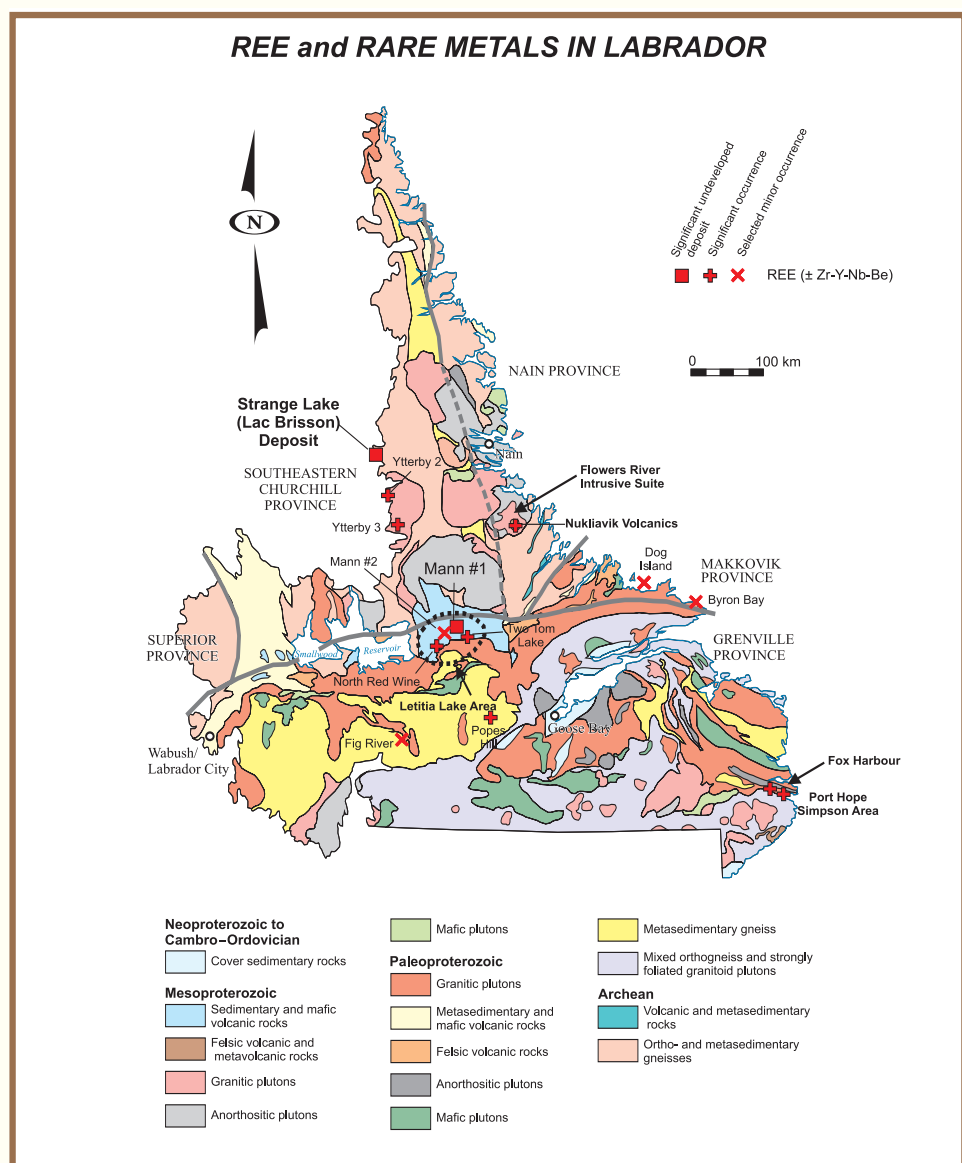


Figure 1. Simplified geological map of Labrador, showing the locations of selected rare-metal occurrences.

