Technical Report
On The Brazil Lake
Lithium-Bearing Pegmatite Property
Nova Scotia, Canada

Prepared for

Petro Horizon Energy Corp.

by

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Report Date: April 23rd, 2010

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Summary

In February, 2010 Mercator Geological Services Limited (Mercator) was retained by Petro-Horizon Energy Corp. (Petro Horizon) to prepare a property technical report compliant with Canadian Securities Administrators National Instrument 43-101 on the Brazil Lake Lithium-Bearing Pegmatite exploration property located in southwestern Nova Scotia, Canada. The property is currently held under exploration title by Champlain Mineral Ventures Ltd. (Champlain) and Petro Horizon has entered into an agreement with Champlain to acquire up to a 75% interest in the 184 mineral exploration claims comprising the Brazil Lake Property (BLP). The primary focus of exploration interest is evaluation of two existing lithium-bearing pegmatite dikes and exploration on the larger holding for additional dikes of similar association.

Combined results of property exploration to date define two northeast striking, near-vertically dipping, spodumene-bearing pegmatites dikes, these being the North Dike and South Dike. Both cross cut confining stratigraphy of the Silurian White Rock Formation at a low angle and show strike lengths exceeding 200 m at surface. They have been tested to date by limited drilling to a maximum depth of 75 m below surface and have geometry characterized by thickened central zones that plunge southwesterly at an angle of approximately 50 degrees. Dike true thicknesses range between 2 m near strike extremities to a maximum of approximately 20.95 m in the thickest central areas. Near-surface internal continuity of dike width and character between trenching and drilling observation points is demonstrated by extensive surface stripping on the South Dike and is inferred for the generally similar North Dike.

Both pegmatite dikes are comprised of typically coarse grained assemblages of K-feldspar, Na-feldspar (as albite-cleavelandite), spodumene, muscovite and quartz along with a variety of secondary minerals including tantalite-columbite, beryl, apatite and, rarely, cassiterite. Anomalous values of lithium (Li), rubidium (Rb) and tin (Sn) are present in both dikes and they are classified as Rare Element–LCT pegmatites using the classification system established by Cerny and Ercit (2005). Spodumene occurs as a medium grained to megacrystic phase within the pegmatites and modally accounts for 20% to 70% or more of dike content in some areas. Spodumene mineralization accounts for the lithium content within the pegmatites. Individual lithium oxide (Li_2O) grades defined to date based on core analysis range between 0.01% and

6.00%, with length weighted averages of all individual pegmatite samples within the North and South Dikes equal to 1.041% and 0.497% Li_2O, respectively.

Work completed to date by Champlain has also been directed toward definition of valuable mineral or metal components of the BLP dikes additional to lithium, and preliminary results indicate that potential exists for development of industrial mineral products such mica and feldspar concentrates. The company is also investigating the possibility of sourcing rubidium from dike materials. Initial processing studies directed toward beneficiation of lithium-bearing spodumene concentrates as well as other products have been successfully carried out but additional work is required on this front.

To meet the established reporting objective, a complete review of property documentation from multiple sources, including operator assessment reports, government reports and academic research was first completed by Mercator to provide an overview of property setting, exploration history and mineralizing environment. This was followed by two visits to the BLP site, one visit to review historic drill core and a review of pertinent economic factors. After evaluation of all available information, Mercator has concluded that additional specified exploration of the property is currently warranted through a two Phase program of recommended exploration. Phase 1 costs total $452,000 Cdn. and Phase 2 costs total $574,000 Cdn. Phase 2 expenditures are contingent on success in Phase 1.

Phase 1 programs include (1) completion of geological mapping and prospecting over all property areas not previously covered, (2) initial in-fill and depth extension core drilling on the North Dike and South Dike, (3) follow-up of the Deerfield and Church Road-Army Road boulder prospect areas through modest programs of Reverse Circulation (RC) drilling and surface trenching, and (5) additional metallurgical studies. The Phase 2 program includes (1) completion of any required delineation core drilling on the North Dike and South Dike, (2) initial core drilling investigation of existing and new Phase 1 targets, (3) completion of a National Instrument 43-101 mineral resource estimate for the North Dike and South Dike pegmatites, (4) continuation of beneficiation or bulk sampling studies, and (5) completion of a preliminary economic assessment of mineral resources defined through (3) above.

1 INTRODUCTION AND TERMS OF REFERENCE

On March 1st, 2010, a management agreement was signed between Mercator Geological Services Limited (Mercator) of Dartmouth, Nova Scotia and Petro Horizon Energy Corp. (Petro Horizon) of Vancouver, British Columbia. This agreement outlines Mercator's commitment to review the nature of the Brazil Lake exploration property, located in Nova Scotia, Canada, audit technical information pertaining to the property, and to prepare a Technical Report (the "Report") based on results of this work that is compliant with National Instrument 43-101 "Standards of Disclosure for Mineral Projects", as regulated by the Canadian Securities Administrators. A further requirement was for report content to meet best practice guidelines of the Canadian Institute of Mining, Metallurgy and Petroleum. Mid to late Devonian lithium-bearing pegmatite dikes form the exploration and reporting focus with respect to the Brazil Lake Property (BLP).

Petro Horizon executed a letter of intent dated February 5th, 2010 with Champlain Mineral Ventures Ltd. (Champlain), of Bridgetown, Nova Scotia to earn up to a 75% undivided ownership interest in the BLP. Champlain has held exploration interests in this area since 1997 and the current Technical Report was triggered by the opportunity presented through the agreement with Petro Horizon for a change in material ownership of the BLP, with associated transfer of material rights from Champlain.

In support of report preparation, hard copy and /or digital records of historic data were provided by the Petro Horizon, which in part included assessment reports, complete drill logs, drill plans, assay records and laboratory records for drilling completed by Champlain. In addition, information acquired through periodicals and public government files that pertain to the BLP was also accessed. All of this information was reviewed by Mercator. Quality Assurance and Quality Control measures were established as necessary by Mercator with respect to review and sampling of archived drill core from the property.

Both authors of this report are Qualified Persons as defined under National Instrument 43-101 and have had no direct involvement in any exploration work carried out to date on the property. Both authors have undertaken field visits, completed data review and interpretation activities specifically for report purposes, and consulted with both Petro Horizon management and geological staff.

As noted previously, the commodity of primary interest on the BLP is lithium (Li) contained in the silicate mineral spodumene ($LiAlSi_2O_6$), with secondary interest focused on separation of mica and high purity feldspar and quartz components of the pegmatite dikes present on the property. Potential for recovery tantalum (Ta), tin (Sn) and rubidium (Rb) may also be present locally. Li is used in a variety of industrial applications and recent demand within the battery technology field has created much interest in exploration and evaluation of primary sources of the metal. Li is used in a broad range of applications but those associated with primary and secondary battery technologies have been of particular recent interest in light of increasing application interest in the automotive market environment. Battery cells used in dischargeable applications such as pace makers, small portable electronics, and some automobile electronics typically contain lithium metal as a cathode, with the metal sourced from primary lithium chloride (LiCl) feedstock. In contrast, battery cells used in rechargeable applications, such as portable electronics and hybrid electric vehicles, utilize lithium as a dry electrolyte (Li^{++}-ion) derived from primary lithium carbonate ($LiCO_3$) feedstock.

Lithium production worldwide is from two primary sources; these being (1) pegmatite-associated bedrock occurrences dominated by lithium silicate (spodumene) mineralization, but including other minerals such as amblygonite, eucryptite, lepidolite and petalite, and (2) highly concentrated groundwater brines. The BLP represents an example of the spodumene-bearing pegmatite association.

2 RELIANCE ON OTHER EXPERTS

This report was prepared by Mercator for Petro Horizon and reflects reliance on opinions of the authors in all instances except those of (1) confirmation of mineral title, (2) confirmation of land access agreements and (3) environmental liability assessment, wherein reliance has been placed on information and opinions received from Champlain and Petro Horizon. Two field trips to the property were undertaken with the Senior Geologist of Champlain, Mr. D. Black, these being on

March 2nd and April 7th, 2010. The visits allowed Mercator staff to inspect the nature of BLP mineralization in outcrop, collect outcrop and drill core samples, assess the character of historic drilling and core storage, and to observe landscape and cultural features proximal to the BLP. Mr. Black's substantial expertise with respect to the BLP is recognized. However, conclusions and recommendations presented herein remain those of the authors and Mercator, subject to the itemized qualifications presented above.

3 PROPERTY DESCRIPTION AND LOCATION

The BLP is located in Yarmouth County, southwestern Nova Scotia, Canada and is centered near the intersection point of National Topographic Service (NTS) map sheets 21/B/1A, 21/A/4B, 20/O/16D, and 20/P/13C (Figures 3.1 and 3.2). It consists of five contiguous mineral exploration licences held at the report date by Champlain under terms of the Mineral Resources Act (1990, c. 18, s.1.) of Nova Scotia. Table 3.1 outlines pertinent BLP information.

Table 3.1: Summary of Champlain's BLP Exploration Holdings

Exploration Licence	Claims	Area (Hectares)	Anniversary Date
5895	36	388.5	Jan 27/2011
5866	41	404.7	Mar 15/2011
09085	15	242.8	Mar 22/2011
09083	78	1262.7	Mar 22/2011
09084	42	679.9	Mar 22/2011
Total	184	2978.6	

Champlain advised Mercator that at the report date all mineral exploration licences comprising the BLP were in good standing with respect to terms and conditions of the Mineral Resources Act (1990, c. 18, s.1.). Mercator checked this against publicly accessible records of the Nova Scotia Department of Natural Resources (NSDNR) but did not commission a legal search of title. Based on the preceding, Mercator cannot provide confirmation of legal exploration title for the BLP, but had no reason at the report date to question either NSDNR records of assertions of title by Champlain.

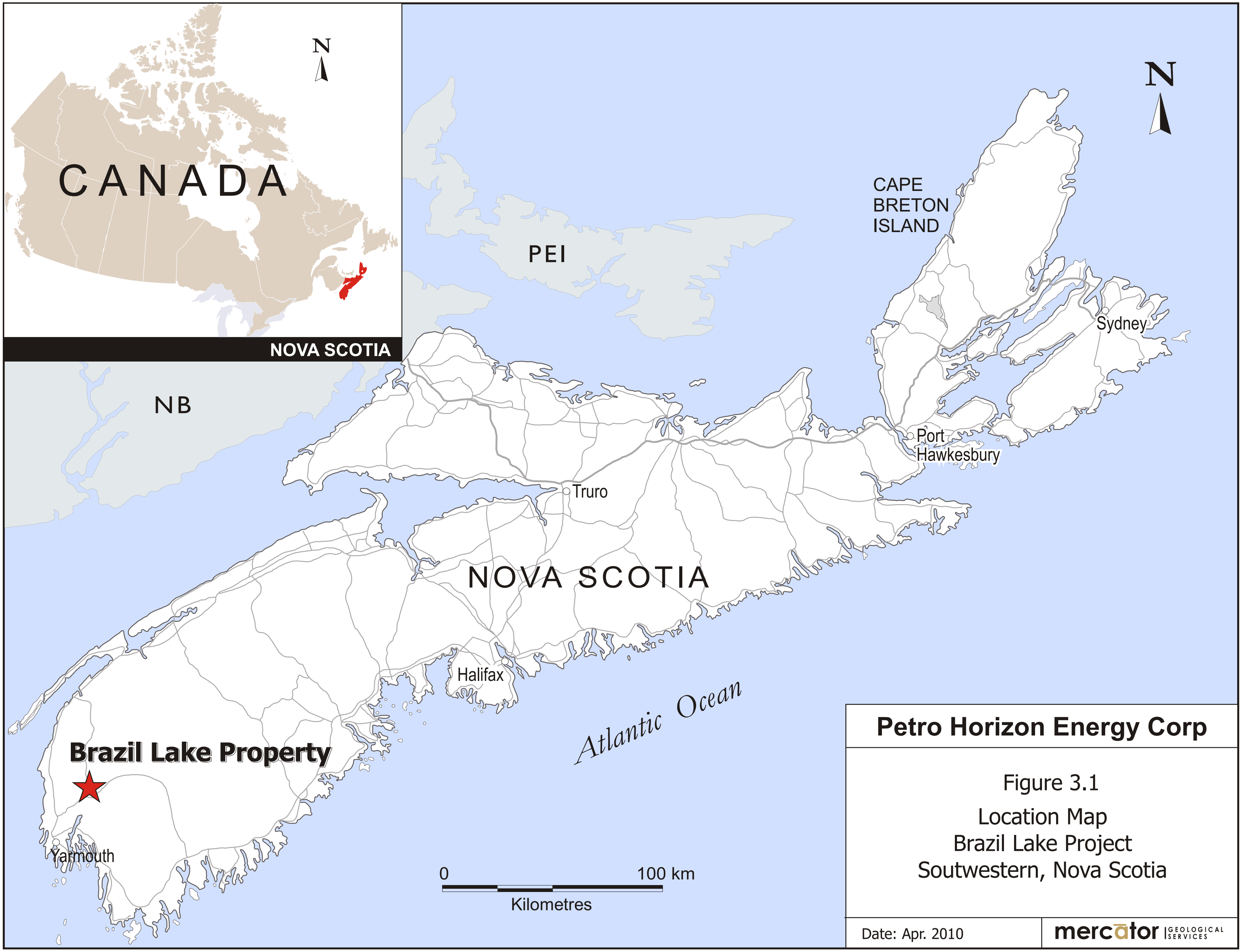

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Figure 3.1
Location Map
Brazil Lake Project
Soutwestern, Nova Scotia

Date: Apr. 2010

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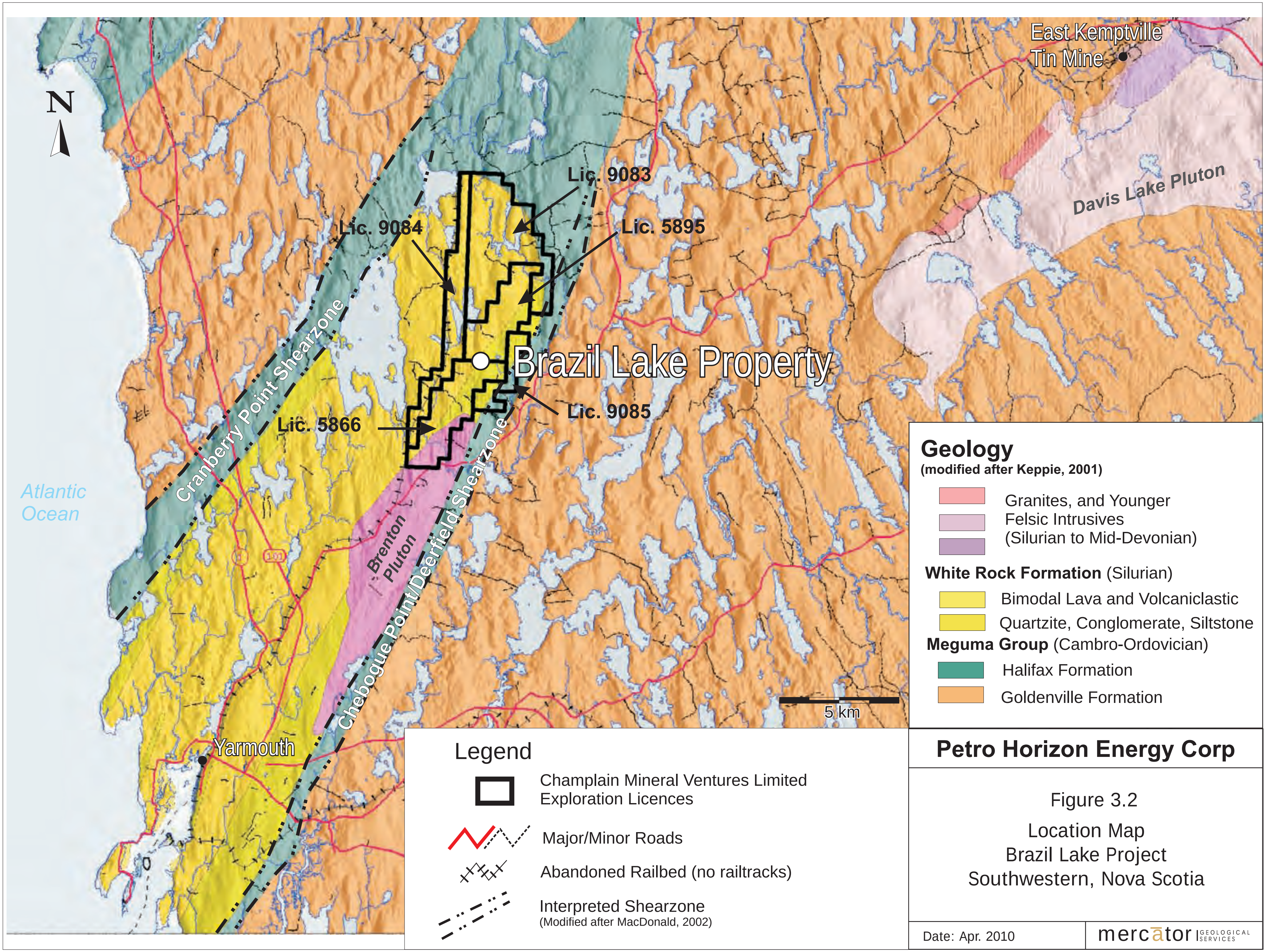

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Figure 3.2

Location Map
Brazil Lake Project
Southwestern, Nova Scotia

Date: Apr. 2010

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Champlain also advised Mercator that access agreements to carry out mineral exploration activities during 2010 had been established with landowners in areas of the BLP for which exploration activities are currently planned. Mercator did not review any of these documents and therefore cannot provide associated comment. However, as in the preceding case, no reason was known to Mercator at the report date to question assertions in this regard provided by Champlain.

4 ACCESSIBILITY, CLIMATE, LOCAL RESOURCES, INFRASTRUCTURE AND PHYSIOGRAPHY

4.1 Accessibility, Local Resources and Infrastructure

The BLP is located less than 25 km north-northeast of the town of Yarmouth, Nova Scotia and is accessible via provincial secondary Highway 340. Yarmouth is an important port, tourism and business center serving southwestern Nova Scotia and is located approximately 400 km southwest of the provincial capital city of Halifax. It has a population of approximately 7,000 (Statistics Canada, 2006), supports deep water shipping, ferry operation and fishing fleet activities, and also serves as a regional center for health care, light industry and municipal government.

Typical support services such as motel, dining and general retail facilities are available in the Yarmouth area and good quality highway connections exist with the rest of Nova Scotia. A commercial ferry link between Bar Harbour Maine and Yarmouth has historically operated but had been temporarily curtailed at the report date. The town also has commercial airport facilities and is an international customs entry point. At present, it is not served by major scheduled air carriers.

This area of Nova Scotia no longer has railway service, with the closest current rail access points being with the Canadian National Railway system in Halifax, approximately 400 highway kilometers to the northeast, or with the Windsor and Hantsport Railway short line in Hantsport, 300 highway kilometers to the north-northeast.

Several small communities and hamlets are located in the general vicinity of the BLP, most notably Brazil Lake, Carleton, and Deerfield, which collectively offer modest convenience, fuelling and retail services. These are rural in character and typified by relatively sparsely distributed homes located along main highways. Lands within the BLP are predominantly forested and owned by individuals or commercial forestry interests.

The areas of spodumene-bearing pegmatite that are of immediate interest to Petro Horizon are readily accessible by roads and trails and occur within 1 km of regular electrical grid access. A combination of public and private roads and trails provide easy access to most other areas of the BLP.

In addition to several very small scale, long-abandoned gold mining ventures, communities in the Yarmouth-BLP area supported large scale, open pit mining operations at the East Kemptville tin mine, located approximately 25 km to the north-east along secondary Highway 203. The mine was operated by Rio Algom Ltd. between 1985 and 1992 and had initial reserves of 56 Mt grading 0.165% tin (Sn). Historical production of 18.8 Mt of ore from the open pit operation is recognized by the Nova Scotia Department of Natural Resources (Patterson, 1993). The mine was recognized as the only producer of primary tin in North America during its operational life and concentrate was shipped by ocean-going vessels from Yarmouth. Mine operations developed an awareness of the industry’s potential for local economic benefit and this should prove favourable for any future mining operations in this area.

4.2 Climate and Physiography

Nova Scotia is situated on the eastern seaboard of Canada and is almost completely surrounded by marine waters of the Atlantic Ocean, Bay of Fundy and Northumberland Strait. The climate is temperate and substantively moderated by heat flux of the surrounding waters. Environment Canada records for nearby Yarmouth airport show average yearly temperature to be 7 degrees Celsius and average yearly precipitation to total 1,274.1 mm. Approximately 13 percent of total precipitation accumulates as snow (~204 cm). Winter periods are milder than in many other regions of Nova Scotia, with the average minimum January temperature being -7 degrees Celsius. The average July maximum temperature is 20.6 degrees Celsius.

The property is located approximately 25 km from the nearest coast and experiences fewer days of fog on an annual basis than coastal areas. Weather conditions generally do not pose substantial challenges for most exploration activities, although soft ground conditions during Spring breakup period can hinder mechanized activities such as drilling. The topography of the region is predominantly rolling hills with rounded broad valleys comprising large catchment and drainage basins. The terrain displays prominent glacial landform features such as drumlins and is further characterized by pervasive presence of locally deep and complex glacial till cover that typically masks recessive bedrock geological features.

5 EXPLORATION HISTORY

5.1 Early History (1960 to 2002 Period)

The first noted occurrence of spodumene-bearing pegmatite on the BLP is through mapping conducted by the Geological Survey of Canada in the Yarmouth area in 1960. Taylor (1967) later reported that this reflected discovery of a large spodumene-bearing pegmatite boulder along the north shoulder of Holly Road, a secondary road connecting Brazil Lake and Hwy 340. The boulder still remains on the side of the road today, and occurs between what have been designated for purposes of this report as the North Dike and South Dike pegmatites of the BLP. These were initially described in Geological Survey of Canada Memoir 349 (Taylor, 1967) and presented on the associated geological map. Initial outcrop stripping by Taylor exposed a portion of the South Dike in which he determined modal mineralogical analysis to be 52% feldspar (potassium feldspar, or K-spar and albite), 34% quartz, 11% spodumene, 3% muscovite and minor to trace beryl/apatite/tourmaline. Subsequent to this, in 1971, a 272 kg bulk sample collected by Brian Walsh of the Mineral Engineering Department at the Technical University of Nova Scotia, reportedly comprising 34.4% modal spodumene, was determined to have 0.18-3% Fe_2O_3. after completion of limited initial metallurgical work.

Little work was subsequently conducted on the property until the late 1970's, when Shell Canada Exploration Ltd. (Shell) completed regional mapping plus geophysical and geochemical sampling programs in the area to follow-up anomalous tin values present in an earlier water survey carried out by the company (Palma, 1982). The further course of this work eventually led to discovery of the East Kemptville tin deposit, with preliminary reserves reported in 1980, and is summarized by Patterson (1993). As mentioned earlier, this deposit was mined by a subsidiary of Rio Algom Ltd. between 1985 and 1992.

Regional B horizon soil sampling carried out by Shell included analysis of Li levels but generally insignificant amounts were returned from the area of mapped BLP pegmatites. As part of an unpublished B.Sc. thesis at Dalhousie University, Hutchinson (1982), in conjunction with Shell, completed regional mineralogical research that included characterization of the geology, geochemistry and genesis of the BLP pegmatites. Additionally, he recognized a metasomatic halo in host rocks surrounding the spodumene-bearing pegmatites that contained tourmaline as well as holmquistite, a lithium bearing amphibole mineral. These results lead to develop of an evaluative system for alteration zones surrounding such pegmatites based on geochemical signatures.

Numerous operators staked claims over the known pegmatites during the 1980s and early 1990s and the bulk of work performed during this period was directed toward market research and product viability of the main potentially economic components of the pegmatite, these being considered to be lithium (Li), rubidium (Rb) and cesium (Cs). Barrett (1987, 1990, 1991) described these efforts in detail, ultimately for Aurion Minerals Ltd. (Aurion), which completed limited rock sampling as late as 1991, with sustained focus on the K-feldspar market with Rb and Cs being complimentary to Li in spodumene as secondary economic interests. While positive results were returned from some of this work, Aurion did not continue evaluation of the property after 1992.

Following work by Aurion, the Nova Scotia Department of Natural Resources completed a regional multi-media geochemical survey in the vicinity of the known BLP pegmatite occurrences, with results of the program being reported by Macdonald (1992). Humus, silt, and spruce bark were used as media in the survey but interpretation of results did not definitively outline the pegmatite dikes.

The first phase of drilling on the property was undertaken by the Nova Scotia Department of Mines and Energy in 1993 and consisted of 5 diamond drill holes totaling 576.64 m of drilling. Corey (1995) reported on this work, which was designed to characterize down dip expression of the partially exposed North Dike pegmatite to a depth of approximately 75 m below surface. Results from 5 holes showed this pegmatite to measure more than 150 m along strike and to range in true thickness between 3.1 m and 20.9 m where drilled, defining promising down-dip potential. The dike was interpreted as being open in all directions after drilling, with thinning at surface recognized near the northern extremity and maintained thickness near the southern extremity. As reported by Corey (1995), substantive analytical investigation of NSDNR core was not carried out due to presence of elevated (>0.10%) iron levels recognized during electron microprobe analysis of certain core samples of BLP spodumene. This core was, however, analyzed by Gwalia Consolidated Ltd. in 1998, as discussed below.

Hughes (1995) reported on the BLP in an unpublished BSc thesis that addressed internal zonation and mineralogy of the BLP pegmatites through detailed petrographic investigation. This work expanded the technical data set for the pegmatites but did not have a significant economic impact.

In 1998, Gwalia Consolidated Ltd. (now Tilson Pty. Ltd.) of Perth Australia, then operators of the Greenbushes spodumene mining operation in Western Australia, carried out an assessment of the Brazil Lake area in search of pegmatite-hosted tantalum mineralization exceeding a minimum threshold value of 200 parts per million (ppm). Associated programs included review and sampling of NSDNR drill core from 1993. Although their search for high concentrations of tantalum fell short, the resulting geochemical database was, at the time, the most extensive for the property. Results of exploration carried out during this period were reported in Hudgins (1998) but the company did not complete any further work on the property. This reflected the fact that Ta values returned during the assessment generally did not exceed the minimum interest threshold.

Initial staking of exploration claims in the Brazil Lake area on behalf of Champlain occurred in 1997 in the form of claims registered to Mr. Avard Hudgins, a senior geologist associated with

Champlain at that time. These holdings were subsequently transferred to Champlain in 1999. As such, the work conducted by Gwalia was credited directly to Champlain's exploration interest.

From 1997 to 2002, Champlain focused field efforts on limited prospecting in and around the main BLP pegmatite zones and this resulted in discovery of various new pegmatite float occurrences. The most promising of these was noted to have been discovered lodged in till north of the main property at what is now known as the Gardiners Mills prospect. Hudgins (2001) reported on this and also presented a positive analysis of potential economic significance of the main pegmatites of this area, with particular focus on tantalum. Reference is also made to earlier discovery by Acadia Mineral Ventures Limited of a pegmatite boulder grading 10% tantalum (Ta) and 10% niobium (Nb) during a regional reconnaissance sampling program in the Gardiner Mills area. However, a specific source reference for this discovery was not provided. Regional work conducted by Champlain at this time does not appear have defined a bedrock source for the well mineralized boulder and no further specific assessment reporting was found for the property between 1999 and 2002.