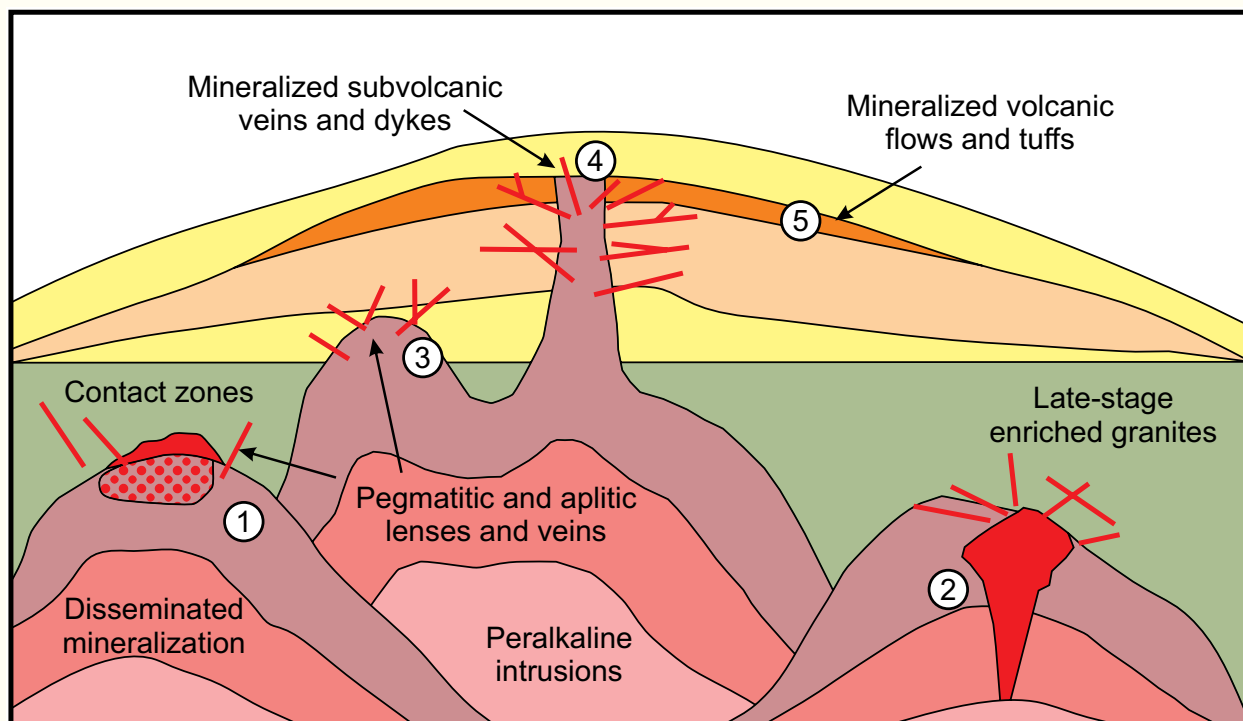


Figure 2. Schematic diagram illustrating the principal environments of formation for rare-metal deposits in Labrador, and perhaps also Newfoundland; modified after Miller (1989). 1. Disseminated mineralization in under-saturated peralkaline intrusive rocks; 2. Pegmatite and aplite segregations in the roof zones of unvented peralkaline granites (e.g., Strange Lake); 3 and 4. Pegmatite and aplite veins in vented environments and near-vent extrusive facies; 5. Disseminated and/or hydrothermal mineralization in permeable peralkaline extrusive facies.

Strange Lake Deposit

This deposit is one of the largest undeveloped REE and rare-metal deposits in the world (Figures 3 and 4). The resource was estimated in 1983 at ~57 million tonnes at 2.93% ZrO_2 , 0.38% Y_2O_3 , 0.08% BeO , 0.31% Nb_2O_5 , and 0.54% total REE oxides. The deposit is located northwest of Nain (Figure 1) on the

Québec–Labrador border; most of the high-grade mineralization and the larger part of the resource defined at that time is located in Labrador. Mineralization was discovered through follow-up prospecting of surficial U and F anomalies; the deposit has a well-defined dispersion train including these elements, Y, REE and Be. Mineralization at



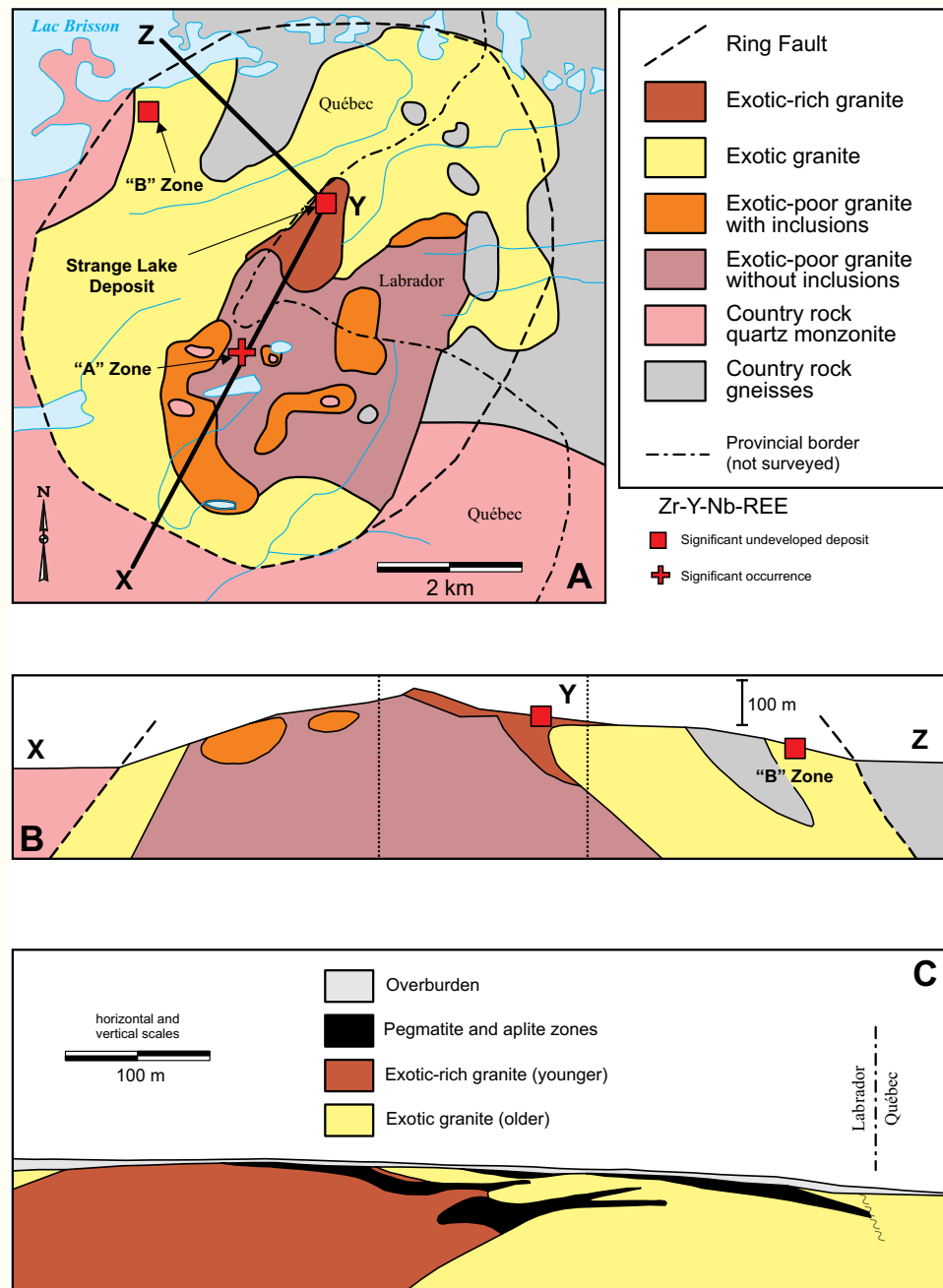
Figure 3. High-grade, fluorite-bearing pegmatite from the Strange Lake deposit, Zone 1 Lens.