5.2 Recent History (2002-2010 Period)

By 2002, sufficient interest and funds had been generated by Champlain to proceed with exploratory core drilling on the BLP, in addition to additional prospecting and water sampling surveys. In total, 16 drill holes totaling 1,324 m were completed between January and February of that year. The program was designed to test the near surface extent of the North Dike and South Dike and to test for bedrock sources in areas of adjacent dense pegmatite floats identified during previous prospecting programs. Results of the 2002 drilling form an important part of Mercator's assessment of exploration potential of the BLP and are discussed in detail in Section 10.2 of this report.

Results of prospecting on the property in 2002 were described by Black (2002) and outlined two additional areas of interest along strike from the North and South pegmatite dikes. The Bloomfield Road and Deerfield prospects both reflect occurrence of abundant fine grained cleavelandite-muscovite rich pegmatite material distributed along float trails located sub-parallel to and down-ice from the extrapolated strike of the known North and South pegmatite dikes.

Both prospects are located along a common, northeast striking trend that extends from 2.3 kilometers northeast to 4.2 kilometers southwest of the known dikes. Of particular note is that some boulders at the Deerfield prospect show granite-hosted pegmatite and are assumed to be derived from the nearby Mid Devonian Brenton granite. This contrasts with the hornblende-chlorite schist and quartzite that host the North and South dikes, but the source of the Deerfield boulders was not located.

Later in 2002 and early in 2003 Champlain completed additional work, including a substantial surface trenching and stripping program on the South Dike and a limited trenching program on boulder field targets areas at Holly Road (North Dike area) Army Road, Church Road and Holly Road. Black (2003) described the nature and results of this work and noted that no new bedrock pegmatite occurrences had been defined.

After completion of the 2002 trenching programs, Champlain considered the primary BLP concern to be completion of an economic assessment of the property, with focus on the lithium bearing spodumene, potassium feldspar, sodium feldspar and mica products. Possible economic consequence of isolated tantalum/niobium, cassiterite and beryl mineralization that the company had identified in small amounts locally within the pegmatites was also of interest.

During 2003 and 2004, Champlain continued research and mineral analysis programs to further ascertain processing viability, separation, purification and market conditions related to spodumene, mica, silica and other accessory industrial minerals. Black (2004) provided basic laboratory documentation of these studies and generally concluded that concentration of economically important mineral fractions such as mica, spodumene and K-feldspar had been successfully accomplished in several instances. Both dry processing and flotation processing options were considered.

A thorough investigation of the trenched and washed South Dike was initiated in 2003 by the NSDNR and results were presented in Kontak (2004). This work included detailed study of spodumene mineralization, dike geochemistry, dike zonation, and structural features, results of which are discussed in report Section 7.0.

To provide context for results of ongoing laboratory studies by the company, Hains Technology and Associates was retained by Champlain in 2004 to carry out research into world markets for lithium metal and lithium chloride. This project provided an in-depth perspective on supply and demand for lithium chloride (LiCl) as an industrial feedstock and also into potential applications of other mineral products. Results presented in Hains (2004) are discussed in report Section 15.0 and showed that positive economic potential existed for lithium-bearing pegmatites having grade and mineralogical characteristics similar to those found on the BLP.

Subsequent to completion of the above work, Champlain also carried out a regional B-horizon soil survey in the Army Road-Church Road area during 2004 and completed a limited amount of trenching on the North Dike. The soil survey was directed toward defining areas of bedrock pegmatite through anomalous Li, Na, K and Rb levels and results of both programs are presented in report Section 9.0. Champlain has advised that no additional significant work has been carried out on the BLP since the soil sampling and trenching program in 2004.

6 GEOLOGICAL SETTING

6.1 Regional Geological Setting

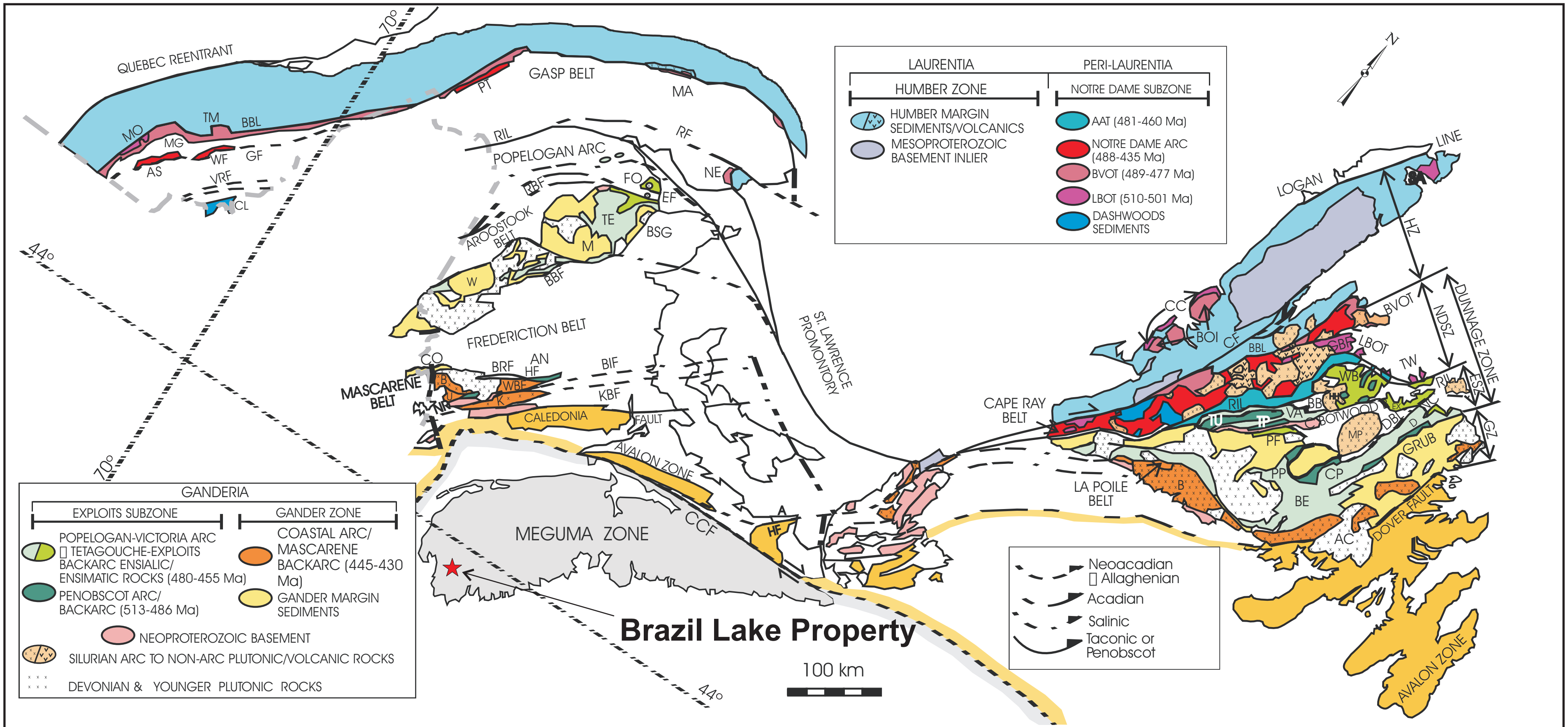
The BLP pegmatite dikes occur within the White Rock Formation of the Meguma Zone of southwestern Nova Scotia. The Meguma Zone is the most outboard, or eastern-most litho-tectonic zone accreted to the northern Appalachian system during the Mid Devonian Acadian Orogeny and is comprised of rocks ranging in age from Cambrian-Ordovician to Mid Devonian. The Meguma Zone in the BLP area of southwest Nova Scotia can be roughly divided into northeast to east trending constituent composite stratigraphies of the Cambro-Ordovician Meguma Group (Halifax and Goldenville Formations) plus the Silurian White Rock Formation and granitic igneous intrusions related to the Devonian South Mountain Batholith (Figure 6.1).

The Meguma Group is comprised of deep-water, turbiditic continental-shelf sediments and is divided into two formations, the older Goldenville Formation and the conformably younger Halifax Formation. The Goldenville Formation is composed of massive meta-sandstones, and locally meta-siltstones, of Cambro-Ordovician age, whereas the Halifax Formation is predominantly comprised of sulphur-rich meta-siltstones and slates of Ordovician age. The latter reflects deposition in a deeper water abyssal plain environment off of the Gondwanan continental shelf. Rocks of both formations were later accreted to unrelated Avalon Zone sequences to the north and west during closure of the Rheic ocean basin that culminated during the Mid Devonian Acadian Orogeny. This accretionary event is marked by development of the prominent Cobequid-Chedabucto fault system that transects west to east through Nova Scotia and separates the Meguma Zone from the Avalon Zone. The rocks of the Meguma Group were deformed into broad northeast trending upright folds which characterize the landscape of southern and eastern Nova Scotia and present the only exposures of these rocks within the broader Appalachian composite stratigraphy.

The White Rock Formation refers to rocks of Silurian age that comprise interbedded sequences of meta-sediments and meta-volcanic rocks. These are interpreted to be part of an overstep sequence that covers both the Meguma Group and some similar-aged rocks of the Avalon Zone (Keppie and Krogh, 2000).

In western Nova Scotia, Silurian age rocks are also found in the Yarmouth, Cape St. Mary, Torbrook, Digby and Wolfville areas, and are commonly associated through presence of interbedded sequences of continental sediments deposited in shallow water environments (MacDonald, 2001, White et al., 1999, and Ferguson, 1990). White Rock Formation sequences in the Yarmouth (BLP), Cape St. Mary and Torbrook areas are unique to those found in other locations in that they record episodes of aqueous to sub-aerial volcanic events (White, 1999, Keppie, 2000). These events have been attributed to an extensional tectonic regime, dated to have occurred between 442±4 Ma (U-Pb, Keppie, 2000) and 438±3 (MacDonald, 2001). Geochemical data indicate that these volcanic rocks display within-plate alkali characteristics (James, 1998) and that contained mafic volcanics show less evidence of crustal contamination than younger Devonian granites (MacDonald, 2001).

In the Yarmouth (BLP) area, the White Rock Formation forms a northeast trending belt extending inland from coastal exposures north and south of Yarmouth, that occurs along the



Tectonic map of the Canadian Appalachians with the distribution of the Early Paleozoic tectono-stratigraphic zones, subzones and other major tectonic elements (coloured) discussed in text. Middle Paleozoic belts are also indicated but not coloured. Adapted from van Staal (2006). AAT: Annieopsquotch accretionary tract; AC: Ackley granite; AN: Annidale belt; AS: Ascott Complex; B: Burgeo batholith; BB: Badger belt; BBF: Bamford Brook fault; BBL: Baie Verte Brompton Line; BE: Baie d'Espoir Group; BIF: Belleisle fault; BOI: Bay of Island Complex; BVOT: Baie Verte oceanic tract; BRF: Basswood Ridge fault; BSG: Bathurst Supergroup; CB: Cripple Back-Valentine Lake plutons; CC: Coastal Complex; CCF: Cobequid-Chedabucto fault; CF: Cabot fault; CL: Chain Lakes Massif; CO: Cookson Group; CP: Coy Pond Complex; D: Davidsville Group; DBL: Dog Bay Line; EF: Elmtree fault; ESZ: Exploits Subzone; EX: Exploits Group; FO: Fournier Group; GBF: Green Bay fault; GF: Guadeloupe fault; GRUB: Gander River ultrabasic belt; GZ: Gander Zone; HF: Hollow fault; HH: Hodges Hill Pluton; HZ: Humber Zone; K: Kingston belt; KBF: Kennebacasis fault; LBOT: Lushs Bight oceanic tract; M: Miramichi Group; MA: Mont Albert ophiolite; MG: Magog Group; MO: Mount Orford ophiolite; MP: Mount Peyton pluton; NC: Noggin Cove Formation; NE: Neckwick Formation; NDSZ: Notre Dame Subzone; NR: New River belt; PF: Pine Falls Formation; PP: Pipestone Pond Complex; PT: Pointe aux Trembles Formation; RBF: Rocky Brook-Millstream fault system; RF: Restigouche fault; RIL: Red Indian Line; SA: St Anthony Complex; TE: Tetagouche Group; TM: Thetford Mines ophiolite; TP: Tally Pond Group; TU: Tulks Group; TW: Twillingate trondhjemite; VA: Victoria arc; VRF: Victoria River fault; W: Woodstock Group; WB: Wild Bight Group; WBF: Wheaton Brook fault; WF: Weedon Fromation.

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Figure 6.1
Geological Zonation
of Northern New Brunswick

Date: Apr. 2009

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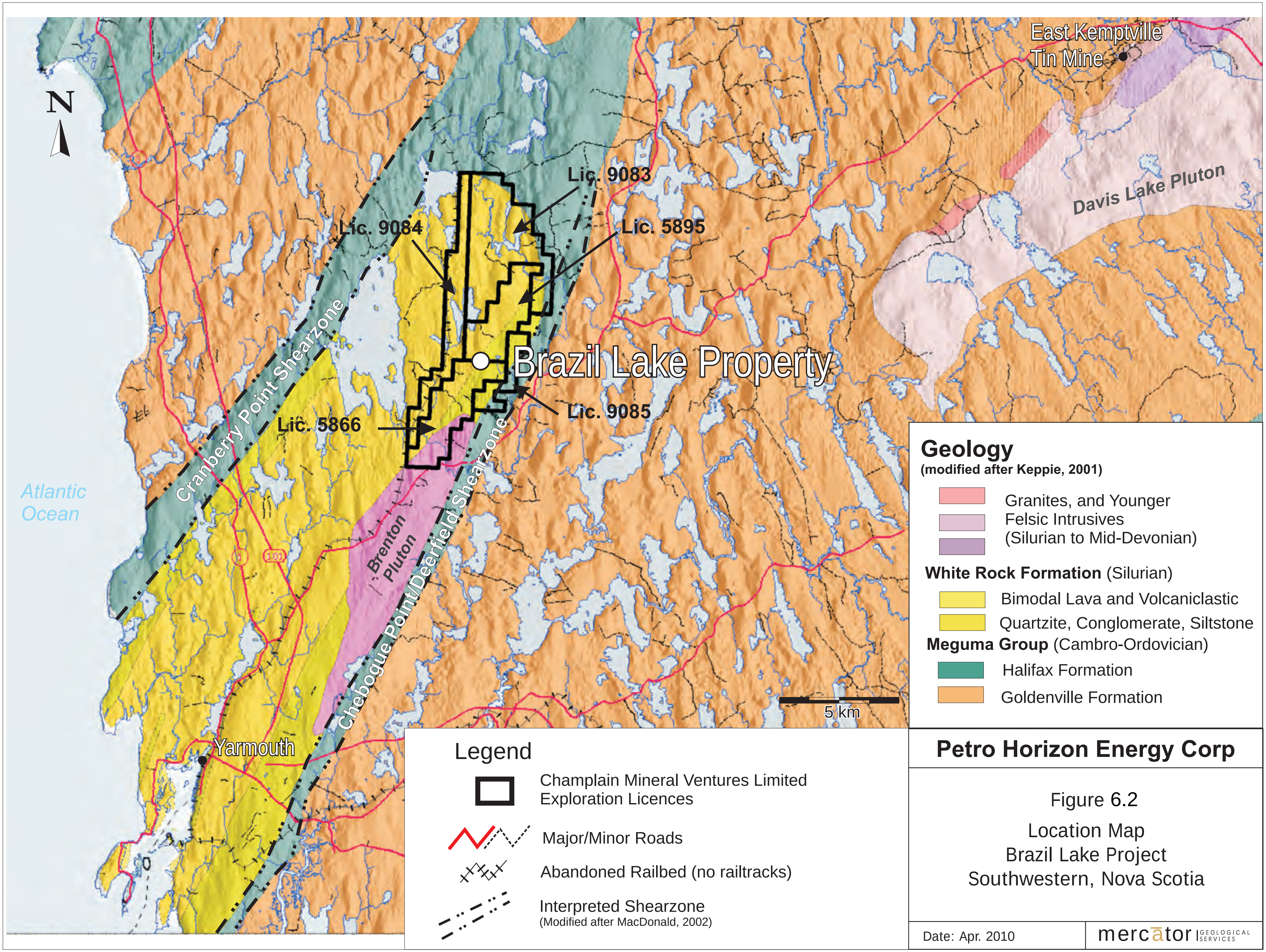
northern contact of the South Mountain Batholith. Related sequences are confined within the regionally significant Yarmouth syncline that affects both White Rock Formation and Meguma Group strata. The White Rock Formation is in unconformable contact with surrounding Halifax Formation in this area and, locally, with the Goldenville Formation (Figure 6.2). Its southeastern contact is inferred to be a brittle fault that follows and post-dates a broader major northeast trending ductile shear zone referred to as the Deerfield Shear Zone by Keppie and Dallmeyer (1995) and, alternatively, the Chebogue Point Shear Zone by Culshaw and Liesa (1997). Both structures cross the BLP and dextral shearing evidence is interpreted to be present in rocks of both Halifax and White Rock Formations. White Rock Formation meta-sediments reached the staurolite-grade of regional metamorphism in this area and are typically schistose (MacDonald, 2001).

Debate exists as to the structural context of the White Rock Formation in the Yarmouth area. It was previously thought by numerous authors (Taylor, 1967, Lane, 1979, Hwang, 1985, Culshaw and Liesa, 1997) that the belt occurs as a synclinal structure reflecting the extension of the Yarmouth syncline, based on mapping of coastal exposures in combination with inland interpretation of aeromagnetic data and the few outcrop localities that occur. MacDonald (2001) argued that the sequence was more accurately interpreted as being right-way up, southeasterly dipping, and younging toward the southeast. Her delineation of 7 distinct, non-repeating lithologic packages across the belt calls into question the previously accepted synclinal interpretation. Details of this discussion are beyond the scope of this report, however, both interpretations depict predominantly staurolite and garnet-bearing metasedimentary rocks interbedded with minor mafic metavolcanic (amphibolite) units that run roughly parallel to the southeastern contact of White Rock Formation in the BLP area, this being long the Deerfield Shear Zone. The White Rock Formation is also consistently identified as forming the host sequence for the late , Brenton Pluton that is located a short distance southwest of the currently defined BLP pegmatites.



Geology

(modified after Keppie, 2001)

🟥 ⬜ 🟪 Granites, and Younger Felsic Intrusives (Silurian to Mid-Devonian)

White Rock Formation (Silurian)

🟨 Bimodal Lava and Volcaniclastic

🟨 Quartzite, Conglomerate, Siltstone

Meguma Group (Cambro-Ordovician)

🟩 Halifax Formation

🟧 Goldenville Formation

Legend

Champlain Mineral Ventures Limited Exploration Licences

Major/Minor Roads

Abandoned Railbed (no railtracks)

Interpreted Shearzone
(Modified after MacDonald, 2002)

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Figure 6.2
Location Map
Brazil Lake Project
Southwestern, Nova Scotia

Date: Apr. 2010

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The Brenton pluton is a medium-grained, syeno-granite to monzogranite (O'Reilly, 1976, MacDonald, 2000) that intrudes along the southeastern contact of the White Rock Formation in the Yarmouth-BLP. A 439 Ma U/Pb zircon age (Keppie and Krogh, 2000) suggests the pluton is Silurian in age. The pluton lies approximately 3 km southwest of the BLP and is fault bounded with both the Halifax Formation to the east and the White Rock Formation to the west. It is typically strongly foliated and lineated, but contains local areas in its central region that are less deformed and characterized by equigranular igneous textures. The pluton is interpreted to have moved upward from depth within the Deerfield Shear Zone and as such may not be directly responsible for metamorphism seen in the immediately surrounding White Rock Formation meta-sediments (MacDonald, 2001).

6.2 Brazil Lake Property Geology

Two highly evolved granitic pegmatite dikes are the current focus of exploration interest within the BLP and these are hosted by meta-sediments and meta-volcanics of the White Rock Formation, which locally include quartzite, amphibolite, and pelitic-schist. The White Rock Formation sequence strikes northeasterly and locally dips steeply to the both northwest and southeast in quarry exposures located within 100 m south of the South Dike's southern limit (*see* Map 1, Appendix 3). This dip orientation differs in part from the regional orientation as mapped by MacDonald (2001).

Mapping of scarce outcrop in the immediate area of the pegmatites has shown that all three varieties of host rock are in contact with the pegmatite, indicating a low angle oblique intersection between the bedding of host rocks and the intrusive bodies. Contact zone host rocks are commonly sheared and/or faulted, but penetrative deformation fabrics associated with such are not present in either the pelitic-schists or amphibolites of the host section or within the dikes themselves. Kontak (2004) noted that adjoining quartzite beds locally display bleaching of colour near the pegmatite contacts, attributing this to possible silicification, and also described abundance of tourmaline-rich xenoliths, likely altered amphibolites, that occur along the contact zone.

A general lack of penetrative deformation is seen in the pegmatite, suggesting discontinuity between development of metamorphic fabric and mineral assemblages seen in adjacent wallrock and the pegmatites. No obvious regional structural features appear to have been exploited during the emplacement of the pegmatites and it is plausible that the dikes represent a parallel set of extensional features, with dilation possibly related to late shear stresses along the nearby Deerfield Shear Zone (Kontak, 2004). Brittle shearing fabrics along dike contact zones reflect a later event, possibly associated in time with late stages of regional brittle faulting.

As noted earlier, the two known BLP pegmatite dikes have been identified as the North Dike and South Dike for report purposes. This reflects their relative position in regard to the Holly Road, which crosses the area between the two intrusions (Figure 6.3). Related surface exposures are separated by about 300 m, and the dikes occur in roughly parallel, en-echelon fashion, strike northeasterly (050 azimuth) and dip steeply to the southeast at inclinations between 75° and. 80°. Results of drilling and surface trenching to date show the dikes to be lenticular in form, with generally wider cores transitioning to thinly tapered extremities (Figure 6.3). The North Dike is at least 300 m in length and distinctly thickened in its center, where a maximum true thickness value of 20.95 m is defined through drilling results. Interpretation of drilling data also shows that the thickened central zone plunges southwesterly at an angle of approximately 50 degrees. The South Dike measures about 300 m in defined strike length, varies between 8 and 12 m in true thickness where completely exposed by trenching, and also bears evidence of a southwest plunging trend of approximately 50 degrees for a thickened zone.

A currently active aggregate quarry is situated on strike and approximately 100 metres beyond the most southerly surface exposure of the South Dike, but shows no evidence of the pegmatite within the estimated 10 vertical meters of bedrock section exposed to date through excavation. This is consistent with the southwest plunging dike interpretation mentioned above that would place the dike extension below the current elevation of the quarry floor (Map 1, Appendix 3).

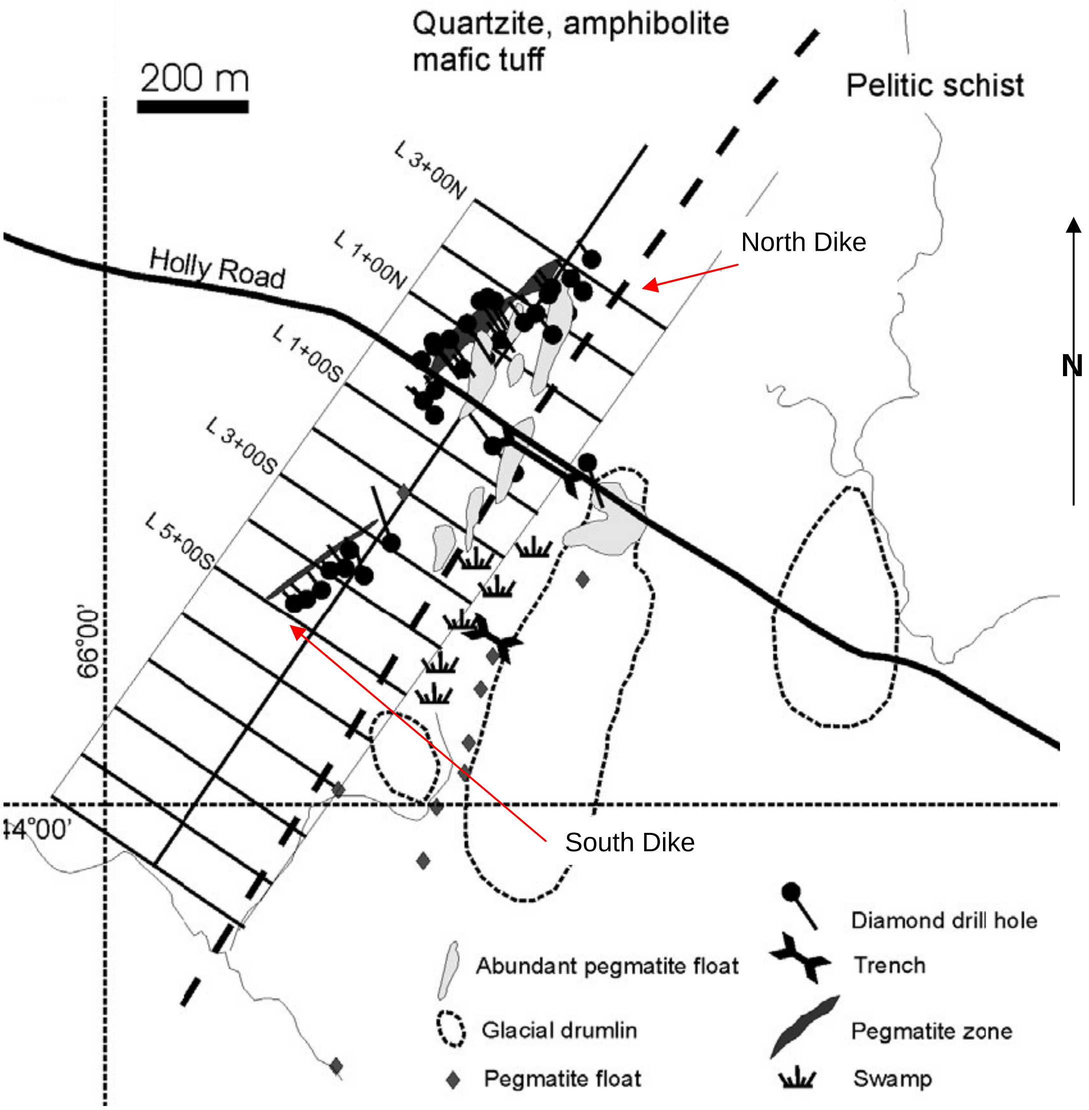

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Figure 6.3
North Dike and South Dike Areas
Modified after Kontak (2004)

Date: Apr. 2010

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Four distinct lithological zones were defined by Kontak (2004) within the South Dike on the basis of distinct textures and modal mineral proportions, these being (1) the blocky feldspar zone (BKF), (2) the modally enriched spodumene zone (Spd), (3) the albite zone (Az) and the beaded-quartz texture zone (BQT). Figure 6.4 presents mapped extents of these zones within the limits of surface trenching exposures of the South Dike established by Champlain in 2003. Although the mineralogical zones are spatially distinct, coherent and predictable mineral zonation consistent with pegmatites such as those outlined in Cerny (1991a) are not present in the surface exposures of the South Dike as described by Kontak (2004).