Figure 4. Mineralized aplitic rock from the Strange Lake deposit, Zone 1 Lens; the red mineral is the Ca–Zr silicate gittinsite, altered to hematite.

Strange Lake is hosted by peralkaline granite that intrudes gneisses and granitoid rocks of the Churchill Province, and also intrudes an older quartz monzonite unit. The peralkaline granite has elevated levels of U, Th, Zr, Nb, Y and REE throughout, but these are particularly enriched in a minor phase, which is located in the centre of the complex (Figure 5). The shape of this 'exotic-rich' granite is reminiscent of a trumpet-shaped flower, with its widest zone close to the erosion surface. Near-surface pegmatite and aplite bodies define a smaller mass (~ 5 million tonnes) of high-grade material. The pegmatite and aplite appear to be the latest units to crystallize within the complex, and veins of similar appearance cut other rock types in the surrounding area. The ore zone and associated rocks include a range of uncommon Zr, Y, Be, Nb and REE-bearing minerals, such as elpidite, armstrongite, gittinsite, pyrochlore, kinosite and gadolinite, in addition to more familiar minerals such as allanite, thorite, titanite and zircon (Table 1). The principal source of Zr is gittinsite, and Nb is hosted largely in pyrochlore; Y and REE are hosted within a still-unnamed Ca–Y silicate, and several other rare minerals. Grade estimates for the Zone 1 Lens vary, but company documents quote values of 3.25% ZrO_2 , 0.66% Y_2O_3 , 0.56% Nb_2O_5 , 0.12% BeO and 1.3%

TREO. The total REE oxide content of most samples was estimated from Y_2O_3 data, but more recent survey data suggest that about 65% of the REE are light and about 26% are heavy. However, if Y is included with



the heavy REE (as is commonly done in exploration), the heavy REE account for about 55 to 65% of TREO* (the asterisk is used to indicate the inclusion of Y with the REE).

The Strange Lake deposit is inferred to have formed from enriched residual magma and associated hydrothermal fluids localized in the roof zone of the peralkaline granite, following emplacement of the evolved granite along the contact between two earlier, less-evolved phases (Figure 5). The enriched magmas and associated fluids appear to have been trapped in the roof zone of the complex, rather than being dispersed in a sub-volcanic to volcanic environment through venting.

Recent exploration in the Strange Lake area has focused in Québec, notably at Lac Brisson, some 3 km west of the border (Figure 5). A new discovery in this area, termed the ‘Strange Lake B-zone’ consists of sub-horizontal zones of highly enriched pegmatite, which resemble pegmatite–aplite sheets associated with the Zone 1 Lens in Labrador. A large resource (almost 100 million tonnes) was announced in 2010, with grades broadly comparable to those previously indicated for the main deposit (*i.e.*, approaching 1% TREO*). The abundances of the individual REE resemble those defined in the main deposit.

Letitia Lake–Red Wine Mountains Area

Beryllium and zirconium were first discovered in Labrador in the Letitia Lake area (Figure 1), at the eastern extremity of the Central Mineral Belt (Figure 6). Here, a sequence of *ca.* 1330 Ma peralkaline volcanic and metavolcanic rocks is intruded by locally undersaturated peralkaline plutons (syenite to granite) assigned to the Red Wine Intrusive Suite (Figure 7). Mineralization occurs in both plutonic and volcanic settings, but is more common in the former. This area was affected by the *ca.* 1000 Ma Grenvillian Orogeny, and the rocks are metamorphosed and locally gneissic to mylonitic. Several prospects and showings are known in the area, and these fall into two distinct groups (Figure 8).

Disseminated (magmatic) mineralization occurs at several locations in the Red Wine Mountains, where gneisses of nepheline–syenite composition contain unusual accessory minerals, of which the most common are zircon, eudialyte, bastnaesite, betafite and perovskite (Table 1). The eudialyte contains up to 13.34% ZrO₂ and 2.56% total REE oxides, and is locally abundant (up to 30% by volume). Recent exploration work suggests TREO* contents of around 1%, with heavy REE enrichment, and significant Zr and Y. Unlike most examples of REE mineralization, the eudialyte zones do not contain radioactive elements such as U and Th. The origin of the eudialyte zones is uncertain, but this mineral is known to be a primary phase in other undersaturated alkaline complexes such as Ilimaussaq in southern Greenland.

“The Strange Lake deposits in Labrador and Québec, form one of the largest undeveloped rare-metal and REE resources in the world”



Figure 6. Banded mylonitic syenite gneiss hosting Be–Nb–REE mineralization, Letitia Lake area.



Figure 7. Coarse-grained eudialyte (pink) in nepheline syenite, Red Wine Mountains area.

lyte contains up to 13.34% ZrO₂ and 2.56% total REE oxides, and is locally abundant (up to 30% by volume). Recent exploration work suggests TREO* contents of around 1%, with heavy REE enrichment, and significant Zr and Y. Unlike most examples of REE mineralization, the eudialyte zones do not contain radioactive elements such as U and Th. The origin of the eudialyte zones is uncertain, but this mineral is known to be a primary phase in other undersaturated alkaline complexes such as Ilimaussaq in southern Greenland.