7 DEPOSIT TYPES

Commercially important sources of lithium occur predominantly in two geological settings, these being in spodumene-bearing pegmatites and in lithium enriched groundwater brines. Currently operating commercial extraction operations provide examples of both settings, with largest production being from brine operations such as those of Sociedad Quimica y Minera (SQM) at Salar de Atacama, Chile. The Bernic Lake Mine, owned by Cabot Corporation and operated by Tantalum Mining Corp. of Canada (TANCO) in Manitoba, Canada, and the Talison Lithium Pty. Ltd. open pit and underground operation in the Greenbushes Camp, Western Australia, are two examples of current commercial mining operations that successfully exploit spodumene-bearing pegmatite deposits for contained lithium. Both operations have produced both lithium and tantalum concentrates as primary products.

7.1 Pegmatite Classification

Classification of granitic pegmatites has evolved as documentation of globally distributed pegmatites has increased. The classification system used in this report is that of Cerny and Ercit (2005) and is based on earlier work by Ginsburg (1979) and Cerny (1991a, 1991b). Revision of the classification system has resulted in 2 schemes which reflect enhanced consideration given to petrologic, petrogenetic and geochemical characteristics of pegmatites. One system deals with the geological emplacement environment as a major consideration, and is grouped in a Class-Subclass-Type-Subtype arrangement, whereas the other considers the provenance of granitic pegmatites though igneous differentiation processes, and is organized within 3 distinct Family populations.

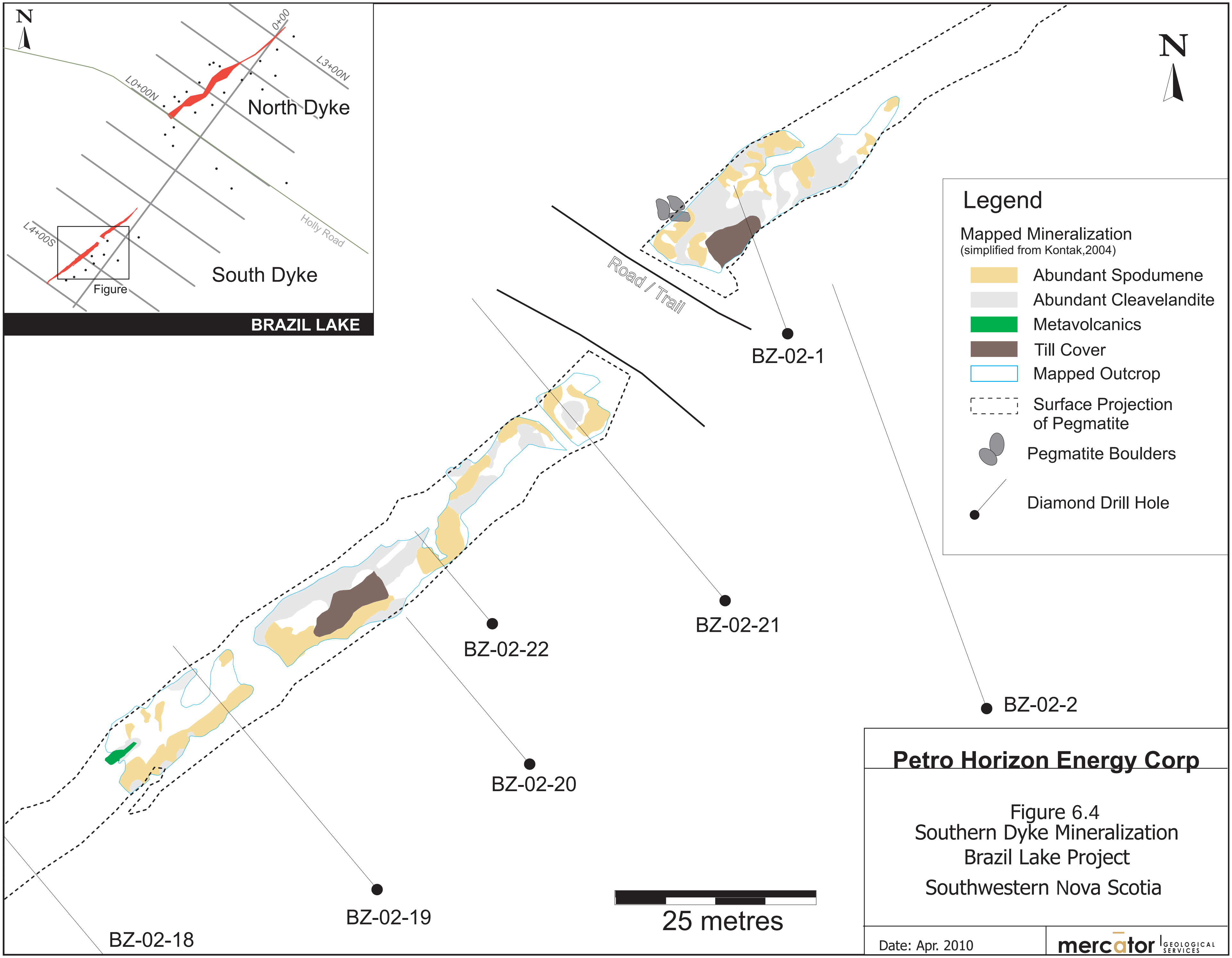

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Figure 6.4
Southern Dyke Mineralization
Brazil Lake Project
Southwestern Nova Scotia

Date: Apr. 2010

A complete copy of the Cerny and Ercit (2005) source document appears in Appendix 1. Table 7.1 presents an excerpt showing their Rare Element (REL) Class category and its descriptive characteristics. This Class is further subdivided into 2 Subclasses, mainly the Rare Earth Element (REL-REE) and Lithium (REL-Li). This classification system is akin to the Family Classification seen in Table 7.2 which is comprised of 3 components, these being (1) the NYF (niobium-yttrium-flourine) type, (2) the LCT (lithium-cesium-tantalum) type and (3) combined NYF-LCT types. These systems assume that pegmatites have been derived through igneous differentiation of plutonic parent magmas that have not been significantly influenced by assimilation of host and/or country rock materials. Intrusion emplacement depth and relationship to metamorphism reflect retained elements of earlier classification systems. As noted in Cerny and Ercit (2005), an association exists between the two classification systems in which the LCT Family pegmatite populations consist of members of the REL-Li Subclass.

Based on combined results of work carried out on the BLP to date, the North Dike and South Dike pegmatites are best categorized using the Cerny and Ercit (2005) system as Rare Element Class, with possible association with the spodumene-albite subtype, and Lithium-Cesium-Tantalum (LCT) Family type intrusions. LCT pegmatites are associated with S-type, peraluminous granites that are typically the product of partial melting of pre-existing sedimentary source rock. The major distinction of NYF and LCT pegmatite sub-classes is the level of fractionation observed in incompatible lithophile element components. Increased abundance of the Rare Elements occurs in association with the more evolved LCT rocks. Fractionation is amplified by included volatiles within such melts, which promotes rapid crystallization of a few large crystals and otherwise lowers melt viscosity, thereby allowing greater transportation distances from the parent granite to be attained by partial melt products. Peraluminous composition of the fertile parent granites is considered to be a common attribute of LCT pegmatites.

Table 7.1: Excerpt of Rare Element Class Pegmatite Classification from Cerny and Ercit (2005)

Class *Subclass*	Type	Subtype	Minerals	Typical Minerals	Metemorphic Environment	Relation to Granites
Rare-element						
REL-REE	allanite-monazite		LREE, U, Th (Be, Nb>Ta, F, [P])	Allanite, monazite, zircon, rutile, fluorite, ilmenite	Variable, largely shallow and postdating regional events affecting the host rocks	interior to marginal (rarely exterior)
	euxenite		L-H-REE, Y, Ti, Zr, Nb>Ta (F, P)	euxenite, monazite, xenotime, zircon, rutile, ilmenite, (fergusonite, aeschynite, zinnwaldite)		
	gadolinite		Be, Y, HREE, Zr, Ti, Nb>Ta, F (P)	gadolinite, fergusonite, samarskite, zircon, rutile, ilmenite, fluorite, (zinnwaldite)		
REL-Li	beryl	beryl-columbite	Be, Nb-Ta (+/- Sn, B)	beryl, columbite, tantalite, (rutile)	low-P, Abakuma amphibolite (andalusite-sillimanite) to upper greenschist faxies, ~2 to 4 kbar, ~ 650 to 450°C	(interior to marginal to) exterior
		beryl-columbite phosphate	Be, Nb-Ta, P (Li, F, +/-Sn, B)	beryl, columbite, tantalite, triplite, triphylite		
	complex	spodumene	Li, Rb, Cd, Be, Ta-Nb (Sn, P, F, +/-B)	spodumene, beryl, columbite-tantalite, (amblygonite, lepidolite, pollucite)		
		petalite	as above	petalite, beryl, columbite-tantalite, (amblygonite, lepidolite, pollucite)		
		lepidolite	Li, F, Rb, Cs, Be, Ta-Nb (Sn, P, B)	lepidolite, beryl, columbite-tantalite, (amblygonite, lepidolite, pollucite)		
		elbaite	Li, B, Rb, Sn, F (Ta, Be, Cs)	tourmaline, hambergite, danburite, datolite, microlite, (polylithionite)		
		amblygonite	Li, Rb, Cs, Ta-Nb, Be (Sn)	amblygonite, beryl, columbite-tantalite, (lepidolite, pollucite)		
	albite-spodumene		Li, (Sn, Be, Ta-Nb +/-B)	spodumene, (cassiterite, beryl, columbite-tantalite)		
	albite		Ta-Nb, Be (Li, +/- Sn, B)	columbite-tantalite, beryl (cassiterite)		

Table 7.2: Petrogenetic Family Classification of Cerny and Ercit (2005)

Family	Dominant Subclass of Pegmatites	Geochemical Signature	Bulk Composition of Pegmatites	Associated Granites	Bulk Composition of Granites	Source Lithologies
NYF	REL-REE, MI-REE	Nb>Ta, Ti, Y, Sc, REE, Zr, U, Th, F	subaluminus to metaluminus (to subalkaline)	(syn-, late, post-) to mainly anorogenic; quasi homogeneous	(peraluminus to) subaluminus and metaluminus: A and I types	depleted middle to lower crust granulites, juvenile granites, mantle metasomatized crust
LCT	REL-Li, MI-Li	Li, Rb, Cs, Be, Sn, Ga, Ta>Nb, (B, P, F)	peraluminus to subaluminus	(synorogenic to) late orogenic (to anorogenic); largely hereogeneous	peraluminus, S/I or mixed S + I	undepleted upper to middle crust, supracrustal rocks and basement gneisses
Mixed (LCT-NYF)	Cross-bred LCT and NYF	mixed	(metaluminus to) moderately peraluminus	(postorogenic to) anorogenic; heterogeneous	subaluminus to slightly peraluminus	mixed protoliths or assimilation of supracrustal rocks by NYF granites

7.2 Pegmatite Mechanism of Emplacement

Granitic pegmatite bodies of variable compositions are found throughout the world and represent a range of emplacement environments. Within Canada, a noticeable association exists between pegmatitic occurrences and major orogenic events, these being (1) the Kenoran Orogeny of the Archean Superior Structural Province (2,750-2,550 Ma), (2) the Hudsonian Orogeny of the Proterozoic Churchill Structural Province (1,800-1,600 Ma), (3) the Grenville Orogeny of the Grenville Province (1,200-900 Ma) and (4) the Acadian Orogeny of the Appalachian Structural Province (375-325 Ma) (Vanstone, 2002). The BLP pegmatites discussed in this report occur within the Appalachian Structural Province.

Fertile peraluminus granitic magmas are generally considered to be the sources of Rare Element LCT type pegmatites, with these giving rise to S-type granite signatures in pegmatites emplaced into meta-pelite supracrustal rock sequences (Cerny, 1991b). In southwest Nova Scotia this model seems applicable, since some granitic plutons associated with the Mid Devonian South Mountain Batholith were emplaced during late stages of the Acadian Orogeny and could be sources of BLP pegmatite fluids. The slightly older Brenton Pluton, located adjacent to the BLP, is also a possible candidate for pegmatite source association, but was structurally disturbed subsequent to emplacement, thereby complicating definition of a direct relationship with BLP pegmatites. Regional pluton emplacement appears to have been influenced by northeast orientated regional fold and shear zone structures. In the case of the Brenton Pluton, ductile shearing along the Deerfield Shear Zone may have in part accompanied intrusion emplacement. Under these emplacement conditions, pegmatite derived from melt components could have invaded country rock along dilational trends related to doming, fracturing or shearing and evolution of granitic melt geochemistry could have occurred along associated magma pathways.

Notwithstanding a possible fit of the granitic source model to BLP pegmatites, their genetic association with a specific granitic pluton in southwestern Nova Scotia has not yet been rigorously established. Other mechanisms may also be applicable and Kontak (2005) considered BLP pegmatite development to be related to anatectic melting of deep sialic crust within a high gradient metamorphic environment. In that model, siliceous partial melts were generated through anatexis and migrated via emplacement conduits defined by zones of high ductile shear strain. The northeast trending Deerfield Shear Zone is invoked as a high strain corridor that could have been related to emplacement of the BLP pegmatites.

8 MINERALIZATION

Mineralization within BLP pegmatites is paragenetically similar to the mineral sequence typical seen in peraluminous granites. Dominant mineral phases are sodium and potassium feldspar, quartz and minor amounts of mica plus accessory minerals. Due, possibly, to extreme fractionation of chemical constituents from magmatic source granite, an increased modal abundance of Rare Element enriched minerals also characterizes the pegmatites. As described by (Cerny and Ercit, 2005) Rare Element LCT type pegmatites typically contain anomalous concentrations of Li, cesium (Cs), tantalum (ta), rubidium (Rb), beryllium (Be), gallium (Ga), tin

(Sn), hafnium (Hf), boron (B), phosphate (P) and fluorine (F). Sampling results for the BLP intrusions show particularly anomalous values of Li and Rb and anomalous Sn and Be levels are also present locally. These correspond, respectively, with dominant host minerals spodumene, potassium feldspar, cassiterite and beryl, all of which have been identified in BLP drill core and outcrops. Table 8.1 highlights ranges and weighted average values extracted from all pegmatite core sampling in the North and South Dikes for these four main elements. The BLP pegmatites do not present consistently anomalous values of Cs and Ta which are typically associated with Rare Element - LCT-type pegmatites, but tantalite crystals are present in both the North Dike and South Dike as well as in metasomatized quartzitic host rocks.

Accumulation of Rare Elements is generally considered a function of the escape of incompatible elements from a parent magmatic body, combined with presence of volatiles in solution that lower the effective solidus temperature and viscosity of the remaining melt. This combination of factors enables the melt to be transported further into country rocks than the equivalent higher viscosity low-volatile granitic melt. Progressive fractionation and evolution of the contained chemical constituents can result in zonation development along such melt migration pathways. Fractional crystallization can occur at various stages in melt migration and results in mineral assemblage variations. Kontak (2004) estimated that BLP pegmatite crystallization occurred at confining pressures of 3.5-4 kilobars and temperatures near 600°C. These P-T conditions are permissive of both the Cerny and Ercit (2005) granite emplacement model for LCT pegmatites as well as the Kontak (2005) metamorphic anatexis model.

Li in BLP pegmatites is specifically hosted within the silicate mineral spodumene which constitutes a significant mineral phase of the North Dike and South Dike pegmatites. Spodumene contains 3.73% Li (8.03% Li_2O) in its purest form and is found throughout the BLP pegmatites as both megacrystic (cm to m-scale) and coarse grained (< 1cm) crystal phases. Distribution of spodumene within the extensive South Dike surface exposures developed during 2003 by Champlain trenching was documented through surface mapping reported by Kontak (2004). Previously referenced Figure 6.4 (p.22) illustrated results of this mapping and general spatial continuity of spodumene occurrence throughout the exposed length of mapped dike is apparent. However, it is also clear that the dike is not uniformly mineralized with spodumene across its full width, that spodumene varies dramatically in grain size and crystal orientation, and that a quartz rich marginal phase devoid of spodumene is generally present (Figures 8.1 through 8.6).

Sampling results from the BLP show that Rb is enriched within the primary potassium feldspar phase and Kontak (2004) showed that late sodic metasomatism has locally obliterated much of the early potassium feldspar, with this being marked by occurrence of albite along intra-crystalline cleavage planes, fractures and partings. The end member of such alteration is near-complete conversion of megacrystic potassium feldpar to cleavelandite. Formation of secondary mica is also related to albite alteration and is attributed to loss of potassium from the potassium feldspar lattice during alteration and relative enrichment in Rb via substitution within the newly formed mica crystal lattice. Anomalous values of Ta and Be are present within the albite phase. Ta to niobium (Nb) ratios have been used to identify relative evolution of pegmatites, with higher Ta:Nb ratios indicating a greater degree of fractionation. These elements are hosted in variable proportions within the tantalite-columbite mineral series. Values of Ta noted on the BLP from previous drilling range up to 1,070 ppm over a 0.8 m interval (Drill hole BZ-02-22). This value was associated with an elevated 8.5% Na_2O level and suggests Ta enrichment associated with secondary albite formation. Mica occurs as both primary and secondary phases and has been a focus in mineral processing studies on the deposit. Sn in the oxide form cassiterite also occurs locally and infrequently in the pegmatites, as do beryl and isolated crystals of tantalite.

Figure 8.1: South Dike surface exposures looking north-east

Figure 8.2: Megacrystic spodumene crystals in South Dike

Figure 8.3: Sodium-metasomatized potassium feldspar with cleavelandite

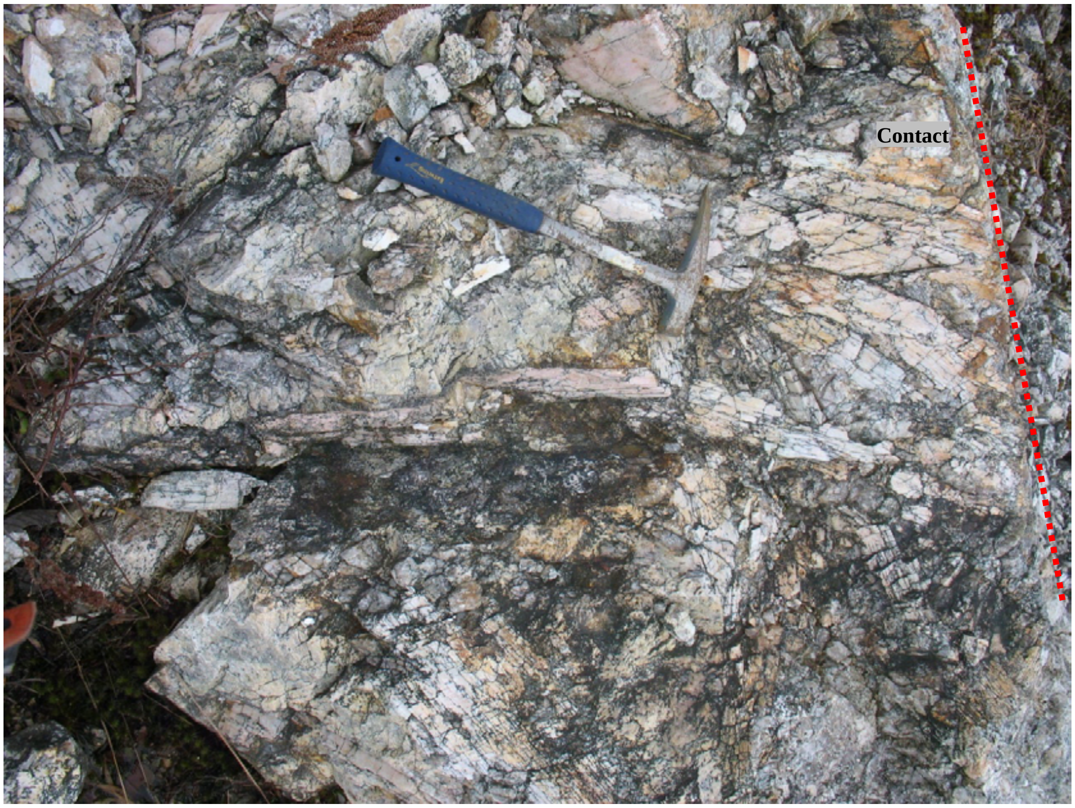


Figure 8.4: Coarse grained spodumene crystallized at high angle to dike contact

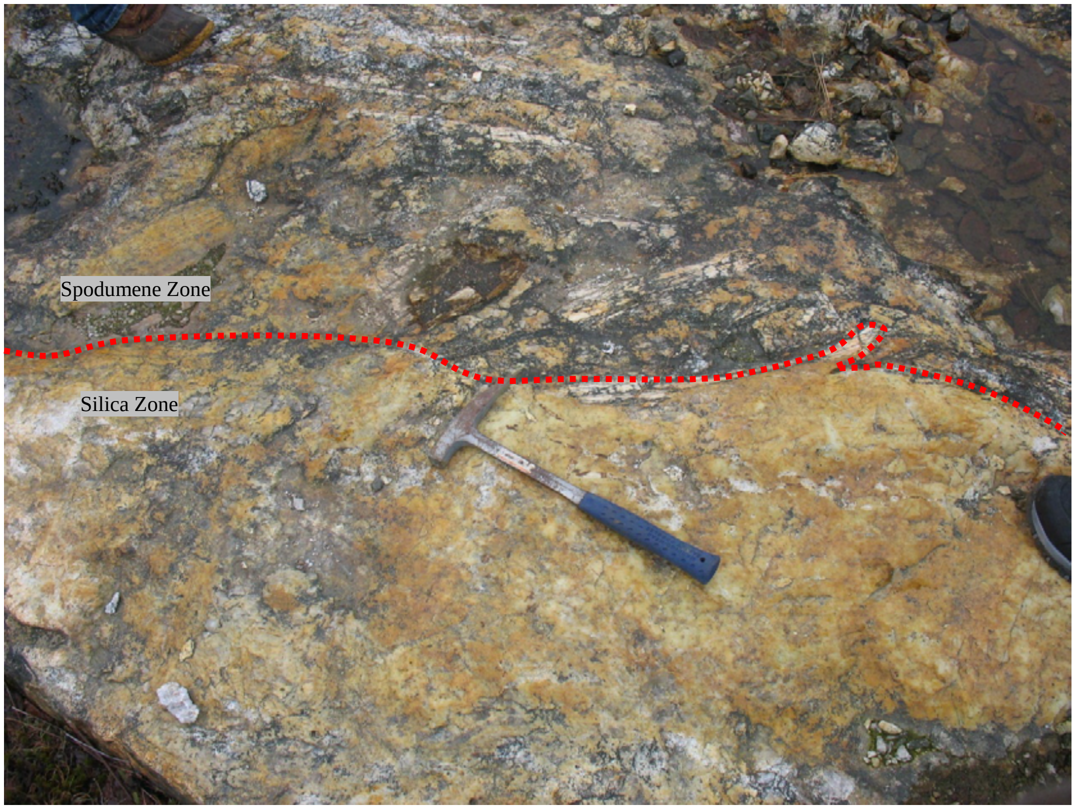


Figure 8.5: Silica rich marginal phase of South Dike with beaded quartz

Figure 8.6: South Dike contact with silicified metasandstone of White Rock Formation

Table 8.1 was modified after Hudgins (1998) to include 2002-2003 Champlain data and highlights elements of potential economic interest found in the BLP pegmatites, along with grade ranges and average weighted values for the North and South Dikes reflecting core drilling results to date and examples of associated commercial applications for elements cited.

Table 8.1: BLP element levels and comparative grade comments (after Hudgins. 1998)

Element	**Common Applications**	**Grade Range from BLP Drilling Data** (weighted average: N / S dike)
Lithium (Li)	Batteries, ceramics, glassware, enamels, alloys, Li-Be superconductors, chemical and pharmaceutical industries, vitamins, smelting of aluminum ores	**0.01 – 6.00% Li_2O** (1.014 / 0.517% Li_2O)
Rubidium (Rb)	Ceramics	**100 – 5,130 ppm Rb_2O** (980 / 1,112 ppm Rb_2O)
Tantalum (Ta)	Electrical capacitors in avionics and microcomputer industries, tantalum-carbide tools, chemical alloys, medical industry for prosthetic devices and surgical implants	**100 – 1,070 ppm Ta_2O_5** (80 / 120 ppm Ta_2O_5)
Beryllium (Be)	Lightweight metal alloys in aerospace industry, heat shields, rocket motor applications, as a moderator in nuclear reactors, non-crystallizing springs, x-ray tube windows	**10 – 5,370 ppm BeO** (380 / 290 ppm BeO)
Tin (Sn)	Lightweight corrosion-resistant metal alloys	**10 – 27,160 ppm SnO_2** (380 / 280 ppm SnO_2)

9 EXPORATION

9.1 Introduction

The BLP area has been the focus of relatively minor amounts of exploration directed toward pegmatites since the 1960’s and only in recent years, under the direction of Champlain, has such work been specifically directed toward detailed evaluation of the North Dike and South Dike intrusions. To date, exploration methods applied within the BLP by various explorers include:

- Surface trenching and mapping
- Induced Polarization (IP) geophysical surveying
- Core drilling
- Prospecting and mapping to delineate pegmatite glacial dispersion trains
- Soil and water geochemistry

Notably, formal discovery of known pegmatites on the property in 1960 is attributed to identification of a large (~1.5 m diameter) spodumene bearing pegmatite boulder on the north side of the Holly Road during mapping of the area by the Geological Survey of Canada (Taylor, 1965). Much work has since been undertaken to broaden the range of glacial float mapping on the property and to better identify glacial dispersion trends. Review of government assessment documents that describe BLP exploration to date showed that this method, in combination with diamond drilling and trenching, has been an effective means of target areas.

Exploration program details pertaining to work carried out by Champlain, the current mineral exploration title holder of the BLP, are presented below in chronological order.

9.2 Champlain - 2002

9.2.1 Prospecting and Water Quality Monitoring

While drilling was underway on the North Dike and South Dike, regional exploration was carried out to identify additional pegmatite sources. Results of prospecting in the vicinity of Brazil Lake were reported by Black (2002) and confirmed presence of two pegmatite prospect areas, referred to as the Bloomfield Road Prospect and the Deerfield Prospect. Both areas of interest were defined through prospecting discovery of abundant pegmatite floats compositionally similar to the main BLP pegmatites. However, while these were typically characterized as being megacrystic and rich in both albite and mica, they did not contain significant quantities of spodumene.

An initial baseline water monitoring program was conducted by Champlain in 2002 immediately before and after a 45 day diamond drilling campaign that is described below in report Section 10.0. The baseline program consisted of sampling at 5 water monitoring sites in the local watershed downstream from the active drilling area. The purpose of such sampling was to monitor the effect, if any, of drilling activities on local surface water quality. Analysis of a full suite of trace elements was completed along with determination of pH, suspended solids, total dissolved solids and conductivity levels. Black (2002) reported that no change in water chemistry or quality had occurred between the two sampling periods.

9.3 Champlain - 2003

9.3.1 Trenching

A mechanized trenching program was conducted on the BLP to test areas with abundant pegmatite float occurrences previously defined by prospecting. The purpose of trenching was to establish bedrock source areas for the float materials.

A total of 5 additional trenches were completed, these being at Holly Road (T1), Army Road (T2), Church Road (T3), Deerfield (T4) and at the South Dike (South #1) (Figure 5.1). With the exception of the South Dike area, where extensive and stripping of the previously drilled main pegmatite body was carried out, no new bedrock occurrences of pegmatite were detected through trenching. The North Dike was considered a probable source for the Holly Road trench float material as well as for some float material in the Army Road area. Source areas to the northeast of the Deerfield and Church Road trenches were suggested, in part based on study of pebble orientation fabrics in till at Deerfield. In contrast, trenching and stripping of the South Dike confirmed the body to exceed 280 m in strike length and showed that its true thickness at surface ranged between 8 m and 12 m over much of the area tested. Continuous exposures of the pegmatite were established at this time and detailed geological mapping and sampling were completed by Champlain as well as by NSDNR. Results of the former were reported in Black (2003) and Kontak (2004) reported on NSDNR work. The relatively systematic zoned character of the dike was clearly documented through this work and detailed mapping of the well-developed spodumene mineralization was completed. Results of the NSDNR work are further described in report Sections 6.0 and 7.0. Excellent exposures of spodumene-bearing pegmatite were established by the 2003 program and most of the originally exposed dike surface mapped by Kontak was still accessible during the 2010 site visits carried out by Mercator staff.

9.3.2 Induced Polarization Surveying

An induced polarization (IP) survey was completed on selected portions of the BLP with the intention of assessing use of apparent resistivity as a means of outlining areas of potential bedrock pegmatite development beneath till cover. The dikes were thought to exhibit higher bulk resistivity values in comparison to foliated amphibolite and quartzite host rocks of the White Rock Formation. Orientation survey lines over the known dikes confirmed that anomalously high apparent resistivity values delineated the pegmatite bodies from surrounding foliated host sequences in areas with shallow overburden cover. On this basis the method was subsequently applied to assessment of regional targets at Deerfield Prospect and Bloomfield Road Prospect. Black (2003) reported on both aspects of the IP program and noted that anomalous apparent resistivity results encountered at both prospect areas could be related to overburden-covered bedrock pegmatite sources. No follow-up of these anomalies was subsequently carried out.

9.3.3 Mineral Processing

A mineral beneficiation research program was initiated by Champlain during the 2003 exploration year which included coordinated mineral processing activities by two analytical laboratories and associated mineral engineering specialists. BLP sample material used for this analysis was extracted from the North Dike pegmatite intersection of Champlain drill hole BZ-02-13 that had been completed in the early part of 2002. The pegmatite was drilled at HQ core size and the associated sample comprised an 18 m long pegmatite intersection that provided 108 kg of material. Head analysis results reported by Cole (2003) in Black (2003) showed a modal pegmatite composition of 13.15% spodumene, 29.14% sodium feldspar, 5.52% potassium feldspar, 15% muscovite and 37.19% quartz for this sample. Trace minerals included 0.25% beryl, 213 ppm columbo-tantalite, and 0.47% apatite. Additional laboratory processing and assessment were carried out on South Dike material during 2003, discussion of which appears below in report Section 15.

9.4 Champlain - 2004

9.4.1 Trenching

Four short trenches sited over the North Dike were completed during 2004 and these showed narrowing of the structure to approximately 3 m in thickness at surface near its northern limit, plus transition to aplitic character lacking substantial spodumene mineralization. Results of this work were not presented in formal reporting (D. Black, personal communication, 2010), but trenched locations were visited by Mercator staff during the March 2nd site visit at which time stated observations regarding dike width and character were confirmed.

9.4.2 Horizon Soil Geochemistry

B horizon soil sampling was carried out in the Army Road - Church Road area, north of Holly Road, to assess target definition potential of this method in areas of know pegmatite glacial dispersion boulder trains. Samples were collected at 25 m spacings along lines having nominal spacing of 100 m. Results of the program were presented in draft form and not incorporated in formal reporting. However, a number of elevated sample sites from this survey were considered worthy of follow up with respect to definition of new spodumene-bearing pegmatite targets (D. Black, 2010 personal communication).

10 DRILLING

10.1 Introduction

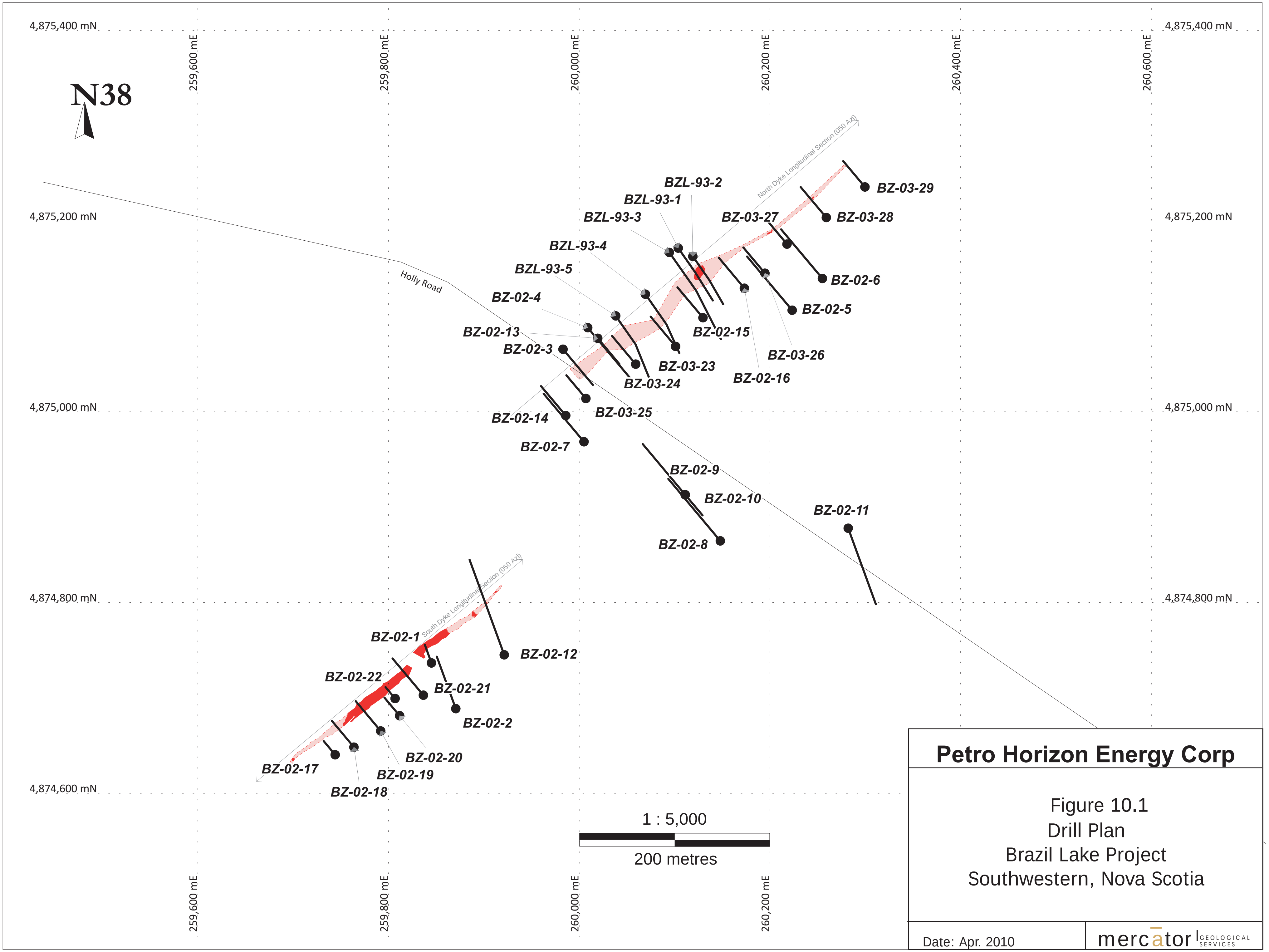
Mercator reviewed all available documentation pertaining to NSDNR and Champlain drilling on the BLP and assembled data in digital format to support assessment of mineralization occurring in pegmatite intersections. In total, 37 diamond drill holes have been completed on the property to date, for a cumulative total of 2702 m of drilling. NSDNR completed 5 of these holes during 1993 and the remaining were completed by Champlain in 2002 and 2003 (Figure 10.1).

Drill hole locations have historically been measured into position relative to a staked local grid and for purposes of this report the local grid was transformed to the Universal Transverse Mercator (UTM) co-ordinate system (NAD83 datum) using MapInfo Professional v.8.5 and Encom Discover v. 11.1 software. Instrument surveying of drill hole locations and trenching features has not been carried out on the BLP to date but a check on drill hole locations was carried out by Mercator during the 2010 site visits using a handheld GPS in UTM (NAD83) co-ordinate system mode.

Details of each drilling program carried out on the BLP are presented under separate headings below, followed by a summary discussion of combined drilling program results.

10.2 NSDNR Drilling (1993)

Interest in lithium and other industrial minerals traditionally known to be hosted in pegmatites prompted NSDNR to evaluate several known pegmatite occurrences during 1993. This included completion of 5 diamond drill holes on the North Dike of the BLP during 1993. Drilling totaled 577 meters and tested down dip continuity of dike outcrops north of the Holly Road. Angled holes were drilled beneath documented dike crops dike to a maximum vertical depth of 75 metres. Drilling was carried out by government drilling crews and recovered NQ size core (47.6mm diameter). Hole locations appear in previously referenced Figure 10.1 and collar coordinate and hole orientation details are included in Appendix 2.



Petro Horizon Energy Corp

Figure 10.1
Drill Plan
Brazil Lake Project
Southwestern, Nova Scotia

Date: Apr. 2010

mercator GEOLOGICAL SERVICES

All five NSDNR holes intersected pegmatite, with down hole intercept lengths ranging between 6.4 m and 41.9 m. Holes were drilled roughly normal to the 050 azimuth dike trend but due to the pegmatite's steep southeasterly dip of 80° to the horizontal, the holes are interpreted to have intersected the dike at a moderate angle. True width calculations resulted in estimated true width intersections for these early drill holes to be approximately 50% of their actual down hole lengths. The true widths of the dike defined by 1993 drilling results ranged between 3.2 m and 20.95 m, with width increasing from northeast to southwest along the length of the dike. One drill casing from NSDNR drill hole BZL-93-4 was identified and confirmed during the 2010 site visit by Mercator (Figures 10.2 and 10.3).

Following the NSDNR field campaign, down hole geophysical logging of the drill hole BZL-93-4 was carried out by NSDNR. This included collection of natural gamma-ray spectrometry, density, spectral gamma-gamma, induced polarization/resistivity/self-potential, magnetic susceptibility, and temperature data sets. Corey (1995) concluded that pegmatites are typically outlined by low magnetic susceptibility, high natural gamma count, low density and low spectral gamma-gamma signatures. He specifically noted that the 'mineralized zone', referring to the spodumene-bearing interval within the logged pegmatite zone, had a lower radiometric signature than enclosing pegmatite.

Corey (1995) reported that BLP spodumene intercepted by NSDNR drilling contained concentrations of Fe_2O_3 that exceeded levels considered to be generally acceptable for industrial ceramic and glass markets (>0.10%), with this determination based on data returned from electron microprobe analysis. As a result, core was not sampled by NSDNR and was instead sent for storage at the NSDNR core library in Stellarton, Nova Scotia. This core was, however, subsequently sampled by Sons of Gwalia Pty. Ltd. in 1998 as described in sections 11.2 and 12.2 with associated results in table 10.1 of this report. No further drilling was conducted on the property by NSDNR, but core stored at Stellarton was later assayed by Gwalia Consolidated Pty Ltd., details of which are discussed in Section 11.1 and Section 12.1 of this report.

Figure 10.2: Location plan for BLP diamond drill holes

Figure 10.3: NSDNR drilling site for hole BZL-93-4 on North dike

10.3 Champlain Drilling (2002)

The second drilling campaign conducted on the BLP was carried out by Champlain in 2002 and was designed to (1) outline subsurface extensions of the North Dike, (2) confirm North Dike and South Dike strike continuity, and (3) test certain regional target areas showing abundant surface pegmatite floats. The program consisted of 16 drill holes, totaling 1325 m, of which 9 tested the North Dike, 3 tested the South Dike and 4 tested other targets (Black, 2003). Maritime Diamond Drilling Limited of Hilden, NS provided contract drilling services for this program and recovered NQ size core (47.6mm diameter) for all but one hole. HQ size core (63.5mm diameter) was recovered from BZ-02-13 to provide sample material for bulk analysis and mineral processing studies. Locations for all BLP drill holes appear in previously referenced Figure 10.1 and collar coordinate and hole orientation details are included in Appendix2.

The 2002 drilling campaign confirmed the North Dike as being continuous from surface to a vertical depth of approximately 75 m and to dip 70-80° to the southeast. A southwesterly plunge of approximately 50° to a central zone defined by thickest pegmatite intervals was also defined, with thinning along strike to both north and south noted. Drill hole BZ-02-14 was drilled near surface along the southerly strike extension of the North Dike but did not intersect an extension pegmatite seen down dip in BZ-02-07. Intersections from these holes provided definition of the southwesterly plunge noted above and indicate fairly abrupt pinch-out of the dike at near surface elevations in this area. However, promising down plunge continuity to the south along the thickened central zone is also indicated.

All pegmatite intersections recovered in the 2002 program were sampled and highlights of associated laboratory analyses and estimated true widths for respective intervals appear in Table 10.1, along with similar data for the NSDNR and 2002-2003 programs. In total, 80 pegmatite samples were collected. Of particular note are results of hole BZ-02-1 which tested an area immediately down dip from a zone of significant spodumene mineralization defined during the 2002 surface trenching and mapping programs on the South Dike. This drill hole intersected 2.75 m (2.25 m estimated true width) of pegmatite grading 1.42% Li_2O, including a 1.10 m interval (0.9 m true width) grading 3.44% Li_2O. In addition, North Dike drill hole BZ-02-15 intersected

Table 10.1: Compiled BLP core drilling analytical results and weighted averages

Hole #	From	To	Interval Downhole Width	Interval True Width*	Drill direction	Dyke	Li20% '	Na20% '	K20% '	Sn02% '	Ta205% '	Nb205% '	Rb20% '	Be0% '
BZL-93-1	89.11	95.4	6.29	3.15	SE	N	0.343	6.637	2.131	0.028	0.013	0.016	0.074	0.034
BZL-93-2	34.81	58.85	24.04	12.02	SE	N	1.370	4.580	2.558	0.156	0.012	0.014	0.101	0.049
BZL-93-2	61.97	64.15	2.18	1.09	SE	N	0.090	9.009	1.468	0.153	0.010	0.013	0.083	0.000
BZL-93-3	88.33	94.52	6.19	3.10	SE	N	0.906	4.299	2.237	0.024	0.011	0.019	0.073	0.044
BZL-93-4	47.1	88.9	41.8	20.90	SE	N	1.266	3.347	2.326	0.020	0.008	0.011	0.088	0.031
BZL-93-5	38.26	71.11	32.85	16.43	SE	N	0.860	4.263	2.199	0.007	0.012	0.018	0.085	0.030
BZ-02-13	18.5	36.5	18	10.32	SE	N	0.918	3.640	2.840	0.026	0.007	0.015	0.070	0.033
BZ-02-15	30.9	46.2	15.3	12.53	NW	N	1.474	2.915	4.661	0.018	0.003	0.005	0.152	0.044
BZ-02-16	32.3	41.3	9	7.37	NW	N	0.390	2.171	4.391	0.005	0.001	0.001	0.154	0.061
BZ-02-3	47.7	61.8	14.1	8.09	SE	N	1.142	3.612	1.621	0.013	0.005	0.007	0.052	0.032
BZ-02-4	51.7	87.5	35.8	20.53	SE	N	1.378	3.552	2.748	0.026	0.008	0.013	0.098	0.056
BZ-02-5	81.7	85.9	4.2	3.44	NW	N	0.247	8.036	0.952	0.068	0.019	0.015	0.030	0.044
BZ-02-7	70.5	73	1.5	1.23	NW	N	1.199	5.715	2.225	0.017	0.004	0.007	0.068	0.001
BZ-03-23	29	43.2	14.2	11.63	NW	N	0.641	3.224	2.275	0.028	0.007	0.007	0.099	0.012
BZ-03-24	21.9	33	11.1	9.09	NW	N	0.849	3.302	3.948	0.011	0.006	0.009	0.146	0.062
BZ-03-26	41	44	3	2.46	NW	N	0.009	6.845	2.909	0.017	0.009	0.004	0.109	0.001
BZ-03-28	23.2	25.5	2.3	1.88	NW	N	0.779	3.750	1.760	0.479	0.012	0.009	0.066	0.001
BZ-03-29	33.5	34.8	1.3	1.06	NW	N	0.005	5.210	0.970	0.007	0.003	0.006	0.034	0.001
						Average Weighted Value^	**1.014**	**3.847**	**2.735**	**0.038**	**0.008**	**0.011**	**0.098**	**0.038**
BZ-02-1	16.25	19	2.75	2.25	NW	S	1.424	8.321	0.916	0.027	0.006	0.010	0.023	0.003
BZ-02-17	21.47	25.25	3.85	3.15	NW	S	0.153	3.911	2.618	0.010	0.005	0.012	0.110	0.010
BZ-02-18	30.28	36.86	6.58	5.39	NW	S	0.243	5.906	1.258	0.010	0.010	0.009	0.044	0.034
BZ-02-19	29	35.9	6.9	5.65	NW	S	0.918	3.360	3.940	0.010	0.009	0.007	0.175	0.018
BZ-02-2	76.8	77.5	0.7	0.57	NW	S	0.017	28.129	0.747	0.015	0.027	0.022	0.032	0.019
BZ-02-21	66.5	68.1	1.6	1.31	NW	S	0.017	2.432	4.496	0.170	0.011	0.012	0.156	0.004
BZ-02-22	15.1	21.1	6	4.91	NW	S	0.368	5.215	3.968	0.043	0.022	0.061	0.155	0.068
						Average Weighted Value^	**0.517**	**5.457**	**2.804**	**0.028**	**0.012**	**0.021**	**0.112**	**0.029**
BZ-02-9	46.2	48	1.8	1.47	NW	regional	0.006	2.408	0.432	0.000	0.000	0.003	0.001	0.001

* True widths have been estimated based on an assumed dyke dip direction of 80 degrees to the southeast
^ Average Weighted Values have been calculated using Estimated Interval True Widths and Composite Grades reported in this table. These values do not imply or are considered to be economic parameters nor do they constitute a resource estiamte as defined by NI 43-101.

15.2 m (12.53 m true width) grading 1.47% Li_2O, including a 1.2 m interval (0.99 m true width) grading 4.90% Li_2O.

Results of a bulk mineralogical analysis of the North Dike pegmatite intercept from BZ-02-13 were reported by Cole (2003) and showed the dike at that location to be comprised of 16.3% spodumene, 11% microcline (potassium feldspar), 33% cleavelandite (sodium feldspar), 6% muscovite and 34% quartz by weight.

BZ-02-9 was drilled southeast of the North Dike (see previous Figure 10.1) to test a separate exploration target and intersected 1.8 m of veining characterized by quartz, coarse grained potassium feldspar and irregular calcite lenses. This was interpreted as possibly marking the edge of a new and distinct pegmatite dike occurring in a zone broadly along strike from the South Dike. However, no further assessment of the target was carried out and no other new bedrock occurrences were defined.

10.4 Champlain Mineral Ventures Ltd. (2002-2003)

Follow-up drilling was performed on the BLP by Champlain soon after the initial program in 2002, with initial holes completed during late 2002. The program included 16 holes, totaling 801 m drilled and Maritime Diamond Drilling Limited of Hilden, NS again provided contract drilling services. HQ size (63.5mm diameter) drill core was recovered from all holes.

The first 6 holes, BZ-02-17 through BZ-02-22, targeted the South Dike with hole BZ-02-17 proving the most southerly extent of the pegmatite to date. This hole intersected 3.78 m (3.10 m estimated true width) of pegmatite comprised mainly of coarse grained quartz, potassium feldspar and cleavelandite. The next 7 holes targeted the North Dike and, with the exception of hole BZ-03-25 that failed to intersect an interpreted southern strike extension of the dike, all holes intersected the pegmatite and served to extend its proven strike extension to the north. The final 3 holes were completed in a fence located approximately 400 m southwest of the South Dike exposures and tested a target area defined by abundant pegmatite boulders and a coincident apparent resistivity anomaly. These holes failed to intersect pegmatite, but did successfully intersect hydrothermal veining, most prominently seen in hole BZ-03-32 as feldspar-chlorite-quartz veinlets hosted in black, chloritic schist (Black, 2003).

Drilling on the northeasterly strike extension of the North Dike generally intersected pegmatite over narrow widths and thereby defined a gradual thinning or tapering of the dike near surface and along strike in this direction. This is consistent with trenching results from a later Champlain program. Drill hole BZ-03-29, the most northerly completed, intersected pegmatite over 1.3 m (1.06 m estimated true width) which contained coarse grained quartz and cleavelandite but lacked spodumene and potassium feldspar. Significant drill hole highlights from the North Dike program include those from BZ-03-23, which intersected 14.2 m (11.63 m true width) grading 0.641% Li2O, including 1.89% Li Li2O over 1.40 m (1.15 m true width). In addition, South Dike drill hole BZ-02-19 intersected 6.9 m (5.65 m true width) which graded 0.92% Li2O, including 1.43 m (1.17 m true width) grading 2.89% Li2O (Black, 2003). Further analytical results of the Champlain program appear in previously referenced Table 10.1.

10.5 Summary of Drilling Results

Drilling to date on the property has served to define near-surface extents of both the North Dike and the South Dike of the BLP. The former shows drilling defined strike continuity of approximately 300 m and is characterized by a distinct central thickening trend that continues through the 75 m maximum vertical depth of current drilling intercepts. Pegmatite true thickness values calculated and contoured by Mercator for North Dike drilling and trenching intercepts provide definition of a 50 degree southwest plunge to the central thickened dike area that is clearly represented on longitudinal Section 2010-1 (Appendix 3). The maximum North Dike true thicknesses defined by drilling on Section 2010-1 is 20.95 m in drill hole BZL-93-04 and the plunge extension of the thickened dike interval remains open at present.

The South Dike has a drilling and trenching confirmed strike continuity exceeding 280 m and confirmed down-plunge continuity southward to a vertical depth of about 50 m where it remains open. Thinning or pinching out of the dike takes place at surface along the strike extensions to the north. While detailed mapping of the excellent South Dike surface trench exposures showed near-continuous distribution of well developed spodumene mineralization along its entire length, results from drilling do not consistently prove corresponding concentrations directly down dip of trenched intervals. This is in part due to the concentration of drilling near the northern limit of the dike where the pegmatite appears to pinch out in a manner similar to that seen in the North Dike. The Section 2010-2 pegmatite thickness and grade longitudinal included in Appendix 3 is similar to that described above for the North Dike and shows that a southwest plunging trend defined by thickest pegmatite intercepts is present in this dike and that drilling to date has not tested its projected 50 degree down-plunge extension from pegmatite intersections seen in drill holes BZ-02-18 and BZ-02-19.

11 SAMPLING METHOD AND APPROACH

11.1 Introduction

Laboratory analysis of drill core samples has been the predominant method of grade evaluation used to date on the BLP. However, grab sampling of bedrock and trench exposures has also been carried out and a limited program of bedrock excavation through blasting was also used to obtain sample material for potential mineral processing purposes. Details of sampling protocols are not clearly outlined in reports describing property exploration, but the following summary descriptions were developed from documents describing each of the main drilling or sampling programs.

11.2 Sons of Gwalia Pty. Ltd. (1998)

Sons of Gwalia Pty. Ltd (Gwalia) carried out a sampling program on drill core from the 1993 NSDNR drilling campaign archived at the NSDNR core library in Stellarton, NS. As mentioned earlier, this NQ size core had not previously been sampled. Core samples were marked out within the pegmatite section by a Gwalia geologist and then cut in half by diamond saw at the NSDNR core facility. The half cores were logged and sampled at approximately 1 m intervals and one half core was then packaged and air freighted to Perth, Western Australia. These were then shipped to Gwalia’s Greenbushes mining operation where laboratory analysis was carried out (Hudgins, 1998).

Representative half core splits of the Gwalia samples were retained at the NSDNR core facility and were viewed by Mercator staff on February 24th, 2010. This core remains available for viewing and sampling. Mercator also viewed core from drill holes BZL-93-1 and BZL-93-4 on the same date but did not collect samples for re-assaying.

11.3 Champlain (2002 Drilling)

Champlain drill core was sampled according to lithologic units defined by the geologist logging core for the project. Separate protocols were established for samples within the pegmatite, with these reflecting whether the sample interval was fine grained (aplitic) or coarse grained. Fine grained zones were regularly sampled based on lithology but sampling of coarse grained zones was further constrained on the basis of predominant modal mineral composition (ie. spodumene-rich, potassium feldpar rich or quartz-rich). Sample lengths in both instances ranged between 0.5 m and 1.5 m. Most core was split using a tile saw but some sampling was carried out using a core splitter. Archived half cores were retained in safe storage by Champlain for future reference (Black, 2002; D. Black, 2010, personal communication).

Float boulders were also systematically sampled by Champlain and bagged subsamples were created where necessary from boulders considered too large for normal processing. Champlain field staff were responsible for all aspects of sample security and all samples were bagged, labeled with sample numbers and recorded in field records prior to commercial shipment of some samples to the analytical laboratory.

11.4 Champlain (2002-2003 Drilling)

Sampling methodology during the 2003 field program was the same as that described above for the 2002 field season (D. Black, 2010 personal communication).

11.5 Mercator (2010 Site Visits)

Mercator geologists visited the BLP on two occasions, the first being on March 5th, 2010 when co-author Michael Cullen was accompanied by Mr. D. Black, Senior Geologist for Champlain and Mr. R. Bourgeois, CEO of Petro Horizon. Numerous hand samples from North Dike and South Dike bedrock exposures were collected at this time but these were not subsequently submitted for analysis. Each sample was placed in a labeled plastic bag in the field with a sample number and rock description then assigned prior to placement in storage at Mercator offices in Dartmouth, NS.

The second visit was on March 25th, 2010 and both co-authors were accompanied by Champlain's Senior Geologist Mr. D. Black and Geologist Mr. S. Chase. This trip included a visit to the South Dike trenching area but was primarily focused on review and sampling of archived 2002-2003 Champlain drill core at the company's off-site drill core storage location near Tusket, NS. No hand samples were collected during this trip but samples of archived drill core were collected from Champlain holes BZ-02-19 and BZ-03-24. The remaining (archived) portions of the HQ core intervals were collected for analysis in each case, with intervals corresponding to those used in the earlier Champlain programs. All samples were placed in labeled plastic bags and then assigned a sample number and description. The intended purpose of these samples was to provide verification of analytical results reported earlier for the intervals by Champlain. Bagged samples were brought to Mercator offices in Dartmouth, NS prior to shipment by commercial courier to SGS Canada Ltd. in Don Mills ON for analysis. Samples were in the secure procession of Mercator staff at all times.

In total, 11 drill core samples representative of complete pegmatite intersections were collected for subsequent laboratory analysis as check samples, results of which are reported in section 12.4. Five samples from hole BZ-02-19 were collected, totaling 6.9 m of pegmatite, and six samples from hole BZ-03-24 were collected, totaling 11.1 m of pegmatite. These holes were selected to represent pegmatite mineralization from the South Dike and North Dike, respectively.