Vein-type and disseminated mineralization is associated with sub-volcanic quartz syenites and an adjacent volcanic facies at the Mann #1, #2 and Two Tom Lake occurrences (Figure 8); these represent a more complex style of deposit, in which Zr, Nb, Y and REE are accompanied by strong

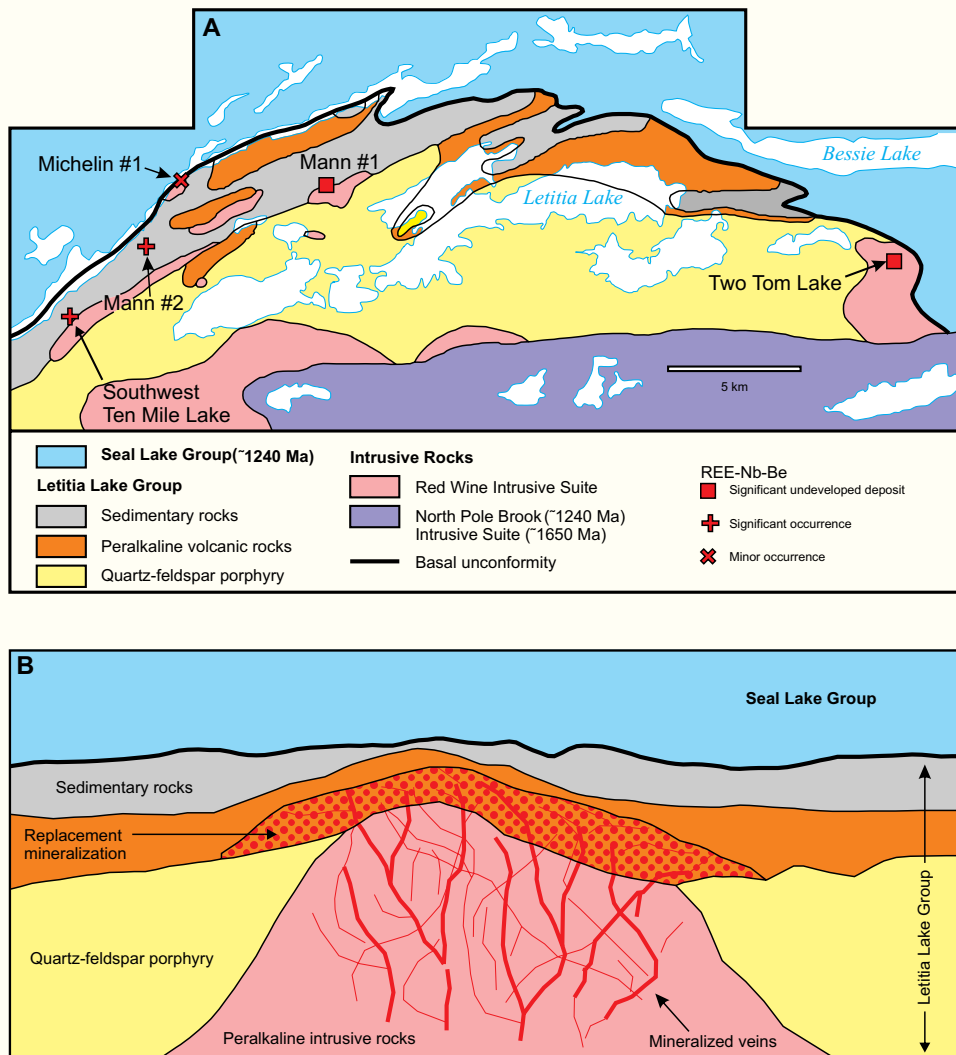


Figure 8. A. Simplified geological map of the Letitia Lake area in central Labrador, indicating the locations of Be and Zr–Y–Nb–REE occurrences, modified after Miller (1989). Note that disseminated eudialyte hosted by undersaturated peralkaline rocks and their metamorphosed equivalents occurs several kilometres south of the Southwest Ten Mile Lake showing. B. Schematic diagram illustrating the inferred settings of rare-metal mineralization in the Letitia Lake area, after Miller (1989).

Be enrichment. The main ore mineral at Mann #1 is barylite, although pyrochlore and niobophyllite are also locally important; the deposit contains up to 0.24% Nb. Recent exploration work has demonstrated that all these zones are Be-enriched and that REE mineralization occurs over significant widths, including 1.35% TREO* over 106 m. Mineralization is present in tabular zones exceeding 1 km in strike length, hosted by strongly deformed (locally mylonitic) peralkaline rocks. The original relationships are obscured by strong deformation, but cross-cutting REE-enriched veins are documented in areas of lower strain, and it is suspected that mineralization

was originally developed as vein swarms and related metasomatic zones. These were later transposed within a regional shear zone. A wide variety of REE-bearing silicate minerals occur, and are listed in Table 1. Data from recent exploration suggests that the REE are dominated by light REE, and that La, Ce and Nd are the most abundant elements. The Be and REE occurrences in the Letitia Lake area have received only limited exploration attention since the 1960s, although potential host rocks of peralkaline composition are widespread.

Flowers River Area

The ~ 1270 Ma Flowers River Intrusive Suite (Figure 1) is the largest peralkaline plutonic complex known in Labrador, and extrusive rocks are locally preserved in a caldera-like structure. The volcanic rocks (known as the Nuiklavik volcanics) exhibit

strong local Zr and Nb enrichment, notably in ash-flow tuffs. Pegmatite and pegmatite–aplite dykes likely associated with nearby high-level peralkaline granites also locally contain mineralization. The area has not been extensively explored for REE, although there has been some recent interest in its uranium potential. Historical data indicate TREO* contents up to 1.1%, with appreciable heavy REE components.

Southeastern Labrador

At Fox Harbour (St. Lewis) in southeastern Labrador, a radioactive ‘mylonitic zone’ sampled

during mapping contained up to 3.4% Zr, and anomalous REE. Subsequent exploration in the area between Port Hope Simpson (Figure 9) and St. Lewis has revealed more extensive Zr–Nb–REE mineralization of at least two discrete types. These include banded gneisses of feldspathic composition that host low-grade (up to 1.2% TREO*) light REE-enriched mineralization scattered over wide areas, possibly representing metavolcanic suites of peralkaline composition. High-grade REE mineralization, with strong enrichment in heavy REE, is associated with dense pegmatite swarms in several areas, and may be associated with younger (post-tectonic) igneous suites. Recognition of these zones has generated significant exploration interest in other parts of the Grenville Province (Figure 1).



Figure 9. Mineralized pegmatite from the Port Hope Simpson area, southeast Labrador; yellow-weathering mineral is believed to be the REE-rich phase.

Other Areas of Labrador

In the Popes Hill area near Goose Bay, REE mineralization of uncertain origin has been detected in metamorphic rocks of the Grenville Province; little is presently known about these occurrences, but they appear to be light REE-enriched and locally high-grade. In the remote area along the Québec–Labrador border region south of Strange Lake, geochemically evolved granites have been detected during recent exploration and these host REE-enriched mineralization. Preliminary interpretation suggests that they are younger intrusive complexes within the *ca.* 1400 Ma Mistastin Batholith. Several other minor occurrences of REE and associated rare metals are known across Labrador, but these have not been described or explored in detail.

Mineralization in Newfoundland

Significant occurrences in Newfoundland (Figures 10 and 11) include showings of Zr–Y and REE in the Fortune Bay area and near Clode Sound, Trinity Bay; there are also scattered indications of beryllium associated with pegmatites. Rare-earth element mineralization is also reported from the Lost Pond area, near Stephenville. As in Labrador, the most significant examples are associated with plutonic and volcanic rocks of peralkaline composition.

Several zones enriched in Zr, Y and REE occur within the late Ediacaran (~547 Ma) Cross Hills Plutonic Suite near Fortune Bay (Figure 11). The suite ranges in composition from alkaline gabbro to peralkaline granite, but all mineralization is hosted by the latter. The most significant showings consist of disseminated zircon, baddelyite and fergusonite in aplitic peralkaline dykes. Grab samples contain up to 2% Zr, 2300 ppm Nb and 1500 ppm Ce, and there is also enrichment in Sn and Ta. There is little data on the concentrations of other REE in the mineralized samples. Rare-earth mineralization, recently reported at the Lost Pond showings in western Newfoundland, includes drill intersections of 5.7 m at 4.5% TREO*, and grab samples containing up to 10% TREO*. The host rock is believed to be the Hare Hill Granite, a small peralkaline pluton of Ediacaran (~605 Ma) age. Peralkaline granites of the Topsails Intrusive Suite are reported to contain Zr and REE-enriched outcrops and boulder fields, with up to 2.3% Zr and 3.1% TREO, but little is presently known about these occurrences.

Two small occurrences in the Clode Sound area contain elevated levels of Zr (up to 0.25%), Y (up to 300 ppm) and Nb (up to 363 ppm), associated with

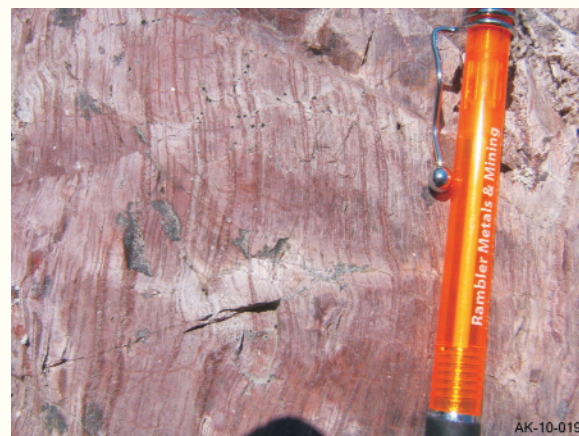


Figure 10. Flow-banded peralkaline rhyolite, Kings Point Complex, central Newfoundland.

sulphides. The host rocks are unidentified, possibly part of the Bull Arm Formation, a regionally extensive unit of mafic and felsic volcanic rocks including peralkaline compositions. The Bull Arm Formation is believed to be similar in age to the Cross Hills Plutonic Suite, and small areas of peralkaline granite are also known in the Clode Sound area.

Other rare-metal occurrences consist of small amounts of beryl hosted by granites and granitic pegmatites. These occur in the Bonavista North area, in and around the Middle Ridge Granite in central Newfoundland, and in southwestern Newfoundland (Figure 11). Most are associated with muscovite-bearing peraluminous granites. None of the beryl occurrences in Newfoundland are reported to contain high-quality transparent gem material.