12 SAMPLE PREPARATION AND ANALYSIS

12.1 Introduction

Lithium content of rock samples can be reported in more than one chemical form, depending upon analytical method used and the purpose of the analysis. In the case of spodumene samples and ores based on presence of this mineral, analytical values are commonly returned in ppm from Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES) methods, or Li_2O % if analyzed by X-Ray Fluoresence methods. The current industry standard for reporting of mineral resources containing lithium is to quote total lithium content expressed as Li_2O %. Other metals of economic significance that are commonly present in Rare Element - LCT Subclass pegmatites such as those of the BLP include tantalum (Ta), niobium (Nb), beryllium (Be), rubidium (Rb) and tin (Sn). Levels of these metals may be quoted in either ppm or oxide forms and conversion of ppm metal levels to associated oxides is sometimes necessary. Table 12.1 presents commonly quoted oxide forms along with conversion factors relating metal analyses and the oxides.

Table 12.1: Element to Oxide Conversion Factors

Converting from	Converting to	Multiply by
Li ppm	Li_2O %	2.153×10^{-4}
Ta ppm	Ta_2O_5 %	$1.221 \times 10-^{4}$
Nb ppm	Nb_2O_5 %	1.431×10^{-4}
Be ppm	BeO %	2.775×10^{-4}
Rb ppm	Rb_2O %	1.094×10^{-4}
Sn ppm	SnO_2 %	1.270×10^{-4}

Laboratory methods used in determination of Rare Element levels typically include standard rock preparation techniques such as crushing and pulverizing followed by either strong acid digestion of a sample pulp split or sodium peroxide or lithium borate fusion of a pulp split followed by analysis using either ICP-AES or Atomic Absorption Spectrometry (AAS) methods. Pressed pellet pulp analysis by XRF methods is also used for lithium determinations. Some commercial laboratories currently offer ICP-ES Rare Element analytical packages that include a Li analysis as a package add-on.

Sample preparation and analytical techniques followed during each of the major exploration programs carried out on the BLP since 1998 are discussed below under separate headings.

12.2 Gwalia (1998)

Gwalia's primary interest in the BLP was in locating concentrations of Ta_2O_5 exceeding a minimum threshold value that is variably reported in historic reports as being either 600 ppm or 200 ppm. It is likely that the 200 ppm Ta_2O_5 (0.02% Ta_2O_5) figure applied, since proven and probable reserves at the company's Greenbushes pegmatite mine were reported in that era as being 28 Mt grading 430 ppm Ta_2O_5 (Cerny, 1991, ref: Sinclair, 1991).

Drill core sample preparation by Gwalia was performed at the company's Greenbushes Mine laboratory in Western Australia and included two stages of crushing (first to -6 mm followed by a second to -2 mm), followed by single stage pulverization to a nominal sub-fraction grain size of 100µm. A split of the 100µm pulp material was analyzed for a wide range of pegmatite-associated elements using XRF methods and levels of the light elements Li and Be were then determined using AAS methods (Hudgins, 1998).

12.3 Champlain Resources (2002-2003)

Samples collected from drill core and regional prospecting programs carried out by Champlain were sent to XRAL Laboratories (now SGS Minerals) in Don Mills, Ontario for preparation and analysis. All samples were subjected to standard crushing and pulverizing routines to obtain analytical pulp material of -200 mesh grain size. Multi-element analysis was performed using ICP-AES (SGS code ICP90) methods after sodium peroxide fusion and a lithium meta-borate fusion followed by ICP-AES (SGS code ICP95) analysis was used to obtain major element oxide and primary lithium values. Additional trace element analysis following lithium metaborate fusion was carried out using Inductively Coupled Plasma – Mass Spectrometry methods (ICP-MS) described under SGS code MS95.

12.4 Mercator (2010)

Mercator collected 11 drill core samples from historic drilling conducted by Champlain on the two main dikes at Brazil Lake. Sample preparation was completed at the commercially operated Minerals Engineering Centre (MEC) at Dalhousie University in Halifax, NS and included multistage jaw crushing to produce a -10 mesh sample from which a 200-250 gram subsample was riffle split and then pulverized with a ring and puck pulverizer to a nominal grain size of 0.15 microns. One blind quality control blank sample was also included in the sample set submitted to MEC to monitor preparation stage cross-contamination. Equipment was cleaned with jets of air and silica sand between samples. All sample pulps prepared by MEC were labeled and placed in dry paper envelopes for delivery to Mercator. At the report date sample coarse reject material was being temporarily stored at the laboratory before return to Mercator.

Prepared pulps were packaged by Mercator after insertion of a quality control standard and then sent to SGS Minerals in Don Mills, ON, where additional pulverizing was performed to ensure a -200 mesh grain size. All samples were analyzed using ICP-OES methods (SGS codes ICP90A and ICP90Q) following sodium peroxide fusion, which provided near-total digestion of the analytical splits. More detailed descriptions of analytical techniques used for Mercator samples appear in Appendix 2.

13 DATA VERIFICATION

13.1 Program Summary

Verification of the BLP property data set was addressed by Mercator through (1) completion of a desktop review of all major reports and publications associated with the property, including review of associated laboratory certificates of analysis, (2) completion of two site visits to the BLP, one to view and verify trench geology and one to view and sample locally archived Champlain drill core from the 2002 and 2003 programs, (3) review of drill core from the 1993 NSDNR program that is archived at the government core library in Stellarton, NS, (5) collection of independently determined drill collar coordinates for several Champlain and/or NSDNR drill holes for comparison with Champlain data files, and (6) completion of a third party check sample program based on analysis of 11 half-core samples collected by Mercator that replicate original Champlain core sample intervals.

Desktop studies showed that historic reports documenting work on the property were typically of good quality and contained appropriate laboratory certifications for associated analytical results. Observations of trench geology made during the site visits were also compared to depictions on historical geological plans where possible. In all instances noted, previously mapped mineralogical and spatial attributes were found to accurately depict those observed by Mercator staff in the field. This observation includes estimates of dike width and defined strike extents for both the North Dike and South Dike.

Core sample review by Mercator at both the NSDNR library and the Champlain core storage site included checking of various logged lithologic intervals and associated descriptions against corresponding archived core intervals. Good correlation was found between recorded core sample records and physical sampling records present in the core boxes.

The Mercator core check sample program returned an average analytical result of 6.35% Li2O for the two certified reference standard splits submitted. This average falls within the acceptable error range of 6.39 ±0.05% Li_2O for the SRM181 certified reference standard obtained by Mercator from the National Institute of Standards and Technology in Gaithersburg, Maryland, USA. The individual sample results for the standard appear in Table 13.1 below. These are interpreted as indicating that the associated sample data set is of acceptable accuracy. Results for the single blind blank sample of anhydrite submitted with the core sample preparation shipment for quality control purposes returned a value of 20 ppm Li that is interpreted as showing that no significant degree of sample preparation Li cross-contamination had taken place within the sample set. Similarly, comparison of duplicate split analyses for two samples showed very close agreement between Li analyses, indicating acceptable precision within the dataset (Table 13.2).

Table 13.1: Analytical Results for Standard SRM181 Analysis

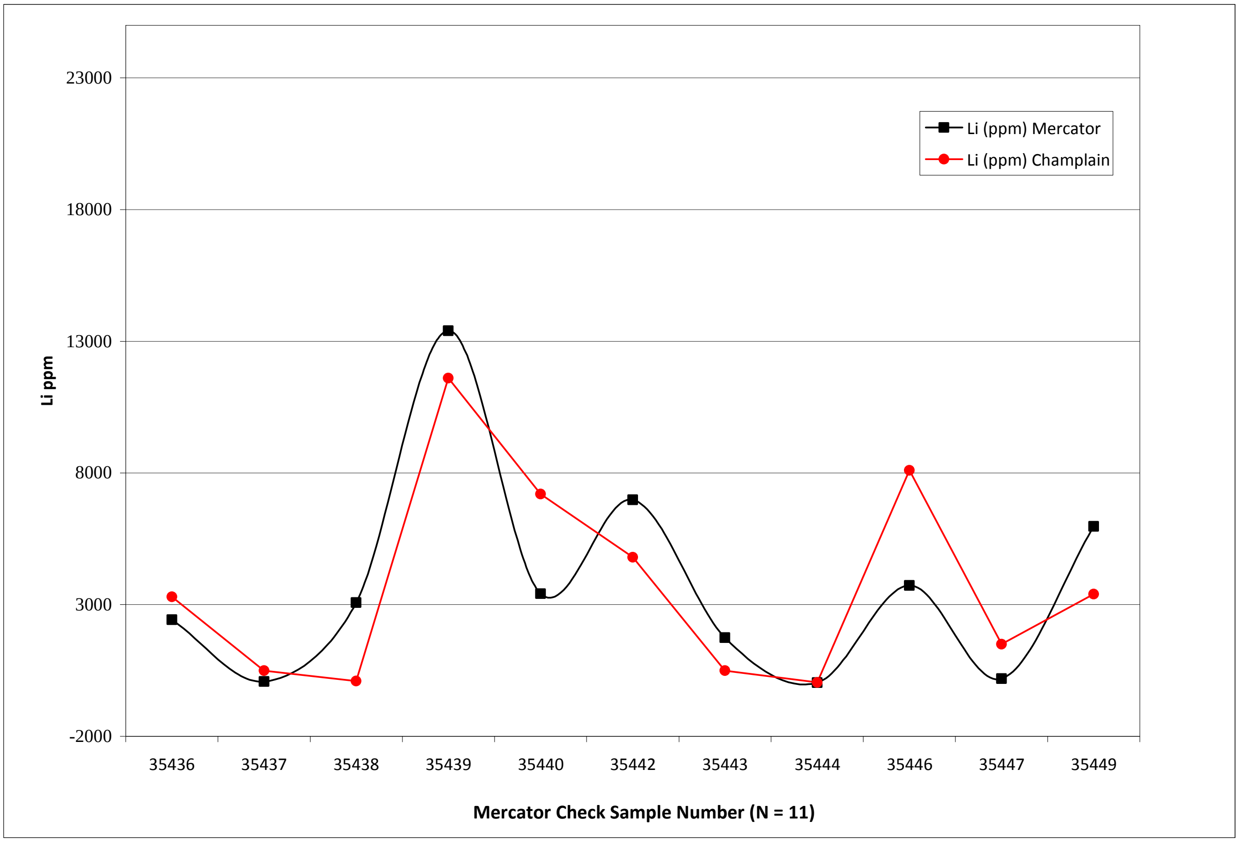
Mercator Sample Number	Li2O%	SRM 181 Certified Value Li2O%
35441	6.42	6.39 ± 0.05
35448	6.27	6.39 ± 0.05
Average	**6.35**	**-----------**

Table 13.2: Analytical Results for Mercator Duplicate Split Samples

Mercator Sample Number	Original Split Li (ppm)	Duplicate Split Li (ppm)	Change (%)
35446	8,580	8,320	3.03
35449	3,540	3,640	-2.82

Li values for the eleven Mercator check samples were also compared with original Champlain core sample values reported by Black (2003). Results returned a correlation coefficient of 0.80 and are presented in Figure 13.1.

Figure 13.1: Comparison of Mercator check sample results with original Champlain results



Half core pairs show absolute Li content differences ranging between 0% and 0.94% and Mercator values were equal to, or higher than, Champlain values for 6 of the eleven samples collected. Various factors contributed to observed sample pair differences, including sample heterogeneity at the half core scale and differences in sample preparation and analysis. However, based on core observations plus knowledge of spodumene distribution based on surface trench mapping of the BLP dikes, the most prominent contributing factor is believed to be heterogeneity of spodumene crystal distribution between the two half core samples. This is an anticipated result when small sample sizes such as those provided by small diameter drill core are used to evaluate materials containing coarse grained to megacrystic mineral components that are unevenly distributed. As such, it represents a “nugget effect”. Results presented in Figure 13.1 are interpreted as generally confirming the range and character of Li2O values reported earlier by Champlain and also as indicating that significant grade variation due to the coarse grained nature of spodumene occurrence at small sample sizes can be expected. This is an expected condition when dealing with megacrystic pegmatite bodies.

13.2 Site Visits by Authors

On two occasions the property was visited by Mercator staff in support of the current report. A trip on March 5th, 2010 was conducted by co-author M. Cullen accompanied by Mr. D. Black, Senior Geologist for Champlain, and Mr. R. Bourgeois, CEO of Petro-Horizon. The trip included inspection of the South Dike and North Dike bedrock trench exposures and a general reconnaissance of immediate areas. Numerous hand samples from both dikes were collected at this time and locations of various historic drill sites were visited. The second site visit was carried out on March 25th, 2010 and was conducted by co-authors M. Cullen and J. Barr accompanied by Mr. D. Black and Mr. S. Chase of Champlain. This trip included a second visit to the South Dike trenched area, but its main purpose was to carry out review and check sampling of Champlain drill core that had been archived in the local area.

Drill core from the 2002 and 2003 Champlain programs has been stacked on pallets and stored outside under plastic sheeting at a private property near Tusket, NS. Core was found to be intact and generally well preserved (Figures 13.1 and 13.2). However, core box deterioration due to water infiltration and associated rotting had occurred in some stacked piles, making some boxes too unstable to be moved. Due to limited time, only core from drill holes BZ-02-19 and BZ-03-24 was selected for check sampling, providing access to material from both the South Dike and North Dike. Sample intervals used in historic sampling protocols were replicated, as described

Figure 13.2: Champlain drill core from 2002-2003 programs in storage

Figure 13.3: Champlain drill core showing deteriorated condition of some boxes

earlier in report Section 11.3. Details of associated analytical methods were described in Section 12.3 and results of the program were summarized above in Section 13.1 .Analytical laboratory reports for the Mercator program appear in Appendix 2. Subsequent to the core storage site visit Mercator recommended that Champlain re-box all archived pegmatite intercepts and provide drier secure storage for this potentially valuable material.

14 ADJACENT PROPERTIES

There are no adjacent properties as defined under National Instrument 43-101 that are currently pertinent to the BLP. It is appropriate to note that no lithium-bearing pegmatites directly comparable to those defined on the BLP have been defined to a similar degree in Nova Scotia to date. However, several prospective areas showing spodumene-bearing pegmatite boulders have been outlined by Champlain along the BLP's interpreted northeast striking pegmatite trend that measures 10 km or more in length. Limited investigation of some of these indicates association with bedrock sources separate from known pegmatite.

In an historic context, the East Kemptville tin mine is located approximately 13 km east northeast of the BLP and was operated by Rio Algom Ltd. between 1985 and 1992. The large associated bedrock tin deposit is predominantly hosted by altered granitic rocks of the Mid Devonian Davis Lake Pluton (DLP), which forms the most southeasterly exposure of the related South Mountain Batholith (SMB). The DLP is composed of leucocratic granite that is locally greisenized and hydrothermally metasomatized in areas of tin and related sulphide mineralization. The average grade during mining of the deposit was 0.16% tin, primarily occurring as cassiterite. While not proven, some workers have proposed that this pluton may continue in the subsurface to a position at depth beneath the BLP. If this proved to be correct, property prospectivity would potentially be enhanced. Avalon Rare Metals Inc., a Canadian junior exploration firm, was actively pursuing exploration on a large ground position at East Kemptville at the report date, apparently with particular focus on Indium, among other metals (Avalon Rare Metals Inc. website project description, April 23rd, 2010).

15 MINERAL PROCESSING AND METALLURGICAL TESTING

15.1 Introduction

During the 2002-2003 field season, Champlain initiated a program of field and laboratory study directed toward assessment of mineral processing and extraction techniques for valued BLP pegmatite components. Representative bulk sample materials to support this work were created from drill core intersections by Champlain staff and then submitted for study at the Minerals Engineering Centre (MEC) of Dalhousie University in Halifax, NS and the Material Research Laboratory Ltd. (MRL) of North Carolina State University in Asheville, North Carolina, USA. Laboratory studies at both facilities led to comparison of mineral recoveries and costing of wet and dry mineral beneficiation processes. Efforts were focused on creating high grade/high purity concentrates of lithium-bearing spodumene, mica, feldspar and silica, all of which were considered to be of importance to economic assessment of the BLP pegmatites (Van Jahnke, 2003a). Initial laboratory analysis was conducted by MEC on a bulk sample created from the entire pegmatite intersection of drill hole BZ-02-13, with further work subsequently conducted at MRL. A second bulk sample was created from core from drill holes BZ-02-17, 18, 19 and 22 plus BZ-03-23 and 24. Core from each hole constituted a separate component of this six component sample set that was sent to MRL for additional processing.

A single formal compilation report on all of Champlain's mineral processing investigation programs did not exist at the report date. However, several interim reports and hard copy documentation of laboratory studies were reviewed for current report purposes. The following discussions of program results and conclusions are based on review of such information. However, Mercator is not providing professional opinion with respect to the referenced metallurgical or mineralogical processing procedures.

15.2 Mica Processing

Laboratory processing of mica was focused on creation of a high purity, finely ground concentrate having very low iron levels and high brightness. Cole (2003) reported on work carried out at MEC and showed that a 92% muscovite concentrate with minor amounts of Na-feldspar (5.4%), spodumene (2.4%) and quartz (0.5%) was created that contained less than 0.5% Fe_2O_3. Black (2003) reported that market interest at that time was directed toward delaminated mica offering bulk density values below 10lb/ft^3 (0.16 g/cm3), and that delamination processing at MEC had returned bulk densities between 52 and 48 lb/ft^3 (0.83 g/cm3 to 0.76 g/cm3). Van Jahnke (2003A) reported on further processing by the Minerals Research Laboratory and showed that Fe_2O_3 concentration in the mica ranged from 0.44% to 0.90% and averaged 0.60%. He also concluded that the associated mica concentrate would be suitable for dry ground markets but possibly not for wet ground markets due to the difficulty encountered during laboratory delamination of the mica. It was noted at this time that the concentrate contained up to 3900 ppm rubidium (Rb), with this considered to be anomalously high.

15.3 Spodumene Processing

Laboratory processing of spodumene was aimed at developing a high purity spodumene concentrate with an iron concentration not exceeding 0.10%. Spodumene concentrates were produced by several methods, but the most attractive recovery rates of 90-97%, at grades of 7.23% to 7.79% Li_2O, were attained through heavy media separation processing. Iron content within the concentrates was higher than desired, with lowest reported values in the range of 0.11-0.18% Fe_2O_3 following fine grinding and magnetic separation at the MRL lab in North Carolina (Black, 2003). Van Jahnke (2003b) concluded that further testing should be performed to determine mineralogical siting of Fe_2O_3 and whether more of this phase could be liberated from the concentrate.

15.4 Silica Processing

Laboratory processing of both pegmatite quartz and surrounding wallrock quartzite was carried out to produce a high purity SiO_2 product. Van Jahnke (2003b) defined a high purity quartz concentrate as having less than 30 ppm aluminum with other impurity levels being below 1.5 ppm. During study of the second bulk sample sent to MRL, a silica concentrate averaging 99% SiO2 was produced using flotation methods and without requirement for magnetic separation processing (Van Jahnke, 2003a). Successful concentration of SiO_2 to comparable levels using both flotation and magnetic separation techniques was also reported by Black (2003).

15.5 Feldspar Processing

Laboratory processing of feldspar was performed exclusively at MRL. Results of this work showed that a low Fe_2O_3 content (0.01-0.04%) K-feldspar concentrate could be produced by flotation methods without use of magnetic separation processing and that resulting concentrate had low and acceptable levels of both Ca and Li. Van Jahnke (2003a) described the course of this investigation and considered concentrate attributes to be suitable for conventional feldspar markets.

15.6 Chlorination of Spodumene

Champlain initiated investigations and research into viability of direct lithium extraction and recovery from BLP spodumene concentrate through means of chlorination processing. The method is based on the premise that at high temperatures (ie. >1050°C) spodumene reverts to the high temperature β-spodumene form that will selectively react with chlorine gas to form lithium chloride (LiCl) having low levels of associated aluminum and silica. Van Jahnke (2003a) and Dunn (2004) provide details of this processing approach, which is not currently being used for commercial production of lithium products from spodumene. LiCl is used as a feedstock for lithium metal production and also in the lithium battery industry. Champlain's ongoing research interest is focused on determining whether chlorination processing offers an economic advantage over traditional flotation methods where multiple processing stages are required to generate lithium carbonate ($LiCO_3$) prior to generation of LiCl. Champlain considers its initial laboratory results for spodumene chlorination processing to be favourable, but a need for additional research is recognized.

Due to the preliminary nature of laboratory work and lack of complete formal reporting to date, relevance of the chlorination process to economic assessment of spodumene-bearing BLP pegmatites cannot be fully assessed at this time. However, if initial positive results are proven to reflect a cost effect means of producing LCI and other Li products, it could factor favorably in future economic viability assessment of the BLP.

16 MINERAL RESOURCE AND MINERAL RESERVE ESTIMATES

No mineral resource of mineral reserve estimates have been prepared for the property to date.

17 OTHER RELEVANT DATA AND INFORMATION

17.1 Environmental Considerations

Field observations made during the two site visits by Mercator staff showed that exploration activities carried out by Champlain to date have had minimal impact on natural site conditions and no obvious issues of immediate environmental concern were noted. However, several small surface water drainages are present in this area and safe guarding of these from impact by future exploration activities must remain a priority. The company has been proactive on this front to date and completed a baseline water quality monitoring program during the 2002-2003 drilling and trenching exploration period. No adverse water quality impacts were detected at that time.

The large trenched area along the surface expression of the South Dike provides excellent access to the pegmatite for sampling, mapping and potentially bulk sample purposes. It is shallow in nature, located in a topographically flat area, and does not discharge water to local drainages. As such, it does not appear to pose environmental risk to local water resources and should be maintained in present form to support Champlain's further BLP investigations. In future, however, it will be necessary to backfill and reclaim the excavated area, which currently measures approximately 200 meters by 10 meters in overall dimension.

17.2 Economic Considerations

Lithium compounds have historically been used in ceramics, glass, lubricants/greases and in the production of synthetic rubber. More recently, use in production of rechargeable and dischargeable batteries has increased dramatically and is generally considered to be a major growth avenue for the world lithium market. Table 17.1 summarizes world lithium production for the period 2004 through 2008 and shows that recent lithium carbonate production has been dominated by operations in Chile and China, with most coming from evaporative brine

Table 17.1: Summary of world lithium production 2004-2008 *(excerpt from USGS 2008 Minerals Yearbook, Jaskula 2010)*

LITHIUM MINERALS AND BRINE: WORLD PRODUCTION, BY COUNTRY[1, 2]
(Metric tons)

Country[3]	**2004**	**2005**	**2006**	**2007**	**2008[e]**
Argentina:[4]					
Lithium carbonate	4,961 [r]	7,288 [r]	8,228 [r]	8,863 [r]	10,000
Lithium chloride	6,315 [r]	8,416 [r]	8,336 [r]	8,843 [r]	7,800
Australia, spodumene	118,451	173,635	222,101	192,277 [r]	200,000
Brazil, concentrates	9,084	8,924	8,585 [r]	7,991 [r]	8,000 [p]
Canada, spodumene[e, 5]	22,500	22,500	22,500	22,500	22,000
Chile:[4]					
Lithim carbonate from subsurface brine	43,971	43,595	50,035	55,452 [r]	52,520 [6]
Lithium chloride	494	681	1,166	4,185 [r]	4,360
China, carbonate[e]	14,000	15,000	15,000	16,000	17,500
Portugal, lepidolite	28,696	26,185	28,497	34,755 [r]	35,000 [p]
United States, subsurface brine	W	W	W	W	W
Zimbabwe, amblygonite, eucryptite, lepidolite, petalite, and spodumene	13,710	37,499	30,000	30,000 [r]	25,000

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data.

[1] Table includes data available through April 1, 2009.

[2] Estimated data are rounded to no more than three significant digits.

[3] In addition to the countries listed, other nations may produce small quantities of lithium minerals, but output is not reported, and no valid
available for estimating production levels.

[4] New information was available from Argentine and Chilean sources, prompting major revisions in how lithium production was reported.

[5] Based on all Canada's spodumene concentrates (Tantalum Mining Corp. of Canada Ltd.'s Tanco property).

[6] Reported figure.

operations or “salars”. The Chilean firm Sociedad Quimica y Minera (SQM) is the world’s largest producer of lithium products, based on brining operations associated with large salars near Antafagasto, Chile. In contrast, world spodumene production from bedrock sources is dominated by Australia, with Canada and Zimbabwe also having significant production levels. The Greenbushes, Western Australia operation of Talison Minerals Pty. Ltd. dominates world spodumene production.

The ability of current producers to increase production levels from existing operations to meet projected future demand is an important factor in economic viability assessment of any new lithium source. This particularly applies to new deposits currently under exploration such as those of the BLP. While long-term growth in total Li demand is generally accepted, a large percentage of this reflects projected demand for lithium carbonate production, with lesser contributions from lithium metal and lithium chloride respectively. These market factors have consequence at the level of exploration for new lithium resources, since unit production costs for brining operations that produce high growth potential lithium carbonate are substantially lower than those associated with development of new open pit or underground mining operations to exploit and process spodumene-bearing pegmatite sources. Importance of innovative beneficiation options for spodumene, such as that of chlorination investigated to date by Champlain, may factor substantially in establishing economic viability of new bedrock spodumene resources.

While lithium contained in spodumene mineralization forms the major component of economic value seen in the BLP pegmatites to date, enhancement of project economics through consideration of other minerals or metals such as feldspar, mica, silica, tantalum or rubidium is also important. This has been apparent to Champlain for some time and is evidenced through the company’s ongoing investigations of mineral processing approaches.

18 INTERPRETATION AND CONCLUSIONS

A complete review of BLP documentation from multiple sources, including operator assessment reports, government reports and academic research was completed by Mercator and provided a general overview of the BLP geological setting and mineralizing environment. In summary, the property has been the subject of three diamond drilling campaigns to date that resulted in completion of 37 diamond drill holes with a cumulative length of 2,702 meters. Exploratory trenching programs have also been completed, including a large surface stripping project. Combined results of these programs have served to define two northeast striking, near-vertically dipping spodumene-bearing pegmatites dikes on the BLP, these being the North Dike and South Dike. Both dikes cross cut confining stratigraphy of the Silurian White Rock Formation at a low angle and individually show drilling and trenching defined strike lengths of approximately 300 meters at surface. They have been tested by drilling to a maximum depth of 75 meters below surface and have geometry characterized by thickened central zones that plunge southwesterly at an angle of approximately 50 degrees. Dike true thicknesses range between a few meters near strike extremities to a maximum of about 21 meters defined by drilling in the thickest central areas. Near-surface internal continuity of dike width and character between trenching and drilling observation points is demonstrated by extensive surface stripping on the South Dike and is inferred for the generally similar North Dike.

Both North Dike and South Dike pegmatites are comprised of typically coarse grained assemblages of potassium feldspar, sodium feldspar (as albite-cleavelandite), spodumene, muscovite and quartz, along with secondary and trace mineral phases including tantalite-columbite, beryl, apatite and, rarely, cassiterite. Anomalous values of Li, Rb and Sn are present in both dikes and they are classified as Rare Element–LCT pegmatites using the classification system established by Cerny and Ercit (2005). Spodumene occurs as a medium grained to megacrystic phase within the pegmatites and modally accounts for 20% to 70% or more of dike content in some areas.