Exploration Potential

The strong association between rare-metal mineralization and peralkaline igneous suites suggests that several areas may have potential for future discoveries. In Labrador, Mesoproterozoic ‘anorogenic’ intrusive suites are widespread, notably north of the Grenville Province, and wherever peralkaline compositions are reported, there are instances of Zr–Y–Be–Nb–REE mineralization. The present level of geological mapping in northern Labrador is not detailed enough to reveal small peral-

“Peralkaline igneous suites in Newfoundland have received little systematic assessment for rare-metals or REE”

kaline plutons such as the Strange Lake complex. In southern Labrador, there are numerous circular granitic plutons representing late-stage magmatism in the Grenville Province, and many of these appear to be compositionally evolved. This also represents a potential environment for peralkaline rocks and related mineralization. Recent high-resolution aeromagnetic surveys completed as part of a joint Federal–Provincial project in the Schefferville–Smallwood Reservoir area show circular magnetic

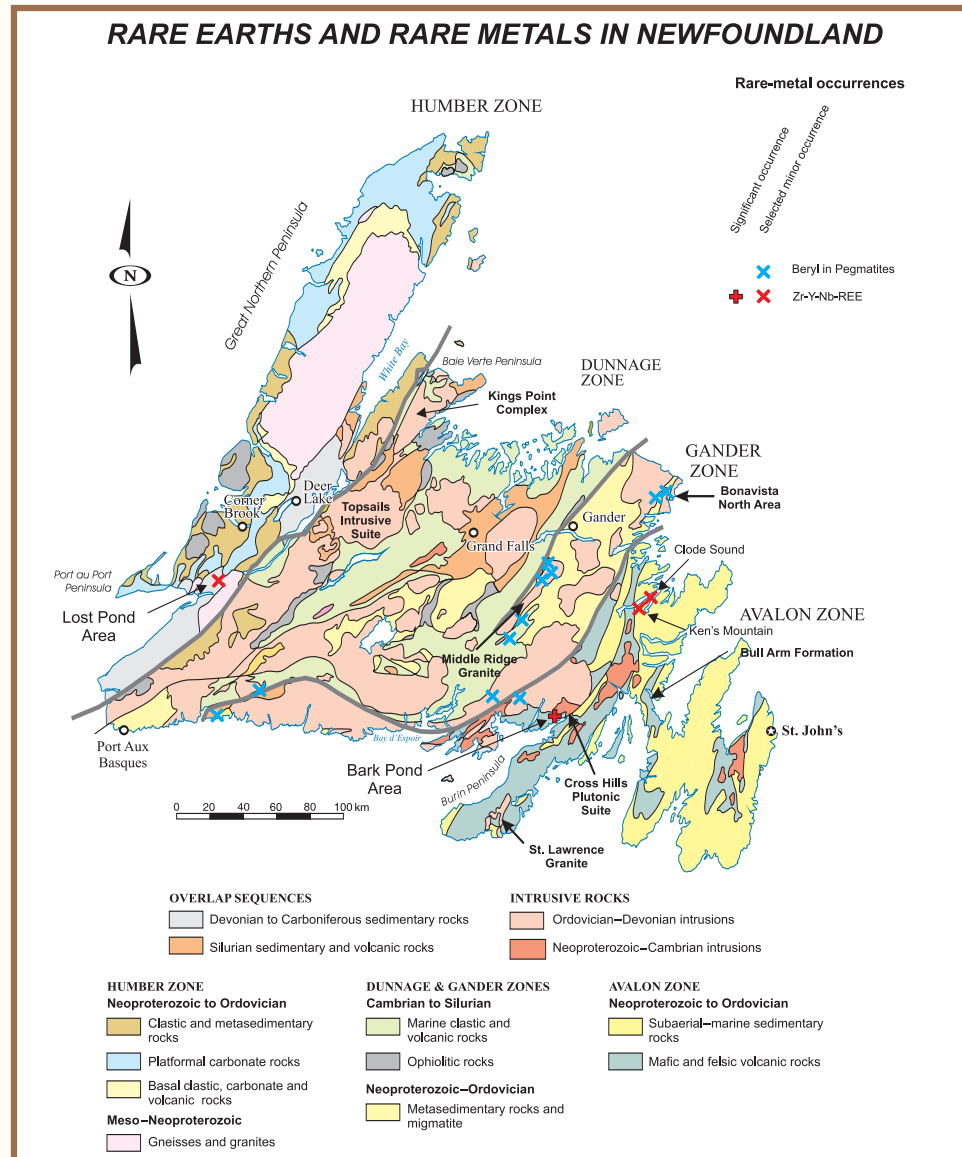


Figure 11. Simplified geological map of Newfoundland showing selected rare-metal occurrences, and also the locations of peralkaline intrusive and volcanic suites that may have exploration potential for rare metals.

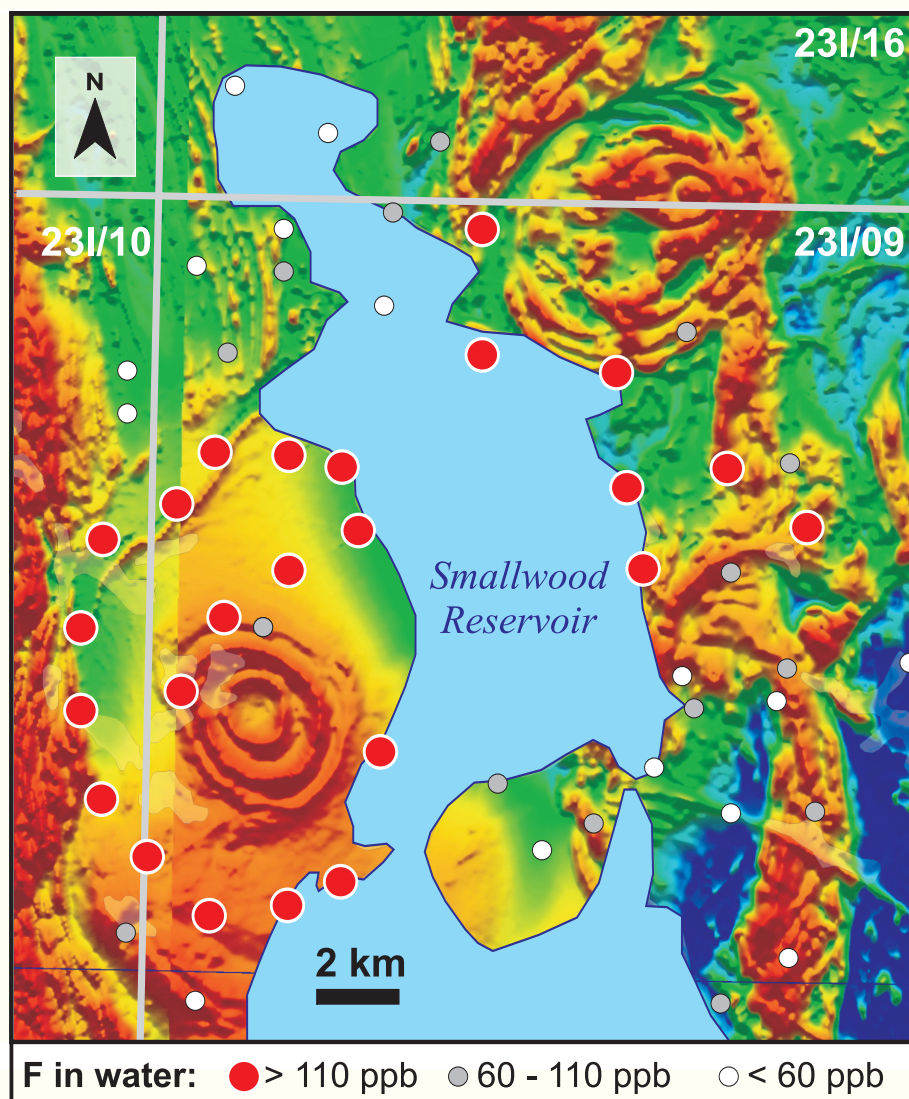


Figure 12. Examples of prominent circular magnetic features in the area of the Smallwood Reservoir, near the Québec–Labrador border, as revealed by recent high-resolution aeromagnetic surveys. These are believed to represent unexplored intrusive complexes, possibly of peralkaline composition. The area is also associated with anomalous fluorine in lake waters.

features (Figure 12) now known to correspond with peralkaline ring-complexes associated with REE enrichment. Similar surveys elsewhere, in poorly exposed regions of Labrador, could easily produce the same outcome. Assessment and re-analysis of lake-sediment geochemical data through the region also suggests that not all U, F and REE anomalies have been satisfactorily explained, and ring-like magnetic anomalies can be revealed by careful analysis of regional geophysical data.

On a percentage areal basis, peralkaline igneous rocks are more abundant in Newfoundland than in Labrador. The largest examples are the Silurian (~429

Ma) Topsails Intrusive Suite and the Devonian (~375 Ma) St. Lawrence Granite, but several other Paleozoic peralkaline suites occur in central Newfoundland. Precambrian peralkaline plutons occur in both eastern and western Newfoundland, where they are associated with minor rare-metal mineralization. There are also peralkaline volcanic rocks of both Precambrian and Paleozoic age (Figure 11). Most peralkaline igneous suites in Newfoundland have never been explored for rare metals or REE, and the few known occurrences remain undrilled.

The well-developed glacial dispersion trails from the Strange Lake deposit (Figure 13) indicate that sur-