Economic interest in the BLP pegmatite dikes is primarily based on lithium content of their spodumene mineral fractions and work to date shows that Li_2O grades of economic interest are present. More specifically, hole BZ-02-15 returned a weighted average Li_2O grade of 1.47% over a true width of 12.53 m and BZ-93-04 returned a weighted average grade of 1.27% Li_2O over 20.90m true width. These intercepts and others contain sub-interval Li_2O grades exceeding 2.5 %. This indicates that potential exists at the BLP for definition of mineralized zones at insitu Li_2O grades comparable to the 2.76 % Li_2O reserve grade of the underground TANCO Mine at Bernic Lake, Manitoba, but over thinner true widths to date. Thin overburden at the North Dike and South dike areas would factor favorably in economic analysis of lower cost open pit development at the BLP, while near-vertical dip to the dikes could factor favorably in consideration of subsequent underground mining of thinner, high grade shoots within the dikes. BLP grades and interval widths are typically lower than those of the high grade Greenbushes Mine in Western Australia, where ore grading between 3.5% and 4.5% Li_2O is processed at present. Notably, recovery of additional metals such as tantalum and tin takes place at such facilities and factors significantly in economic viability.

Work by Champlain has also been directed toward definition of valuable mineral or metal components of the BLP dikes additional to lithium, and preliminary results show that potential exists for creation of industrial mineral products such feldspar, quartz and mica. The company is also investigating potential for recovery of rubidium, tantalum and tin from dike materials. Initial processing studies directed toward beneficiation of spodumene, as well as feldspar, quartz and mica have returned favourable results but additional work is required on this front.

Based on information reviewed for this report, the authors have concluded that the presently known North Dike and South Dike pegmatites of the BLP, along with adjacent boulder prospect areas such as those at Deerfield, Army Road, Church Road and Gardiners Mills define a district scale area in which spodumene-bearing pegmatites can be expected to occur. The North Dike and South Dike provide indications of lithium grades that can be expected in this setting and are considered to be of economic interest under current market conditions. Combined attributes of the BLP are further interpreted as indicating that good potential exists for new discoveries of spodumene-bearing pegmatites along the northeast trending BLP corridor, and that further exploration to evaluate district-scale potential is warranted.

19 RECOMMENDATIONS

Based on results of the technical review presented in this report, further exploration of the BLP is recommended. Future exploration should include additional drilling-based evaluation of the North Dike and South Dike pegmatites as well as continuation of basic exploration programs along the favourable northeast trend of the BLP. Drilling focus should initially be placed on assessment of the North Dike, with particular attention given to testing of the potential down-plunge extension of the dike’s thickened central zone of enhanced spodumene occurrence. Initial investigation to a vertical depth of 75 to 100 meters below surface is recommended for both dikes and associated core drilling should be planned to initially establish coverage at 50 meter spaced sections along strike.

All existing and future drill collar and trench locations should be formally surveyed and all data associated with drilling, trenching and other exploration programs should be established in an accessible digital format with suitable backup copies available. Review of compiled project data from rock and drill core sampling programs should be evaluated to define trends of geochemical zonation that may provide exploration vectors for tantalum-bearing pegmatites as well as those showing spodumene association. In addition, drill core measurement of the true width of individual pegmatite intersections is recommended for all future and existing drill core to substitute the estimated values calculated for this report.

Regional property exploration should be pursued with emphasis initially placed on detailed prospecting in all areas not covered to date. This will serve to identify glacial float trains and provide target areas for focused follow-up by surface trenching or reverse circulation drilling methods to test for bedrock pegmatite sources.

Finally, further laboratory metallurgical study of spodumene, mica, silica and feldspar beneficiation methods is necessary to better establish technical and costing parameters for future economic assessment of the BLP. It is recommended that discussions with recognized experts in this field be undertaken, with this leading to development of further focused laboratory assessment programs and evaluation of surface bulk sample needs, if any.

After completion of the above, a mineral resource estimate compliant with National Instrument 43-101 should be prepared to support a subsequent National Instrument 43-101 compliant preliminary economic assessment of the property.

A two Phase approach to recommended BLP exploration is proposed, with Phase 1 consisting of (1) completion of geological mapping and prospecting over all property areas not previously covered, (2) initial in-fill and depth extension core drilling on the North Dike and South Dike, (3) follow-up of the Deerfield and Church Road-Army Road boulder prospect areas through modest programs of Reverse Circulation (RC) drilling and/or surface trenching, and (5) initiation additional metallurgical studies.

The Phase 2 program is entirely contingent on success in Phase I and constitutes (1) completion of delineation drilling on the North Dike and South Dike, (2) initial core drilling investigation of existing and new Phase 1 targets, (3) completion of a National Instrument 43-101 compliant mineral resource estimate for the North Dike and South Dike pegmatites, (4) continuation of beneficiation or bulk sampling studies, as warranted, (5) completion of a National Instrument 43-101 preliminary economic assessment of mineral resources defined through (3) above.

Cost estimates prepared for the recommended Phase 1 and Phase 2 work programs are presented below in Table 19.1 and Table 19.2 respectively.

Table 19.1: Cost Estimate for Recommended Phase 1 BLP Exploration

Program Component	**Calculation Base**	**Estimated Cost $ Cdn**
Project Geologist	4 month @ $8,000 per month	32,000
Prospecting crew/ field assistance - 2 persons	3 months @ $10,000 per month	30,000
Core Drilling on North Dike and South Dike	2,000 meters @ $150 per meter	300,000
Rock and core analytical charges	300 @ $35 per sample	10,500
RC or RAB Drilling or Trenching on Existing or New Targets	5 days @ $3,000 per day	15,000
Accommodations and Meals	180 days @ $100 per day	18,000
Transportation	60 days @ $300 per day	18,000
Landowner access and reclamation payments	Estimated	7,500
Metallurgical Professional Services Consulting	20 days @ $700 per day	21,000
Phase 1 Exploration Total		**452,000**

Table 19.2: Cost Estimate for Recommended Phase 2 BLP Exploration

Program Component	**Calculation Base**	**Estimated Cost $ Cdn**
Project Geologist	3 months @ $8,000 per month	24,000
Prospecting crew/ field assistance - 2 persons	3 months @ $10,000 per month	30,000
Core Drilling	2000 meters @ $150 per meter	300,000
Rock and core analytical charges	350 samples @ $35 per sample	10,500
RC or RAB Drilling on Existing or New Targets	2 days @ $3,000 per day	6,000
Excavator Trenching	5 days @ $1,000 per day	5,000
Accommodations and Meals	180 person days @ $100 per day	18,000
Transportation	60 days @ $300 per day	18,000
Landowner access and reclamation payments	Estimated as 30 at $250 per	7,500
Preparation of National Instrument 43-101 resource estimate	Estimated	50,000
Metallurgical Professional Services Consulting	60 days @ $750 per day	45,000
Preparation of a Preliminary Economic Assessment	Estimated	30,000
Phase 2 Exploration Total		**544,000**

Respectfully submitted,

(Original signed and sealed by)

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Project Geologist

(Original signed and sealed by)

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Senior Geologist

April 23rd, 2010

20 REFERENCES CITED

Black, D., 2002: Assessment Report on 2001-2002 Work Program Carried Out on Exploration Licences 03049, 04427 and 04774, Brazil Lake Area, by Champlain Resources Inc., Prepared for Nova Scotia Department of Natural Resources; 150p.

Black, D., 2003: Assessment Report on 2001-2002 Work Program Carried Out on Exploration Licences 03049, 04427 and 04774, Brazil Lake Area, by Champlain Resources Inc., Prepared for Nova Scotia Department of Natural Resources; 150p.

Cerny, P., 1991a: Rare-Element Granitic Pegmatites. Part I: Anatomy and Internal Evolution of Pegmatite Deposits, Geoscience Canada, v. 18, no. 2, pp. 49-67.

Cerny, P 1991b: Rare-Element Granitic Pegmatites. Part II: Regional to Global Environments and Petrogenesis, Geoscience Canada, v. 18, no. 2, pp. 68-81.

Cerny, P. and Ercit, T.S., 2005: The Classification of Granitic Pegmatites Revisited, The Canadian Mineralogist, v. 43, pp. 2005-2026

Cole, C., 2003: Recovery of Spodumene, Mica, Feldspars and Quartz by Gravity, Electrostatic, Magnetic and Flotation from Brazil Lake Project, Minerals Engineering Centre, Dalhousie University, March 2003.

Corey, M.C., 1995: Diamond Drilling of Rare-Element Pegmatites in Southwestern Nova Scotia, *within* Mineral Inventory Program: Update on Progress, Nova Scotia Department of Natural Resources, Mines and Energy Branch Open File Report 95-001, ISN 18650.

Crouse, R.A., Èerný, P., Trueman, D.L. and Burt, R.O., 1984: The Tanco Pegmatite, Southeastern Manitoba; in: The Geology of Industrial Minerals in Canada; Editors G.R. Guillet and W. Martin; The Canadian Institute of Mining and Metallurgy, Special Volume 29, pages 169-176.

Dunn, W., 2004: Chlorination of Spodumene Ore, Unpublished report to Champlain Resources Inc. for work completed May 1st to June 30th, 2004.

Ferguson, S.A., 1990: Geological Map of the Black River Lake Quadrangle (part of 21A/16C), Nova Scotia Department of Mines and Energy, Open File Map 90-009.

Hudgins, A., 1998: Assessment Report on 1998 Work Program Carried Out on Exploration Licence 03049, Brazil Lake Area, by Champlain Resources Inc., Prepared for Nova Scotia Department of Natural Resources; 25p.

Hudgins, A., 2001: Assessment Report on 2001 Work Program Carried Out on Exploration Licence 04427, Gardiners Mills Area, by Champlain Resources Inc., Prepared for Nova Scotia Department of Natural Resources; 25p.

James, J.A., 1998: Stratigraphy, Petrochemistry and Economic Potential of the Silurian New Canaan Formation, Meguma Terrane, Nova Scotia, B.Sc thesis, Acadia University, Wolfville, NS.

Jaskula, B.W., 2010: Lithium [Advance Release], *in* U.S. Department of the Interior, U.S. Geological Survey 2008 Minerals Yearbook, January 2010, pp 44.1-44.9.

Keppie, J.D., Krogh, T.E., 2000: 440 Ma Igneous Acitivity in the Meguma Terrane, Nova Scotia, Canada: Part of the Appalachian Overstep Sequence?, American Journal of Science, v 300, pp 528-538.

Kontak, D.J., 2004, Geology of the Southern Lobe of the Brazil Lake LCT-type Pegmatite (NTS 21A/04), Yarmouth County, Nova Scotia, *in* Mineral Resources Branch, Report of Activities 2003, Nova Scotia Department of Natural Resources, Report 2004-1, pp 14-68.

Kontak, D.J., Creaser, R.A, Heaman, L.M., Archibald, D.A., 2005: U-Pb Tantalite, Re-Os Molybdonite, and Ar/Ar Muscovite Dating of the Brazil Lake Pegmatite, Nova Scotia: A

Possible Shear-zone Related Origin for an LCT-type Pegmatite, Atlantic Geology, v 41, pp 17-29.

MacDonald, L.A, Barr, S, White, C, Ketchum, J.W.F, 2001: Petrology, Age and Tectonic Setting of the White Rock Formation, Meguma Terrane, Nova Scotia: Evidence for Silurian Continental Rifting, Canadian Journal of Earth Science, v. 39, pp. 259-277.

MacDonald, M.A., Boner, F.J., and Lambert, P.A., 1992: Multi-Media Detailed Geochemical Study of the Brazil Lake Pegmatites (NTS 20P/13), Yarmouth County, Nova Scotia; Nova Scotia Department of Natural Resources, Open File Report 92-016, 125 pp.

Palma, V.V, Sinclair, P.E., Hutchinson, H.E., Kohlsmith, R.L., 1982: Report on Geological Mapping, Till and Rock Geochemical Surveys and Magnetic and VLF-EM Surveys at Brazil Lake, Yarmouth County, Nova Scotia, Shell Canada Resources Ltd. Assessment Report submitted to NSDNR, ISN 7093.

Patterson, J.M., 1993: Granite-Associated Deposits: East Kemptville and Duck Pond, in Metalliferous Environments in Nova Scotia (Base Metals), Nova Scotia Department of Natural Resources, Mineral Resources Branch, Information Series ME 22, Halifax Nova Scotia, pp. 53-58.

Taylor, F.C., 1967: Reconnaissance Geology of Shelburne Map-Areas, Queens, Shelburne, and Yarmouth Counties, Nova Scotia; Geological Survey of Canada Memoir 349, 83pp.

Van Jahnke, J., 2003a, Bench Flotation Tests of Six Composite Samples from a Nova Scotia Spodumene/Feldspar Deposit, Minerals Research Laboratory, North Carolina State University, 21 April, 2003.

Van Jahnke, J., 2003b: Letter to Mike Granito (JP Morgan) from Jeff Van Jahnke (Minerals Research Laboratory, North Carolina State University), dated 28 January, 2003.

Van Staal, C.R., 2007: Pre-Carboniferous Tectonic Evolution and Metallogeny of the Canadian Appalachians; *in* Geological Asscociation of Canada Special Publication No. 5, Wayne Goodfellow editor, p. 793-818.

Vanstone, P, Young, S, Galeshuk, C, Simard, R, and Gibb, A., 2002: The TANCO Rare-element Pegmatite, Southeastern Manitoba, Tantalum Mining Corporation of Canada Limited.

White, C.E., Horne, R.J., Muir, C., Hunter, J., 1999: Preliminary Bedrock Geology of the Digby Map Sheet, Southwestern Nova Scotia, *in* Report of Activities 1999, Nova Scotia Department of Natural Resources, Mines and Energy Branch, Report 98-1, pp. 119-134.

21 STATEMENT OF QUALIFICATIONS

CERTIFICATE OF AUTHOR

I, P. James F. Barr, P. Geo. do hereby certify that:

1. I reside in Musquodoboit Harbour, Nova Scotia, Canada
2. I am currently employed as a Project Geologist with:

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3. I received a Bachelor of Science degree (Honours – Environmental Science, Geology and Chemistry) in 2003 from the University of Waterloo, Waterloo Ontario, Canada.
4. I am a registered member in good standing of the Association of Professional Geoscientists of Nova Scotia.
5. I have worked as a geologist in Canada since graduation.
6. I have read the definition of “qualified person” set out in National Instrument 43-101 (“NI 43-101”) and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a “qualified person” for the purposes of NI 43-101.
7. I am one of the qualified persons responsible for preparation of the Technical Report entitled: Technical Report On The Brazil Lake Lithium-Bearing Pegmatite Property, Nova Scotia, Canada, Prepared for Petro Horizon Energy Corp. by P. James F. Barr, P. Geo. and Michael P. Cullen, P.Geo. and dated April 23rd, 2010.
8. I have professional experience with respect to geology of the Northern Appalachians and, more specifically, that of Nova Scotia. This includes bedrock units that are represented on the Brazil Lake Property. I visited the Brazil Lake Property most recently on March 25th, 2010 accompanied by co-author Michael P. Cullen, P. Geo. and Mr. D. Black of Champlain Resources Inc.
9. As of the date of this certificate, to the best of my knowledge, information and belief, this Technical Report contains all scientific and technical information that is required to be disclosed to make this report not misleading.
10. I am independent of both Petro Horizon Energy Corp. and Champlain Mineral Ventures Ltd., applying all of the tests in section 1.5 of National Instrument 43-101.
11. I have read National Instrument 43-101 and Form 43-101F1, and believe that this Technical Report has been prepared in compliance with that instrument and form.

Dated this 23rd day of April, 2010

[Original signed and sealed by]

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CERTIFICATE OF AUTHOR

I, Michael P. Cullen, *P.Geo.* do hereby certify that:

1. I reside at 2071 Poplar St. in Halifax, Nova Scotia, Canada
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4. I am a registered member in good standing of the Association of Professional Geoscientists of Nova Scotia (Registration Number 064), Newfoundland and Labrador Professional Engineers and Geoscientists (Member Number 05058) and Association of Professional Engineers and Geoscientists of New Brunswick, (Registration Number L4333).
5. I have worked as a geologist in Canada and internationally since graduation.
6. I have read the definition of "qualified person" set out in National Instrument 43-101 ("NI 43-101") and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purposes of NI 43-101.
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Dated this 23rd day of April, 2010

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Appendix 1

Copy of Cerny and Ercit (2005) Pegmatite Classification

The Canadian Mineralogist
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THE CLASSIFICATION OF GRANITIC PEGMATITES REVISITED

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Abstract

The classification of granitic pegmatites was frequently attempted during the past century, with variable degrees of success and applicability. Internal structure, paragenetic relationships, bulk chemical composition, petrogenetic aspects, nature of parent medium, and geochemical features were applied. However, all schemes were marked by contemporary degrees of understanding of these parameters, and most attempts were hindered by ignoring differences in geological environment. Substantial progress was achieved only since the late 1970s. The classification is approached here from two directions, based on but broadened and refined from earlier works by Ginsburg and Čern´y. The first concept deals with geological location, leading to division of granitic pegmatites into five classes (abyssal, muscovite, muscovite – rare-element, rare-element, and miarolitic), most of which are subdivided into subclasses with fundamentally different geochemical (and in part geological) characteristics. Further subdivision of most subclasses into types and subtypes follows more subtle differences in geochemical signatures or P–T conditions of solidification, expressed in variable assemblages of accessory minerals. The second approach is petrogenetic, developed for pegmatites derived by igneous differentiation from plutonic parents. Three families are distinguished: an NYF family with progressive accumulation of Nb, Y and F (besides Be, REE, Sc, Ti, Zr, Th and U), fractionated from subaluminous to metaluminous A- and I-type granites that can be generated by a variety of processes involving depleted crust or mantle contributions; a peraluminous LCT family marked by prominent accumulation of Li, Cs and Ta (besides Rb, Be, Sn, B, P and F), derived mainly from S-type granites, less commonly from I-type granites, and a mixed NYF + LCT family of diverse origins, such as contamination of NYF plutons by digestion of undepleted supracrustal rocks.

Keywords: classification, granitic pegmatites, geochemistry, mineral assemblage, petrogenesis.

Sommaire

Il y a eu plusieurs tentatives de classification de pegmatites granitiques au cours du siècle dernier, avec un taux de réussite et une applicabilité variables. La structure interne, les relations paragénétiques, la composition chimique globale, les aspects pétrogénétiques, la nature du milieu de croissance, et les caractéristiques géochimiques ont tous été utilisés comme bases de classification. Toutefois, ces schémas ont été limités par le niveau de compréhension de ces paramètres lors de leur application, et par négligeance des différences du milieu géologique. Des progrès substantiels ont seulement été atteints depuis la fin des années 1970. La classification est abordée ici de deux directions, fondées sur les travaux antérieurs de Ginsburg et Černý, mais affinés et considérés dans un contexte élargi. Le premier concept porte sur la situation géologique, et mène à cinq classes de pegmatites granitiques: abyssale, à muscovite, à muscovite – éléments rares, à éléments rares et miarolitique), la plupart des classes étant ensuite subdivisées en sous-classes ayant des caractéristiques géochimiques (et, en partie, géologiques) fondamentalement différentes. Une subdivision plus poussée des sous-classes en types et sous-types repose sur des différences plus subtiles des traits géochimiques ou des conditions de solidification distinctes en termes de P et de T, exprimées par des assemblages variables de minéraux accessoires. Le second concept est pétrogénétique, développé pour les pegmatites dérivées par différenciation d'un parent plutonique. Nous distinguons trois familles. La famille NYF , caractérisée par l'accumulation progressive de Nb, Y et F (en plus de Be, REE, Sc, Ti, Zr, Th et U), est fractionnée à partir de granites subalumineux à métalumineux de types A et I, qui peuvent être générés par une variété de processus impliquant une croûte stérile ou une contribution du manteau. La famille hyperalumineuse LCT, reconnue par son enrichissement marqué en Li, Cs et Ta (en plus de Rb, Be, Sn, B, P et F), serait dérivée surtout de granites de type S, et à un degré moindre, de granites de type I. Enfin, il y a la famille mixte NYF + LCT d'origines diverses, par exemple une contamination des plutons NYF par digestion de roches supracrustales fertiles.

(Traduit par la Rédaction)

Mots-clés: classification, pegmatites granitiques, géochimie, assemblages de minéraux, pétrogenèse.

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Introduction

The broad spectrum of mineralogical, geochemical, textural and economic types of granitic pegmatites has been the subject of numerous attempts at classification since about a century ago. Most of the early attempts did not go beyond simple field-based subdivisions, but some of them developed into more sophisticated schemes, the general principles of which still apply today (*e.g.*, Fersman 1940). A variety of criteria were applied to the classification: internal structure, paragenetic relationships, bulk chemical composition, petrogenetic aspects, nature of parent medium, and geochemical signatures, among others. The successes and failures of individual efforts were, to a high degree, controlled by the regional *versus* global experience of the authors, by the state of understanding of the petrological aspects of granitic pegmatites, and by the strong tendency to classify all granitic pegmatites by a single criterion. The early attempts were reviewed and commented on by Jahns (1955), Schneiderhöhn (1961), Solodov (1971) and Černý (1982a).

The modern era was ushered in by Ginsburg & Rodionov (1960), and particularly Ginsburg *et al.* (1979), who distinguished four geological classes (abyssal, muscovite, rare-element and miarolitic) on the basis of their crustal environment, more specifically on the depth of their intrusion, and on their relationship to metamorphism and granitic plutons. Černý (1990, 1991a) revised this classification using improved petrological, paragenetic and geochemical criteria, and introduced a new, separate concept of three petrogenetic families (NYF, LCT and mixed). This petrogenetic classification was fairly widely accepted, and some parts of it were expanded to cover granites (*e.g.*, London 1995). However, it was presented in a rather telegraphic style, which caused uncertainties and misconceptions about some of its aspects. With progress of time, a need emerged to revise some of the pegmatite classes and families (*e.g.*, Černý & Kjellman 1999, Černý 2000), and to take into account several new (or previously omitted) classifications (Zou & Xu 1975, Zou *et al.* 1985, Wise 1999, Hanson *et al.* 1999, Gordiyenko 1996, Zagorskyi *et al.* 2003).

The impetus for revamping the two classifications was provided by Ercit (2005), who reviewed REE-bearing granitic pegmatites, and collected general information on the abyssal- and muscovite-class pegmatites in the process. These two classes were poorly represented in the original versions (Černý 1990, 1991a), in which the main focus was on the rare-element category. We present here the current status of our ideas on these three classes, we incorporate the muscovite – rare-element class, and we modify the subdivision of the miarolitic pegmatites and their links to the rare-element class. Also, the system of petrogenetic families is clarified in greater detail. Otherwise, the scope of the classification remains the same as in the previous versions: pegmatites and granites of peraluminous, subaluminous and metaluminous (to subalkaline) compositions are considered, to the exclusion of the peralkaline kindred [dealt with, in part, by Wise (1999), and by Zou & Xu (1975) and Zou *et al.* (1985) in their mantle-related category]. Also, the classification deals exclusively with what Fersman (*e.g.*, 1940) called pegmatites of "pure-bred lineage". Those that are demonstrably contaminated to hybridized ("cross-bred lineage"; Fersman 1940) by reaction with country rocks are not considered, such as the desilicated pegmatites in ultrabasic rocks and amphibolites (*e.g.*, Martin-Izard *et al.* 1995, Laurs *et al.* 1996), or the danburite-rich pegmatites in marble-dominant host rocks (Pezzotta 2001).

Geological Classes of Granitic Pegmatites and their Geochemical–Paragenetic Subdivisions

Derived from the depth-related "formations" of Ginsburg *et al.* (1979) (a term with an unfortunate sedimentological connotation), five *classes* of granitic pegmatites are distinguished here. They are based on the pressure (and, in part, temperature) conditions that characterize their host-rock suites; these, however, do not necessarily reflect the conditions of consolidation of the synkinematic to post-kinematic (granite +) pegmatite populations themselves (Table 1, 2, Fig.1).

TABLE 1. THE CLASS SYSTEM OF GEOLOGICAL, PARAGENETIC AND GEOCHEMICAL CLASSIFICATION OF GRANITIC PEGMATITES

Class	Subclass	Type	Subtype
Abyssal (AB)	AB-HREE AB-LREE AB-U AB-BBe		
Muscovite (MS)			
Muscovite – Rare-element (MSREL)	MSREL-REE MSREL-Li		
Rare-element (REL)	REL-REE	allanite-monazite euxenite gadolinite	
	REL-Li	beryl	beryl-columbite beryl-columbite-phosphate
		complex	spodumene petalite lepidolite elbaite amblygonite
		albite-spodumene	
		albite	
Miarolitic (MI)	MI-REE	topaz-beryl gadolinite-fergusonite	
	MI-Li	beryl-topaz MI-spodumene MI-petalite MI-lepidolite	

As such, these P–T conditions should be considered as *maximal* estimates for the environment during pegmatite emplacement, as they characterize peak metamorphism, which usually substantially predates intrusions of the pegmatite-forming melt. This P–T gap is locally the largest in the abyssal class, and minimal (if any) in the muscovite class. The difference increases again in the rare-element and miarolitic classes.

In some classes, the next step leads down to subclasses distinguished by fundamental differences in geochemical signature. If permitted by the current insight into individual classes and subclasses, further subdivision leads to pegmatite types and subtypes, marked by significant differences in mineral assemblages, geochemical signature, conditions of consolidation, or a combination of these aspects. The classes are based on geological criteria, but within individual classes, the subdivision follows geochemical features, mineral assemblages and textural attributes that reflect the P–T conditions of pegmatite consolidation. Thus the above hierarchy serves to place a given pegmatite into a gross geological context, and into a descriptive geochemical–paragenetic category.

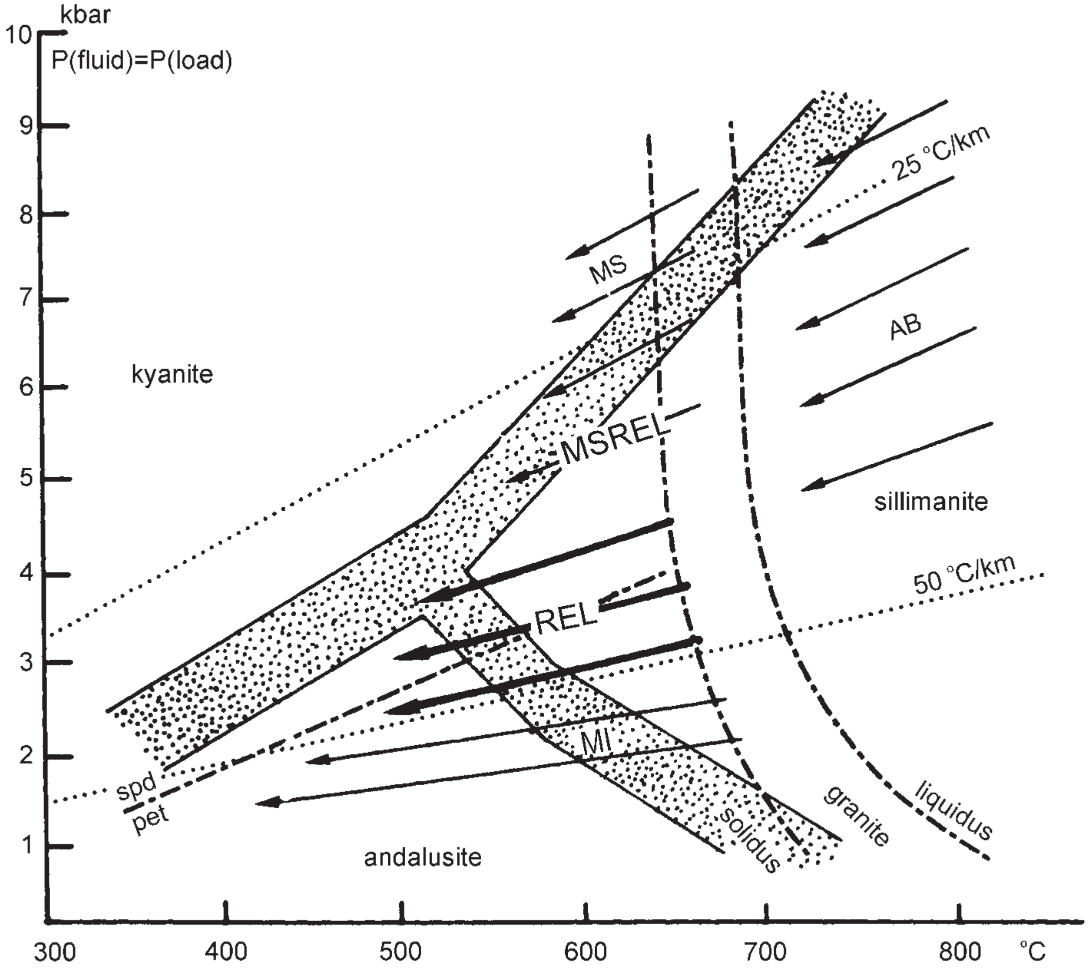

FIG. 1. Schematic P–T fields of regional host-rocks that harbor granitic pegmatites of the abyssal (AB), muscovite (MS), muscovite – rare-element (MSREL), rare-element (REL) and miarolitic (MI) classes. Arrows indicate regional trends of fractionation in the pegmatites relative to metamorphic grades of the host rocks. The MS and MSREL populations, as well as those of the REL and MI pegmatites, tend to be in some cases transitional one to the other. See text for comments on the diversified environment of the AB-class pegmatites. Aluminosilicate fields from Robie & Hemingway (1984), spodumene–petalite boundary from London (1984), granite liquidus – solidus from Jahns (1982). The 25°C/km and 50°C/km gradients correspond to average Barrovian and Abukuma metamorphic facies-series, respectively.