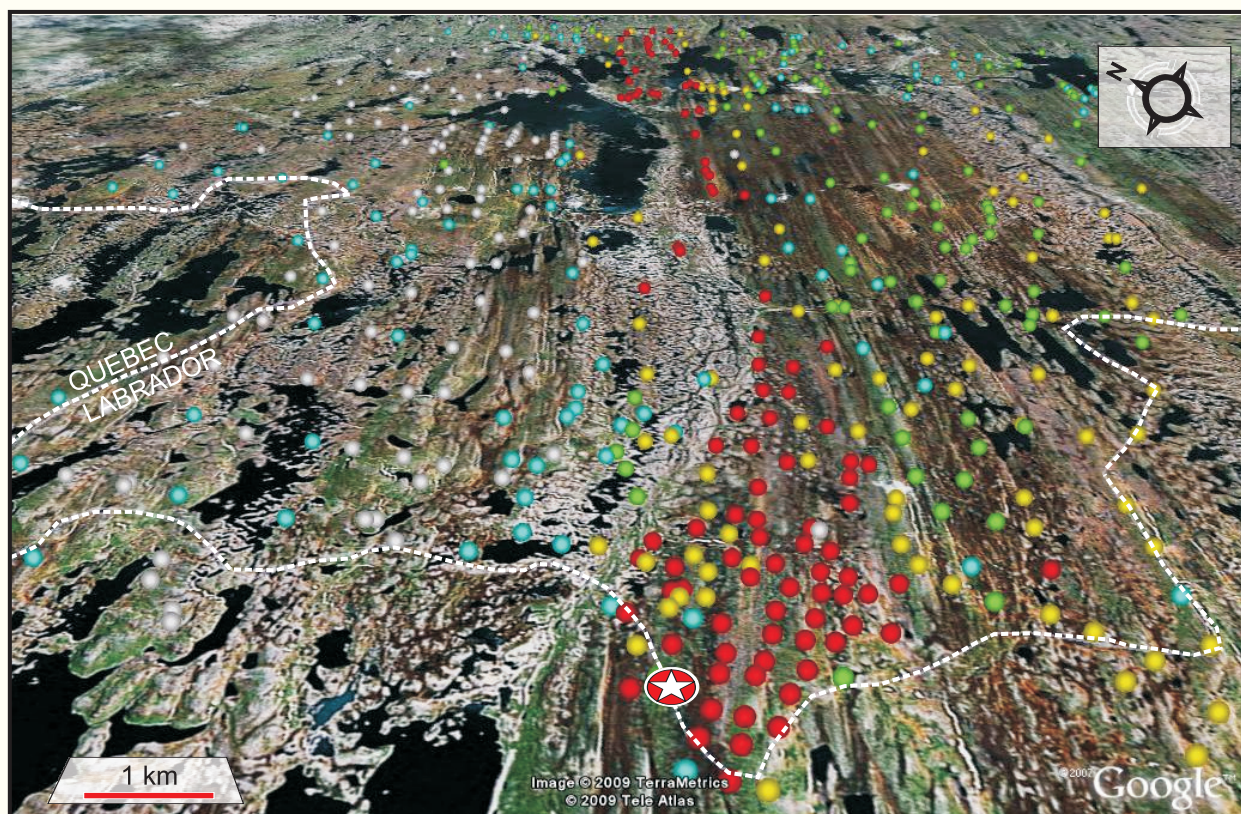


Figure 13. Perspective aerial view of the glacial dispersion trail from the Strange Lake deposit, as shown by the distribution of yttrium (Y) in till samples. The white sample sites represent background values and the red circles indicate the strongest enrichment in Y.

ficial geochemical methods represent an effective exploration tool for deposits of this type, and lake-sediment data from across Labrador have now been re-analyzed for selected REE elements. The common association between rare-metal mineralization and elevated U and Th concentrations indicates that radiometric surveys are also effective in discovering such occurrences. Known rare-metal mineralization in the province was, in most cases, discovered through the radioactivity imparted by associated U and Th, and this remains the most useful prospecting tool, coupled with lake-sediment geochemical data. The surge in uranium exploration since 2000 has already led to the discovery of rare-metal mineralization in western Newfoundland, and it may yet lead to new discoveries elsewhere. The re-analysis of archived lake-sediment geochemical data, and the acquisition of similar data from till sampling, will be useful in assessing potential in unexplored areas. The resistant and dense nature of many of the unusual REE-bearing minerals suggests that indicator mineral surveys similar to those used to explore for diamondiferous kimberlites may also have utility in this search.

Selected References

- Batterson, M. J.
1989: Glacial dispersion from the Strange Lake alkalic complex, northern Labrador. Geological Survey of Canada, Paper 89-20, p. 31-40.
- Birkett, T.C., Miller, R. R., and Roberts, A. C.
1992: Zirconium-bearing minerals of the Strange Lake Intrusive Complex, Québec-Labrador. Canadian Mineralogist, Volume 30, p. 191-205.
- Curtis, L. W., and Currie, K. L.
1981: Geology and petrology of the Red Wine alkaline complex, central Labrador. Geological Survey of Canada, Bulletin 294, 61 p.
- Gale, G. H.
1967: Economic assessment of pegmatites, Newfoundland. Newfoundland Department of Mines, Agriculture and Resources, unpublished report (NFLD/0314).

- Hill, J., and Miller, R. R.
1990: A review of Middle Proterozoic epigenic felsic magmatism in Labrador. Geological Association of Canada, Special Paper 38, p. 417-431.
- Iron Ore Company of Canada (IOC)
1985: Preliminary feasibility study and related documents, Strange Lake Project. Unpublished Report, Iron Ore Company of Canada [Geological Survey File 024A/08/0029]
- Kerr, A.
2011: Rare Earth Element (REE) mineralization in Labrador: A review of known environments and the geological context of current exploration activity. *In* Current Research. Newfoundland and Labrador Department of Natural Resources, Geological Survey, Report 2011-1, p. 109-145.
- Miller, R. R.
1986: Geology of the Strange Lake alkalic complex and associated Zr-Y-Nb-Be-REE mineralization. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 86-1, p. 11-19.
- Miller, R. R.
1988: Yttrium (Y) and other rare metals (Be, Nb, REE, Ta, Zr) in Labrador. *In* Current Research Newfoundland Department of Mines and Energy, Mineral Development Division, Report 88-1, p. 229-245.
- Miller, R. R.
1989: Rare-metal targets in insular Newfoundland. *In* Current Research, Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 89-1, p. 171-179.
- Miller, R. R.
1990: The Strange Lake pegmatite-aplite hosted rare metal deposit, Labrador. *In* Current Research, Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 90-1, p. 171-182.
- Miller, R. R., Heaman, L. M., and Birkett, T. C.
1997: U-Pb zircon age of the Strange Lake peralkaline complex: implications for Meso-proterozoic peralkaline magmatism in north-central Labrador. *Precambrian Research*, Volume 81, p. 67-82.
- Richardson, D. G., and Birkett, T. C.
1996: Peralkaline rock-associated rare metals. *In*, *Geology of Canadian Mineral Deposit types*. Geological Survey of Canada, *Geology of Canada*, Volume 8, p. 523-540.
- Salvi, S., and Williams-Jones, A. E.
1990: The role of hydrothermal processes in the granite-hosted Zr-Y-REE deposit at Strange Lake, Québec-Labrador. *Geochimica Cosmochimica Acta*, Volume 54, p. 2403-2418.
- Saunders, C. M., and Tuach, J.
1989: Zr-Y-Nb-REE mineralization in the Cross Hills Plutonic Suite. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 89-1, p. 181-192.
- Tuach, J.
1991: The geology and geochemistry of the Cross Hills Plutonic Suite, Fortune Bay, Newfoundland. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 91-2, 73 p.