The degree of subdivision in individual classes is highly variable, depending on the current state of understanding of the classes and on the degree of variability encountered in them. In all cases, the hierarchy is open-ended downward (Table 1), providing elbow room for further subdivision as it may become desirable with progress of research. We resisted the temptation to expand the number of types and subtypes where differences would be hazy or minor. Excessive "pigeonholing" would defeat the purpose of the classification, which is aimed at clearly definable types that constitute substantial segments of the global population of granitic pegmatites. Consequently, we feel confident that a vast majority of granitic pegmatites can be correlated with one or another of the proposed categories. Pegmatites with transitional characteristics do occur and may be locally abundant, but they can be described, with appropriate qualifications, by their relationship to the closest "end-members", even if they are not totally identical with any of them. A negligible minority of pegmatites with unorthodox mineral assemblages and geochemical signatures, usually restricted to isolated local populations, must necessarily remain outside the generalized scheme, unless proven to be more widespread and significant in the future. This applies, for example, to the enormously Cs- and B-enriched pegmatites of Madagascar (Simmons *et al.* 2001).

Abyssal class

Despite its shortcomings, the original term is retained for this category, which is hosted within most of the P–T range of the granulite facies (extending to upper-amphibolite conditions) as defined by Yardley (1989) or Bucher & Frey (1994), but excluding the high extremes of pressure. Thus the abyssal class also encompasses pegmatites of intermediate depth but in largely dehydrated high-temperature host terranes. Pegmatites of the abyssal class most commonly correspond to products of partial melting or metamorphic re-equilibration, generally conformable to the metamorphic fabric of the host environment where synkinematic, or discordant where late-kinematic. Migmatitic leucosome and its segregations are common, whereas more voluminous edifices merging into autochthonous anatectic granites with interior pegmatite bodies and exterior pegmatite fringes are much less abundant (*e.g.*, Baie Johan Beetz, Rimšaite 1981). Even rarer are abyssal pegmatites magmatically derived from granites (Bushev & Koplus, 1980). Processes of magmatic differentiation and fractionation within populations of pegmatites are virtually absent. Mineralization, largely restricted to a narrow range of HFSE (U, Th, Y, REE, Nb, Zr: Table 2), is commonly sparse, rarely economic (*e.g.*, Hewitt 1967b, Cuney 1980, Shmakin 1992).

All of the above characteristics indicate that the generation of pegmatites does not necessarily take place at the peak conditions of the granulite-facies regional metamorphism. Quite to the contrary, the host terranes are commonly polymetamorphic (Grew 1998, Grew *et al.* 2000), and pegmatites are related to relatively late processes connected with adiabatic melting during uplift.

Four subclasses of abyssal pegmatites (Table 3) can be distinguished, three of them characterized by extremes in the geochemical relationships of U and Th to Y, LREE, HREE and Nb. In the presence of relatively abundant Nb, most of the U and Th is concentrated as substituent elements in Y–REE–Nb-oxide minerals (*e.g.*, euxenite, samarskite, fergusonite and pyrochlore groups), hence the AB–HREE subclass.

TABLE 2. PRINCIPAL SUBDIVISION AND CHARACTERISTICS OF THE FIVE CLASSES OF GRANITIC PEGMATITES

Class *Subclass*	Typical minor elements	Metamorphic environment	Relation to granites
Abyssal (AB)			
AB–HREE	HREE, Y, Nb, Zr,U,Ti	(upper amphibolite to) low- to high-P granulite facies; ~4 to 9 kbar, ~700 to 800°C	none (?) (segregations of anatectic leucosome ?)
AB–LREE	LREE, U, Th, Ti		
AB–U	U, Th, Zr, LREE		
AB–BBe	B, Be		
Muscovite (MS)			
	no rare-element mineralization (micas and ceramic minerals)	high-P, Barrovian amphibolite facies (kyanite–sillimanite) 5 to 8 kbar, ~650 to 580°C	none (anatectic bodies) to marginal and exterior
Muscovite – Rare-element (MSREL)			
MSREL–REE	Be, Y, REE, Ti, U, Th, Nb–Ta	moderate to high P, (T) amphibolite facies; 3 to 7 kbar, ~650 to 520°C	interior to exterior; locally poorly defined
MSREL–Li	Li, Be, Nb		
Rare-element (REL)			
REL–REE	Be, Y, REE, U, Th, Nb>Ta, F	variable, largely shallow and postdating regional events affecting the host rocks	interior to marginal (rarely exterior)
REL–Li	Li, Rb, Cs, Be, Ga, Sn, Hf, Nb–Ta, B, P, F	low-P, Abukuma amphibolite (andalusite–sillimanite) to upper greenschist facies; ~2 to 4 kbar, ~650 to 450°C	(interior to marginal to) exterior
Miarolitic (MI)			
MI–REE	Y, REE, Ti, U, Th, Zr, Nb, F	very low P, postdating regional events that affect the host rocks	interior to marginal
MI–Li	Li, Be, B, F, Ta>Nb	low-P amphibolite to greenschist facies, 3 to 1.5 kbar, 500 to 400°C	(interior to) marginal to exterior

With significantly diminished Nb and HREE, yet relatively abundant LREE, most U and Th are dispersed, again as substituent elements, between silicate and phosphate phases (*e.g.*, allanite and monazite), hence the AB–LREE subclass. However, with negligible Nb, Y and REE, most U and Th necessarily reside as structurally important elements in species of their own: uraninite UO_2 and thorite $(U,Th)SiO_4$, hence the AB–U subclass.

The fourth subclass is provisional, pooling pegmatites enriched in B and Be, although most of their prominent concentrations are separate. The minerals hosting these elements are quite characteristic (Table 3), consisting largely of high-pressure species and developed mainly in complex environments during multistage events (*e.g.*, Grew *et al.* 2000). The pegmatites of this subclass commonly are strongly peraluminous (as are most of the typical minerals). In the absence of data on bulk composition of these pegmatites, the degree of their departure from truly granitic compositions is not clear and deserves attention.

Muscovite class

Pegmatites of this class are largely conformable to, and in part deformed with, host rocks of high-pressure amphibolite facies characterized by the kyanite – sillimanite progression of the classic Barrovian metamorphic facies-series (Table 1). The pegmatites are generated directly by partial melting (Shmakin & Makagon 1972, Gorlov 1975, Sokolov *et al.* 1975) or by very restricted extent of differentiation of anchi-autochthonous palingenetic granites (Bushev 1975, Gordiyenko & Leonova 1976, Ginsburg *et al.* 1979, Shmakin 1976). However, modern petrogenetic studies based on isotopic evidence are so far not available for this pegmatite class! Nevertheless, the field evidence, enclosed relics of unaltered metamorphic assemblages and lack of fractionation all indicate that the conditions of magma generation, intrusion (if any) and pegmatite consolidation were very close to those of the metamorphic grade of the kyanite–sillimanite-bearing host rocks (Gordiyenko & Leonova 1976, Ginsburg *et al.* 1979, Gordiyenko 1996).

TABLE 3. SUBDIVISION OF GRANITIC PEGMATITES OF THE ABYSSAL CLASS

Subclass	Geochemical signature	Typical minerals	Examples	References
AB–HREE	HREE, Y	Y-Nb-oxide minerals uraninite, zircon, (allanite)	Parry Sound, Hybla and Madawaska districts, ON	Hewitt (1955, 1967a), Goad (1990)
			Evans-Lou and Lapointe quarries, Gatineau, QC	Hogarth (1972), Spence (1932)
			Aldan, Anabar shields, Siberia, Russia	Bushev & Koplus (1980)
			Antsirabe-Kitsamby district, Madagascar	Joo' (1970), Bourret (1988)
AB–LREE	LREE	allanite, monazite, (uraninite, thorite)	Wolverine field, Mt. Bisson, BC	Halleran & Russell (1993)
			Five Mile mine, Madawaska, ON	Storey & Voss (1981)
			Lac à Baude, QC	Ellsworth (1932)
			Part of Chupa-Yena district, Karelia, Russia	Leonova & Polezhaeva (1975)
AB–U	U, Th	uraninite, thorite, zircon, (allanite)	Mont-Laurier, QC	Henderson (1982)
			Sharbot Lake, ON	Ford (1982)
			Hearne and Rae subprovinces, SK	Tremblay (1978)
			Rössing, Namibia	Cuney (1980)
			Baie Johan Beetz, QC	Rimšaite (1981)
AB BBe	B, Be	dumortierite grandidierite, kornerupine, werdingite, chrysoberyl, sapphirine series, surinamite	Rogaland, southwestern Norway	Huijsmans *et al.* (1982), Grew *et al.* (1998)
			Andrahomana, SE MAD	Grew *et al.* (1998)
			Kutná Hora, CZ	Cempírek & Novák (2004)
			Enderby Land, eastern Antarctica	Grew (1998), Grew *et al.* (2000)
			South Kerala, India	Soman *et al.* (1986)
			Kalanga Hill, NE Zambia	Žáček & Vrána (2002)

Geographic symbols: BC: British Columbia, CZ: Czech Republic, MAD: Madagascar, ON: Ontario, QC: Quebec, SK: Saskatchewan.

The pegmatites are typically barren, carrying feldspar of ceramic grade, quartz and industrial mica, which gave them the original name. The name is retained here because of lack of any other suitable term, although the economic importance of muscovite has vastly diminished with time. The simple mineralogy of accessory silicates and lack of even minor mineralization in most occurrences preclude any meaningful subdivision of this class. Exceptional traces of rare-element minerals generally match the phases found in pegmatites of the muscovite – rare-element class (Table 4).

Muscovite – rare-element class

Pegmatites of this class were historically treated either as members of a specific class, or as intermediate links between muscovite and rare-element classes without a pigeon-hole of their own. However, analysis of the subject by Shmakin (1976) and Ercit (2005) persuasively supports this split. Thus we assign a class status to these pegmatites, with two broadly based but mutually distinct subclasses (Table 4). The metamorphic environment that typically hosts pegmatites of this class is intermediate to the parameters typical of the muscovite and rare-element classes (Table 1, Fig. 1). Pegmatites of the muscovite – rare-element class, unlike those of the muscovite class, are mostly discordant with respect to the metamorphic foliation of their host rocks, and occasionally show regional zonation with respect to parental granites (Shmakin 1976, Ercit 1992, 2005, Wood 1996). Unlike pegmatites of the muscovite and rare-element classes, pegmatites of the muscovite – rare-element class contain *both* high-quality muscovite of economic potential (*e.g.*, ruby grade), and concentrations of rare-element minerals that in rare cases verge on economic (*e.g.*, beryl, cassiterite, columbite-group minerals, REE–Nb–U oxides, Li silicates). The links of the muscovite – rare-element pegmatites to granites or regional metamorphism are largely ill-defined, although in some cases the granitic parentage is spatially obvious or at least mandated geochemically (Gordiyenko & Leonova 1976, Ginsburg *et al.* 1979, Ercit 1992, 2005, Wood 1996). This statement applies particularly to members of the *MSREL–Li subclass*, whose geochemical signature implies a plutonic source (saturation in beryl, Li-bearing minerals). Nonetheless, a granitic parentage is doubtful for a significant number of examples of this category, notably those of the *MSREL–REE subclass* (Mineyev & Salye 1971, Gordiyenko & Leonova 1976). As in the case of the muscovite class, genetic considerations are commonly based, mainly to solely, on field relationships and estimates of the bulk composition of the igneous rocks involved. An up-to-date petrogenetic analysis of typical cases of muscovite – rare-element class populations is currently not available, and sorely needed.

TABLE 4. SUBDIVISION OF GRANITIC PEGMATITES OF THE MUSCOVITE AND MUSCOVITE – RARE-ELEMENT CLASSES

Class Subclass	Geochemical signature	Typical minerals	Examples	References
Muscovite class (MS)				
(*unsubdivided*)	Ca, Ba, Sr, Fe>Mn	muscovite, biotite, almandine-spessartine, (kyanite, sillimanite)	White Sea region, Russia Mama–Vitima, Siberia most of the Appalachian pegmatite province	Gorlov (1975) Shmakin (1976) Jahns *et al.* (1952)
Muscovite – Rare-element class (MSREL)				
MSREL–REE	Be, Y, REE, Ti, U, Th, Nb–Ta	muscovite, fergusonite, samarskite, monazite, beryl, almandine–spesssartine	Mattawa, ON parts of Chupa–Yena district, NW Russia Spruce Pine, NC some migmatite terranes, Ural Mtns., Russia	Ercit (1992, 2005) Leonova & Polezhaeva (1975) Olson (1944), Lesure (1968) Ayzderdzis (1976)
MSREL-Li	Li, Be, Nb	beryl, cassiterite, columbite, lepidolite, (spodumene)	Shelby–Hickory, NC (most) parts of Bihar belt, India Poběžovice-Domažlice, SW Bohemia, CZ	Griffitts & Olson (1953) Shmakin (1976) Vejnar (1968)

Geographic symbols: CZ: Czech Republic, NC: North Carolina, ON: Ontario.

Rare-element class

This class, most thoroughly investigated in the past and best known today, encompasses pegmatites generated by differentiation from granitic plutons, emplaced largely at intermediate to relatively shallow depth, and marked by a tendency to accumulate economic concentration of lithophile rare elements in the more fractionated pegmatite bodies. This class is split here into two subclasses: REL–REE and REL–Li (Tables 1, 2, 5). Members of the REL–REE subclass are derived chiefly from post- to anorogenic metaluminous to peraluminous granites at somewhat variable crustal depth, largely (but not exclusively) in extensional crustal settings (Černý 1991a, b). In contrast, the REL–Li subclass corresponds to Ginsburg's classic concept of this class, emplaced in the low-pressure, (upper-greenschist to) amphibolite-facies host-rocks of the Abukuma-type metamorphic series, and differentiated dominantly from (syn- to) late-orogenic peraluminous granites, largely (but not exclusively) in compressional orogenic regimes (Černý 1991a, b).

The gap between the peak metamorphic conditions of the country rocks and the P–T regime of pegmatite crystallization is in many cases emphasized by the brittle behavior of the consolidated host-rocks along pegmatite contacts, and is enhanced by recent experimental work. Significant undercooling of pegmatite-forming magmas and their solidification at subsolidus temperatures increase the difference between the dominant conditions of the host rock and those of consolidation of the REL magma.

The *REL–REE subclass* has a characteristic assemblage of HFSE, and is subdivided into three types (Table 5): *allanite–monazite type*, characterized by predominance of LREE, *euxenite type* with prominent Y, variable HREE/LREE ratio and negligible amounts to virtual absence of Be (Wise 1999), and *gadolinite type*, marked by dominance of HREE, Y and Be. Some local populations of this subclass are restricted to a single type, whereas others are more diversified (Trout Creek Pass *versus* South Platte district or Iveland, respectively; Table 5). The REL–REE pegmatites are impoverished in phosphorus (despite the characteristic presence of accessory REE phosphates), boron and sulfur (the last one is negligible in rare-element pegmatites of any kind) and the contents of lithium, rubidium and cesium also are typically low (Černý 1991a, Brown 1999, Nizamoff *et al.* 1999).

The *REL–Li pegmatites* constitute the most diversified subclass in the whole classification spectrum, reflecting a broad array of rare elements and conditions of solidification. Rare alkalis, Be, Sn, Nb < Ta, B, P and F are typically accumulated with progress of fractionation in the REL–Li pegmatite suites. This is reflected in the types and subtypes defined for this subclass (Table 5).

The *beryl type* is represented in its simplest form by the widespread *beryl–columbite subtype*. Although present in virtually all pegmatite bodies of this subtype, and commonly in substantial proportions, abundances of the minerals of Be and Nb–Ta are widely variable and their ratio may become very steep. Beryl very strongly dominates over Nb–Ta-bearing minerals in the CAT group in southeastern Manitoba (Černý *et al.* 1981) and in the Lamoureux Lake pegmatites at Yellowknife (Meintzer 1987, Wise 1987), whereas the Plex pegmatite, Baffin Island (Tomascak *et al.* 1994) and the YITT–B group, southeastern Manitoba (Anderson *et al.* 1998) are rich in Nb and Ta phases, but contain mere traces of beryl (*cf.* Černý 1992).

The *beryl–columbite–phosphate subtype* is less common than members of the beryl–columbite category, but by no means rare. Phosphates of Fe, Mn and Ca (graftonite – beusite) grade locally to the Li-bearing triphylite, representing the first lithium-bearing phase in fractionation sequences of cogenetic pegmatite suites (*e.g.*, Smeds *et al.* 1998). As above, deviations from substantial proportions of beryl and columbite-group minerals also occur: *e.g.*, in the beryl-dominant Nancy pegmatite, Argentina (Tait *et al.* 2004) and the beryl-free Dolní Bory dikes (Staněk 1991). The percentage and diversity of phosphates also are variable. Anionic and transition-metal composition of the pegmatite-forming melt may skew the mineralogy in favor of microlite (F) and "exotic" phosphate species such as members of the wyllieite group (with Mn>>Fe) (Cross Lake, Manitoba, Ercit *et al.* 1986; the Nancy pegmatite, in Argentina, Tait *et al.* 2004).

The *complex type* is characterized by substantial proportions of lithium aluminosilicates. Complex pegmatites also display the most evolved internal structure and attain the most extreme levels of fractionation encountered in terrestrial rocks (Černý *et al.* 2005a). The bulk composition of the parent melts and P–T conditions of consolidation, both reflected in mineral assemblages, participate in defining the subtypes.

The *spodumene subtype* is the most common category of complex pegmatites, crystallizing largely at relatively high pressures (~3 to 4 kbar, Fig. 1; London 1984). In contrast, the less widespread *petalite subtype* consolidates at somewhat higher temperatures but lower pressures (~1.5 to 3 kbar). However, the defining aluminosilicate of Li may locally reflect the stage at which it attains saturation, rather than the overall pressure regime: Mongolian Altai #3 has the same P–T path of solidification as Tanco, but crystallizes primary spodumene at a later, lower-temperature stage than the early precipitation of petalite at Tanco (Lu & Wang 1997, Černý *et al.* 2005a). Also, the distinctive differences in pressure regimes are today somewhat blurred by the influence of undercooling and subsolidus crystallization, which may shift low-pressure crystallization of Li-rich magma into the stability field of spodumene (London 2005). Other than the difference in the dominant or sole Li-aluminosilicate, the overall paragenetic and geochemical characteristics of these two subtypes are about identical (Table 5). Both subtypes usually show Li contents lower than the experimentally established maximum (Heinrich 1975, Stewart 1978).

TABLE 5. SUBDIVISION OF GRANITIC PEGMATITES OF THE RARE-ELEMENT CLASS

Subclass Type	Subtype	Geochemical signature	Typical minerals	Examples	References
REL–REE					
allanite-monazite		LREE, U, Th, (Be, Nb>Ta, F, [P])	allanite, monazite, zircon, rutile, fluorite, ilmenite	Pacoima, Los Angeles, CA	Moller (1995)
				S group, South Platte, CO	Simmons *et al.* (1987)
				Helle, Kokjen and Sonnevig, Hitterö, NO	Adamson (1942)
				Oku–Tango belt (most), JP	Tatekawa (1955)
euxenite		L-H-REE, Y, Ti, Zr, Nb>Ta, (F, P)	euxenite, monazite, xenotime, zircon, rutile, ilmenite, (fergusonite, aeschynite, zinnwaldite)	Georgeville, NS	Murphy *et al.* (1998)
				Trout Creek Pass, CO	Hanson *et al.* (1992)
				Topsham, ME	Hanson *et al.* (1998)
				S Iveland (most), NO	Bjørlykke (1935)
				Alto Molocue, MOZ	Cílek (1989)
				Otozan and Morigami, JP	Minakawa *et al.* (1978)
				Mukinbuin field (most), WA, Australia	Jacobson *et al.* (2005)
gadolinite		Be, Y, HREE, Zr, Ti, Nb>Ta, F, (P)	gadolinite, fergusonite, samarskite, zircon, rutile, ilmenite, fluorite, (zinnwaldite)	N Iveland (most), NO	Bjørlykke (1935)
				White Cloud, CO	Simmons *et al.* (1987)
				Central Mineral dist., TX	Ehlmann *et al.* (1964)
				Shatford Lake group, MB	Buck *et al.* (1999)
				Ytterby and Osterby, SWE	Smeds (1990)
				West Keivy, Kola, Russia	Lunts (1972)
				Mategawa and Hama, JP	Minakawa *et al.* (1978)
				Cooglegong, WA, AU	Simpson (1951)
				Pyörönmaa, Finland	Vorma *et al.* (1966)
REL–Li					
beryl	beryl–columbite	Be, Nb–Ta, (±Sn, B)	beryl, columbite, tantalite, (rutile)	Meyers Ranch, CO	Hanley *et al.* (1950)
				Greer Lake group, MB	Černý *et al.* (1981)
				Donkerhoek, Namibia	Schneiderhöhn (1961)
				East Selden, CT	Cameron & Shainin (1947)
				Scheibengraben, CZ	Novák *et al.* (2003)
				Big Alstead, NH	Cameron *et al.* (1949)
	beryl–columbite phosphate	Be, Nb-Ta, P, (Li, F; ±Sn, B)	beryl, columbite, tantalite, triplite, triphylite	Hagendorf-Süd, Germany	Strunz *et al.* (1975)
				Dan Patch, SD	Norton *et al.* (1964)
				Crystal Mtn. field, CO	Thurston (1955)
				Palermo No. 1, NH	Francis *et al.* (1993)
				Cross Lake #22, MB	Ercit *et al.* (1986)
				Tsaobismund, Namibia	Fransolet *et al.* (1986)
				Nevados de Palermo, AR	Galliski *et al.* (1999)
complex	spodumene	Li, Rb, Cs, Be, Ta–Nb, (Sn, P, F; ±B)	spodumene, beryl, columbite, tantalite, (amblygonite, lepidolite, pollucite)	Harding, NM	Jahns & Ewing (1976)
				Hugo, SD	Norton *et al.* (1962)
				Mongolian Altai #3	Wang *et al.* (1981)
				Etta, SD	Norton *et al.* (1964)
				White Picacho, AZ	London & Burt (1982)
				Manono, DRC	Thoreau (1950)
	petalite	as above	petalite, beryl, columbite–tantalite, (amblygonite, lepidolite, pollucite)	Tanco, MB	Černý (2005)
				Bikita, Zimbabwe	Cooper (1964)
				Varuträsk, Sweden	Černý *et al.* (2004)
				Luolamäki, Finland	Neuvonen & Vesasalo (1960)
				Londonderry, Australia	McMath *et al.* (1953)
				Hirvikallio, Finland	Vesasalo (1959)
	lepidolite	Li, F, Rb, Cs, Be, Ta-Nb, (Sn, P, B)	lepidolite, beryl, topaz, microlite, columbite–tantalite, (pollucite)	Brown Derby, CO	Heinrich (1967)
				Pidlite, NM	Jahns (1953)
				Himalaya district, CA	Foord (1976)
				Khukh-del-Ula, Mongolia	Vladykin *et al.* (1974)
				Red Cross Lake, MB	Černý *et al.* (1994)
				Wodgina, Australia	Sweetapple & Collins (2002)
				Phangnga field, Thailand	Garson *et al.* (1969)
				Rožná, Czech Republic	Černý *et al.* (1995)

TABLE 5. SUBDIVISION OF GRANITIC PEGMATITES OF THE RARE-ELEMENT CLASS (cont'd)

Subclass Type	Subtype	Geochemical signature	Typical minerals	Examples	References
	elbaite	Li, B, Rb, Sn, F (Ta, Be, Cs)	tourmaline, hambergite, danburite, datolite, microlite, (polylithionite)	western Moravia, CZ	Novák & Povondra (1995)
				Malkhan field, Siberia, Russia	Zagorskyi & Peretyazhko (1992)
				Sahatany, Madagascar	Ranorosoa (1986)
				Belo Horizonte #1, CA	Taylor *et al.* (1993)
	amblygonite	Li, Rb, Cs, Ta–Nb, Be, (Sn)	amblygonite, beryl, columbite–tantalite, (lepidolite, pollucite)	Viitaniemi, Finland	Lahti (1981)
				Malakialina, Madagascar	Varlamoff (1972)
				Peerless, SD	Sheridan *et al.* (1957)
				Finnis River, Australia	Jutz (1986)
				Marowijne R., Surinam	Montagne (1964)
				Lithium Lode, Lutope, Zimbabwe	Lockett (1979)
albite–spodumene		Li (Sn, Be, Ta-Nb ± B)	spodumene, (cassiterite, beryl, columbite–tantalite)	Kings Mountain, NC	Kesler (1976)
				Preissac Lacorne, QC	Mulligan (1965)
				San Luis I, Argentina	Oyárzabal & Galliski (1993)
				Weinebene, Austria	Göd (1989)
				Violet–Thompson, MB	Černý *et al.* (1981)
				Gods River, MB	Chackowsky (1987)
				Little Nahanni field, NWT*	Groat *et al.* (2003)
albite		Ta-Nb, Be, (Li; ± Sn, B)	columbite–tantalite, beryl, (cassiterite)	Hengshan, China	Einfalt *et al.* (1996)
				Tin Dike, MB	Chackowsky (1987)
				Totoral field, Argentina	Galliski & Černý (2006)
				Cap de Creus field, Spain*	Abella *et al.* (1995)
				Wodgina district, AU*	Sweetapple & Collins (2002)

* Part of the pegmatite population. Geographic symbols: AR: Argentina, AU: Australia, AZ: Arizona, CA: California, CO: Colorado, CT: Connecticut, CZ: Czech Republic, DRC: Democratic Republic of Congo, JP: Japan, MB: Manitoba, ME: Maine, MOZ: Mozambique, NC: North Carolina, NH: New Hampshire, NM: New Mexico, NO: Norway, NS: Nova Scotia, NWT: Northwest Territories, QC: Quebec, SD: South Dakota, SWE: Sweden, TX: Texas, WA: Western Australia.

The *lepidolite subtype* is much less common than the two subtypes above. Lepidolite as the dominant (to only) Li-aluminosilicate is stabilized by high μKF and μLiF and relatively low acidity; increasing μHF stabilizes lepidolite + topaz in some members of this subtype (*cf.* London 1982). Dominance of Mn over Fe, moderate Nb–Ta fractionation but substantial presence of microlite-subgroup minerals, and commonly also an abundance of tourmalines characterize the lepidolite subtype (*e.g.*, Novák & Povondra 1995, Selway *et al.* 1999, Černý *et al.* 2004).

The *elbaite subtype* is not truly scarce but definitely less abundant than the lepidolite subtype above, from which it appears to be locally transitional. Elbaite is the dominant Li-bearing phase here, with the anhydrous Li-aluminosilicates and lepidolite (mainly polylithionite) scarce to absent (Novák & Povondra 1995). Boron plays a significant role, as borosilicates and borates are stabilized (Table 5). Pegmatites of the elbaite subtype locally tend to contain an appreciable proportion of miarolitic cavities (*e.g.*, Novák & Povondra 1995).

The *amblygonite subtype* is generated from pegmatite-forming melts with high μPFO_2 which suppresses Li-aluminosilicates and stabilizes minerals of the amblygonite–montebrasite series instead (London 1982). This subtype is less common than the lepidolite-dominant pegmatites, but it is known from quite a few well-documented examples on global scale (Table 5). Pegmatites of the amblygonite subtype may actually be more widespread: in the near-absence of Li-aluminosilicates and lithian micas, amblygonite may easily escape attention in the field.

The *albite–spodumene type* of complex pegmatites is compositionally related to the spodumene subtype quoted above, and undoubtedly consolidates at the same somewhat elevated pressures. However, it differs in its bulk composition by substantial dominance of albite and quartz over K-feldspar, and by lithium commonly within the uppermost range established by experimental magmatic enrichment (~2.0 wt.% oxide; Stewart 1978). The most conspicuous difference is in the simple zoning, approaching textural near-homogeneity, of individual bodies, and strong preferred orientation of lath- and club-shaped crystals of spodumene and K-feldspar, subnormal to oblique to the attitude of the pegmatite dikes. In some cases the present-day preferred orientation fabric could have resulted from, or been enhanced by, deformation or recrystallization owing to a tectonic (or metamorphic) overprint [Kings Mountain belt in North Carolina: Kesler (1976) and Kunász (1982); Weinebene in Austria: Göd (1989)]. However, at many localities this fabric is demonstrably a primary growth-induced feature [Mateen in South Dakota: Norton *et al*. *(*1964); Violet–Thompson in Manitoba: Černý *et al*. (1981); Weinebene in Austria: Göd (1989); San Luis I, Argentina: Oyarzábal & Galliski (1993); Little Nahanni, NWT, Canada: Groat *et al*. (2003)]. The factors responsible for the primary oriented fabric of phenocrystic phases, imbedded in an apparently randomly aggregated matrix, are obscure and sorely in need of detailed investigation.

Pegmatites of the *albite type* are the least widespread and least understood in the whole array of the REL–Li subclass. These pegmatites feature aplitic to saccharoidal albite dominant over quartz, and generally minor to accessory K-feldspar, spodumene or lepidolite. Individual dikes range from almost homogeneous to strongly layered. The localities quoted in Table 5, and some undisclosed occurrences in the former Soviet Union (Solodov 1962) are the only pegmatites of albite type that were described in reasonable detail. So far, albite pegmatites pose a considerable genetic problem (Černý 1992). Despite the tendency of differentiating fertile leucogranites and derived rare-element pegmatites to become progressively enriched in Na (Breaks & Moore 1992, Černý *et al*. 2005a), and despite the segregation of late aplitic albite in Macusani-glass-based experiments (*e.g*., London 1992), huge volumes of melt crystallizing as virtually pure Ab + Qtz can hardly be expected at the tail-end of these processes. Yet such melts are required, commonly on a considerable regional scale, to form the populations of albite pegmatites. As in the case of the albite–spodumene type, thorough multifaceted studies are required here.

Miarolitic class

Primary cavities result from trapping bubbles of an exsolved gas phase inside the parent pegmatite body. They are generally known in all categories of granitic pegmatites, but largely in insignificant numbers and sizes. However, two prominent categories of shallow-seated pegmatites with elevated contents of primary cavities deserve specific designation (*cf*. Černý 2000, Ercit 2005) and are treated here as separate subclasses of a redefined miarolitic class.

The designation of MI–REE is used for pegmatites in which the gas-phase separation was triggered by a pressure quench, and MI–Li is applied to pegmatites in which the exsolution of a vapor phase follows a combined chemical and pressure quench.

Given suitable tectonic conditions, the exsolved gas phase may escape out of the cooling pegmatite body, and the number and volume of cavities may be reduced or eliminated. Thus the abundance of cavities in populations of cogenetic shallow-seated pegmatites may be quite variable.

An apparent schism evolved during the 1990s, based on equilibrium relationships in the lithium-rich pegmatite system (London 1984, 1986). These experiments suggested ~3 kbar P(H_2O) for spodumene-bearing miarolitic pegmatites, and led to doubts about the shallow level of emplacement of these dikes (*e.g*., Černý 2000). However, more recent work not only confirmed the generally disequilibrium course of crystallization of lithium-rich pegmatites, but also consolidation from a supercooled melt some 200°C below the liquidus surface: this is sufficient to shift the conditions into the stability field of spodumene (London 1984, 1986, 2005; pers. commun. 2005). Thus the regimes of consolidation of pegmatites of the MI–REE (*e.g.,* subvolcanic in the Pikes Peak area) and MI–Li subclasses (*e.g*., ~1.5 kbar in Elba and southern California; Ruggeri & Lattanzi 1992, Webber *et al*. 1999) are near-identical, if one disregards the different Li-phases in the latter category (lepidolite, petalite, or spodumene).

The *MI–REE subclass* is related mainly to anorogenic granites that rise to shallow intrusive levels in the crust. Exsolution of the vug-forming vapor phase follows reduction of the confining pressure in the residual pegmatite-forming melts, which are generally contained within the parent granitic plutons. A broad paragenetic and geochemical variety of pegmatites falls within this subclass, roughly subdivided into two types but with numerous examples of transitional assemblages (Table 6).

The *topaz–beryl type* is known from a number of localities in its "end-member" composition, topaz–beryl virtually *sensu stricto* (*e.g*., Luumäki: Lahti & Kinnunen 1993). Rapakivi granites seem to carry minor occurrences of this type of pegmatite in the Baltic Shield and elsewhere (Lyckberg 1997). However, most occurrences show an array of associated accessory minerals, including lithium micas (dominantly zinnwaldite), fluorite, Nb-, Ta- Ti-bearing phases, REE phosphates or phenakite [*e.g*., Mount Antero: Switzer (1939), Korosten: Lazarenko *et al*. (1973), Pikes Peak: Foord (1982)].

The designation of the *gadolinite–fergusonite type* refers to an extreme counterpart of the topaz–beryl type, characterized by a conspicuous concentration of REE- and Nb–Ta-bearing minerals (with Nb>Ta) *e.g*., Baveno: Pezzotta *et al*. (1999). However, as in the previous case, most pegmatites of this category also carry other accessory phases, including oxide

TABLE 6. SUBDIVISION OF GRANITIC PEGMATITES OF THE MIAROLITIC CLASS

Subclass	Geochemical signature	Typical minerals	Type	Examples	References
MI–REE	Y, REE, Be, Nb, F, Ti, U, Zr	topaz, "amazonite" zinnwaldite, fluorite, beryl, (zircon, euxenite, xenotime, monazite, cheralite)	topaz–beryl	Luumäki, Finland	Lahti & Kinnunen (1993)
				Kl. Spitzkopje, Namibia	Schneiderhöhn (1961)
				Korosten, Ukraine	Lazarenko *et al.* (1973)
				Pikes Peak, CO	Foord (1982)
				Mt. Antero, CO	Switzer (1939)
				Sawtooth batholith, ID	Menzies & Boggs (1993)
			gadolinite–fergusonite	Baveno pluton, Italy	Pezzotta *et al.* (1999)
				Cuasso al Monte, Italy	Pezzotta *et al.* (1999)
				Wausau complex, WS	Falster *et al.* (2000)
MI–Li	Li, Be, B, F	tourmaline, beryl, topaz, lepidolite, (spodumene, petalite, pollucite, spessartine, microlite)	beryl–topaz	Murzinka, Urals, Russia	Fersman (1940)
				Nagar, Dache and Dassu, Pakistan	Laurs *et al.* (1998)
			MI–spodumene	Sahatany, Madagascar	Ranorosoa (1986)
				part of Hindu Kush, Afghanistan	Rossovskyi & Chmyrev (1977)
				Drot, Pakistan	Laurs *et al.* (1998)
				Safira district, Brazil	Bilal *et al.* (1997)
			MI–petalite	part of Elba, Italy	Pezzotta (2000)
				Malkhan field, central Transbaikal, Russia	Zagorskyi & Peretyazhko (1992)
			MI–lepidolite	part of Elba, Italy	Pezzotta (2000)
				Mount Mica, Maine	Francis *et al.* (1993)
				Himalaya and other districts, California	Foord (1976)
				part of the Safira district, Brazil	Bilal *et al.* (1997)

Geographic symbols: CO: Colorado, ID: Idaho, WS: Wisconsin.

minerals of Ti, silicates of Sc, zircon, aeschynite and ferrocolumbite.

The *MI–Li subclass* is related to the same type of fertile granites that generate REL–Li-class pegmatites, and locally develops by gradual transition from the latter. Pressure reduction leads to exsolution of a vapor phase as in the MI–REE subclass, but is aided here by stabilization of B- and Li-bearing silicates, which also sharply reduces solubility of H_2O in the parent melt, and promotes the formation of miarolitic cavities (London 1986, 1987, Černý 2000). Tourmalines of variable composition are a typical, and abundant, component of the MI–Li pegmatites, as boron is the main and rather omnipresent factor in the chemical quench involved. Some explicitly miarolitic pegmatites carry tourmaline throughout their zonal sequences, but hardly any other significant minerals of rare elements [*e.g.*, Stak Nala in Pakistan: Laurs *et al.* (1998)].

The subdivision of this subclass (Table 6) bears some similarity to the subdivision of the REL–Li subclass, mainly in the application of the Li-alumino-silicate discriminant, but must be considered preliminary and subject to future modification. Dominance of phases controlling the nomenclature is commonly difficult to establish, and two or more of these minerals may be present in about equal quantities. For example, the distinction of spodumene and petalite types is somewhat blurred by the fact that minor quantities of "the other" phase are relatively commonly found with the name-giving major one; fluctuating fluid pressure and undercooling also must be involved in shaping the mineral assemblages in MI–Li pegmatites (Jahns 1982, London 1986, 1992, Černý 2000). The situation is further complicated by the fact that assemblages between individual pockets within the same body are typically not in equilibrium. Furthermore, highly diversified populations of pegmatites are common, even in relatively small districts, and in many cases described in the literature, specific dikes of pegmatite corresponding to a given type cannot be identified. Consequently, we list only a few examples of each type in Table 6 that are reasonably "pure" representatives across their narrow spectrum.

The *beryl–topaz type* is typical of some of the classic gem-producing pegmatite populations such as Murzinka (Lyckberg & Rosskov 1997) and other districts in the

Ural Mountains. Individual dikes of pegmatite of this category are relatively widespread, but only as rather minor components of populations dominated by more diversified pegmatites.

The *MI–spodumene type* ranges from spodumene-poor occurrences (such as Drot in Pakistan, Laurs *et al.* 1998) to spodumene-enriched pegmatites (*e.g.*, Hindu Kush, Rossovskyi & Chmyrev 1977). The *MI–petalite type* seems to be poor in petalite; nevertheless, this phase is the main (and in some cases, the only) aluminosilicate of lithium present. In contrast, the *MI–lepidolite type* is commonly rich in this mica, and the spodumene and petalite pegmatites are transitional into it, as in the Safira district, Brazil (Bilal *et al.* 1997) and Elba, Italy (Pezzotta 2000), respectively.

Petrogenetic Families of Granitic Pegmatites

In contrast to the mainly geological-environmental and descriptive purpose of the class – subclass – type – subtype hierarchy, the concept of pegmatite families deals with provenance of granitic pegmatites that are derived by igneous differentiation from diverse plutonic sources (Černý 1990, 1991a, b, c). Thus the concept extends beyond pegmatites *per se* to their parental granites, and to granites in general (*e.g.*, London 1995).

In view of the fundamental requirement of plutonic parentage, the concept is currently applicable only to pegmatites of the rare-element and miarolitic classes. Some authors strongly suggest that some of the MS and particularly MSREL populations are derived from granitic parents (*e.g.*, Ginsburg *et al.* 1979, Shmakin 1976). However, petrological, petrochemical and isotopic studies that would identify the metamorphic protolith(s) and processes leading to formation of potentially parental granitic melts, and the processes involved in the derivation of the pegmatite-forming melts, are not available. Consequently, the petrogenetic classification of the MS and MSREL pegmatites of potential plutonic parentage is at present beyond our reach.

The concept concerns large-scale pegmatite populations from individual granites + derived pegmatite groups to field-sized assemblies of mutually related suites, linked by common provenance and processes. The acronyms NYF and LCT stand for the rare elements most conspicuously enriched in fractionation sequences of these two families (**n**iobium, **y**ttrium and REE, **f**luorine *versus* **l**ithium, **c**esium, **t**antalum), and they symbolize overall enrichment trends in these families. The enrichment cannot be expected to be commensurate, and does not occur evenly, for all three typical elements in all pegmatite populations or individual pegmatites that belong to one or another of these families. Thus, the occasional attempts to establish more specific families on the basis of mineralogy of local populations of pegmatites alone are not realistic at present (*e.g.*, the NY category of Hanson *et al.* 1999) and tend to obscure the principle of the general concept.

This does not mean that the need for subdivisions of the current families, or additional families, does not exist. Quite to the contrary, the ultimate goal of the family classification is a scheme of specific categories, each with a well-defined sequence of crustal environment – protolith – process – granite – pegmatite generation. The need to follow this line of inquiry was repeatedly indicated (Černý & Kjellman 1999, Buck *et al.* 1999, Hanson *et al.* 1999), but it is currently hindered by lack of thoroughly documented individual case-histories.

It should be emphasized that the assignment of pegmatite populations to the NYF or LCT signature does not necessarily mean that the elements characteristic of the other family are absent. Early, less-fractionated members of LCT pegmatite populations commonly contain some minerals typical of the NYF family (*e.g.,* REE phosphates, allanite, euxenite; Smeds 1990), and highly evolved NYF pegmatites may carry some minerals typical of the LCT family (*e.g.*, lepidolite, elbaite; Ercit 2005, Novák *et al.* 1999). Some quantities of the atypical rare elements can be found in any granitic magma, and their concentrations may attain saturation levels of the above minerals at appropriate stages of evolution of the pegmatite-forming melts (early for NYF phases, late for LCT minerals). However, these atypical phases are usually quantitatively insignificant if compared to the signature minerals, which are the ones that are the dominant products of fractionation in each family. Note: emphasis on F in the NYF family relates to the abundance of fluorite or topaz, or both, in the "prototype" NYF pegmatites; neither the relative abundance of F in lithium-dominant micas nor the somewhat elevated contents of Y and REE (Černý & Ercit 1985) mark the lepidolite-subtype pegmatites as NYF members.

Nevertheless, pegmatite populations with a combined signature do exist (based on significant quantities of both suites of typical minerals), and they are assigned to the mixed NYF + LCT family. The genetic possibilities are particularly broad in this case, as there are virtually no thoroughly examined examples available, and ideas about the derivation of the mixed populations are currently based only on field evidence and gross petrochemical considerations (*e.g.*, Černý 1991a).

The final introductory note concerns the fundamental change in the family concept which took place in the early nineties, was not explicitly pointed out, and occasionally escaped attention. Originally, the NYF and LCT families and their precursors were correlated with anorogenic and orogenic settings, respectively (Černý 1982b, 1989), following the model of Martin & Piwinskii (1972, 1974). However, significant and widespread exceptions were identified from this correlation that prevented it from being used as the principal classification yardstick, and the emphasis was shifted to the NYF and LCT geochemical signatures grounded in the source lithologies (see Černý 1991a for details). This shift does not mean that the tectonic affiliation of the NYF and LCT families with the respective anorogenic- and orogenic-related granites was discarded. These relationships are well documented and valid in a great number of cases, but not as universal as implied in the past and in the more recent arguments by Martin (1989, 1999) and Martin & De Vito (2004).

The NYF family

The NYF family is marked by a Nb>Ta, Ti, Y, Sc, REE, Zr, U, Th, F array of typical elements. The parent granites are fairly homogeneous to texturally and geochemically somewhat differentiated, in part also pegmatitic (Garrison *et al.* 1979, Simmons & Heinrich 1980, Wilson *et al.* 1986, Simmons *et al.* 1987, Buck *et al.* 1999, Ercit 2005). They are mainly subaluminous to metaluminous A- to I-types, but with some representations of peraluminous compositions and peralkaline relationships. The degree of fractionation within the fertile granites is usually moderate. Abundances of the REE range from most commonly LREE-enriched at 100 to 800 times chondritic, but relatively flat to LREE-depleted trends are not uncommon (Ercit 2005). In contrast, HREE-depleted abundances are much less widespread. The patterns are usually undisturbed, compatible with crystal–melt fractionation (*cf.* references quoted above). Radiogenic and stable isotope systematics also tend to be undisturbed; δ^{18}O data are centered on a single maximum of about +8.0‰ (Černý 1991a).

Geological, isotopic and geochemical evidence (scattered and incomplete as it is) and petrological–geochemical considerations suggest several possible modes of origin of the NYF magmas: (i) direct differentiation from mantle-derived basaltic magmas (Fowler & Doig 1983, Wilson *et al.* 1986, Martin 1989); (ii) melting of middle- or lower-crust protoliths, modified by a previous melting causing LCT elements to be mobilized but NYF elements to be conserved (White 1979, Collins *et al.* 1982, Whalen *et al.*1987, Wilson *et al.* 1986, Christiansen *et al.* 1988, Martin 1989, Černý 1990, 1991a); (iii) melting of undepleted juvenile igneous lithologies in an orogenic setting (Wilson 1980, Anderson 1983, Vocke & Welin 1987, Buck *et al.* 1999); (iv) a combination of processes (ii) and (iii) above (Andersson & Wikström 1989); (v) melting of sialic crust pre-enriched in NYF elements by mantle-derived fluids (including bimodal gabbro–granite suites; Harris & Marriner 1980, Jackson *et al.* 1984, Öhlander & Zuber 1988, Martin 1989, 1999, Martin & De Vito 2004). A more detailed discussion of the above proposals and their intricacies is given in Černý (1991a).

The NYF pegmatites comprise those that fall within the REL–REE and MI–REE subclasses, with possible future incorporation of some of the MSREL–REE populations, if proven to be of plutonic derivation (see Tables 1, 2, 5, 6 and 7, and the relevant text in the description of pegmatite classes). Table 7 shows two potential subdivisions in the NYF family that may be developed into "subfamilies" as progress is made in petrogenetic studies of additional cases.

The LCT family

The LCT pegmatite family typically carries, and gets progressively enriched in, Li, Rb, Cs, Be, Sn, Ta, Nb (with Ta>Nb), and largely also in B, P and F, with progressive fractionation of the melt. The parent granites are mildly to substantially peraluminous, of the S, I or mixed S + I type. The granites are usually strongly fractionated and texturally diversified within individual intrusive bodies, attaining maximum enrichment in rare elements in the pegmatitic facies (Černý & Meintzer 1988, Breaks & Moore 1992, Breaks *et al.* 2005, Shearer *et al.* 1992, Černý *et al.* 2005b). Patterns of REE distribution are variable, commonly displaying the tetrad effect and other deviations from simple crystal–melt fractionation, and the REE abundances are generally low, with LREE at 100 to 10 times chondritic. Radiogenic and stable isotope systems are commonly disturbed, but δ^{18}O data show a distinct, albeit somewhat overlapping, bimodal distribution, with peaks at +8.5 and +11.5‰ (Meintzer 1987, Černý 1991a). This bimodal pattern reflects the two principal sources of the LCT fertile granites. Their parent melts form by (i) anatexis of undepleted upper- to middle-crust metasedimentary and metavolcanic protoliths (*e.g.,* Osis Lake leucogranite in Manitoba, Černý & Brisbin 1982; other examples in Černý *et al.* 2005a), or (ii) low-percentage anatexis of (meta-) igneous rocks of the basement (Köhler & Müller-Sohnius 1981, Wright & Haxel 1982, Walker *et al.* 1986). Both types of protolith generated fertile leucogranitic LCT melts during their first melting event (Černý 1991a), commonly marked by different arrays of minor anions (Table 7). However, many fertile granites are proven to have been derived by melting of a mix of basement and supracrustal protoliths, and they show intermediate geochemical parameters (Meintzer 1987, Walker *et al.* 1986, Propach 1978, 1989). It is not uncommon to find different single-source and mixed-source granites in a single field of pegmatites (Meintzer 1987, Černý 1991a, Černý *et al.* 2005b).

The LCT pegmatite populations consist of members of the REL–Li and MI–Li subclasses, with possible future incorporation of some of the MSREL–Li populations, if proven to be of plutonic derivation (see Tables 1, 2, 5, 6 and 7, and the relevant text in the description of pegmatite classes). Table 7 shows examples of possible subdivisions in the LCT family that have a

TABLE 7. THE FAMILY SYSTEM OF PETROGENETIC CLASSIFICATION OF GRANITIC PEGMATITES OF PLUTONIC DERIVATION

Family	Dominant subclass of pegmatites[§]	Geochemical signature	Bulk composition of pegmatites *	Associated granites	Bulk composition of granites *	Source lithologies **
LCT	REL-Li MI-Li	Li, Rb, Cs, Be, Sn, Ga, Ta>Nb, (B, P, F)	peraluminous to subaluminous	(synorogenic to) late-orogenic (to anorogenic); largely heterogeneous	peraluminous, S, I or mixed S + I types	undepleted upper- to middle-crust supracrustal rocks and basement gneisses
NYF	REL-REE MI-REE	Nb>Ta, Ti, Y, Sc, REE, Zr, U, Th, F	subaluminous to metaluminous (to subalkaline)	(syn-, late, post-) to mainly anorogenic; quasi-homogeneous	(peraluminous to) subaluminous and metaluminous; A and I types	depleted middle- to lower-crust granulites, juvenile granites, mantle-metasomatized crust
Mixed	Cross-bred LCT and NYF	mixed	(metaluminous to) moderately peraluminous	(postorogenic to) anorogenic; heterogeneous	subaluminous to slightly peraluminous	mixed protoliths or assimilation of supracrustal rocks by NYF granites

Potential subdivisions in the LCT family

LCT-I fertile granites generated by low-percentage anatexis of igneous protoliths and subsequent extensive differentiation; subaluminous fertile granites and derived pegmatites poor in Cs, B, P, S, with relatively low δ^{18}O; *e.g.*, the Greer Lake leucogranite + pegmatite suite, Manitoba (Černý *et al.* 2005b); part of the Yellowknife field, Northwest Territories (Meintzer 1987)

LCT-S fertile granites generated by anatexis of supracrustal protoliths and subsequent differentiation; peraluminous fertile granites and derived pegmatites enriched in Cs, B, P, S, with high δ^{18}O; *e.g.*, the Osis Lake leucogranite + pegmatite suite, Manitoba (Černý & Brisbin 1982), and the Preissac–Lacorne suite, Quebec (Mulja *et al.* 1995, Ducharme *et al.* 1997)

Potential subdivisions in the NYF family

NYF-A anorogenic granites, as members of bimodal gabbro–granite suites, generated by partial melting of depleted lower crust; topaz- and fluorite-bearing, largely metaluminous (to subalkaline) pegmatites with the "prototype" NYF signature; *e.g.*, the South Platte granite + pegmatite system, Colorado (Simmons *et al.* 1987), and the Grötingen granite + Abborselet and other associated pegmatites, Sweden (Kjellman *et al.* 1999)

NYF-I syn- to late-orogenic granites generated by (multiple) high-percentage anatexis of I-type tonalitic protoliths and subsequent moderate differentiation; topaz-bearing pegmatites; *e.g.*, the Lac du Bonnet biotite granite + Shatford Lake pegmatite group, Manitoba (Buck *et al.* 1999), and the Stockholm granite + the Ytterby pegmatite group, Sweden (Kjellman *et al.* 1999)

* peraluminous, A/CNK > 1; subaluminous, A/CNK ≈ 1; metaluminous, A/CNK < 1 at A/NK > 1; subalkaline, A/NK ≈ 1; peralkaline, A/NK < 1, where A = Al_2O_3, CNK = CaO + Na_2O + K_2O, and NK = Na_2O + K_2O (all molar quantities). ** See text for further details and possibilities. [§] See Table 4.

good potential to become "subfamilies" if documented by additional thoroughly examined examples.

The mixed NYF + LCT family

The mixed NYF + LCT family consists of granites and pegmatites that display mixed geochemical and mineralogical characteristics. Only a few cases of NYF + LCT systems have been examined to date [Kimito in Finland: Pehrman (1945), Tørdal district of Norway: Bergstøl & Juve (1988), Černý (1991a), O'Grady batholith in the NWT: Ercit *et al.* (2003)], but additional ones were observed in the field (Ercit 2005). The usually minor LCT component is manifested as either LCT trace-element content of rock-forming minerals and accessory LCT phases in highly differentiated members of NYF populations, or as more-or-less pristine LCT pegmatites formed in late stages of evolution of the principally NYF pegmatite groups. With exception of the huge O'Grady batholith, NWT (Ercit *et al.* 2003), which requires a petrogenetic study, all other cases may be explained by LCT contamination of originally "pure" NYF granites. However, in the absence of rigorous geochemical data, three possibilities must be considered for the genesis of the mixed systems, based on the model of anatexis of depleted crust for the dominant NYF component, and on the local geological situation: (i) a pristine NYF magma from depleted crust may become contaminated by digestion of undepleted supracrustal lithologies (Černý 1991a), (ii) the crustal protolith may have been only partially depleted (Whalen *et al.* 1987), or (iii) the anatexis may have affected a mixed range of depleted and undepleted protoliths (Whalen *et al.* 1987).

Further notes on the mixed-signature granites and pegmatites are to be found in Černý (1991a), dealing primarily with the model (i) above. The spectrum of genetic possibilities may considerably expand once the other above-mentioned models of NYF-granite derivation (and diverse potential modes of LCT enrichment) are considered. In this respect, the mixed NYF + LCT granite and pegmatite populations are currently the least fathomable of the three families. Thus it is not surprising that they are occasionally subject to unrealistic speculations, such as a specialized contamination of NYF pegmatites by Sn and Sc from host rocks (Bergstøl & Juve 1988), or a selective hydrothermal lateral secretion of LCT components into a magmatic NYF pegmatite precursor (Martin & De Vito 2004).

Concluding Remarks

The principles of the dual classification of granitic pegmatites presented here are rather demanding with respect to petrological and petrogenetic aspects. This is the main reason why even the descriptive hierarchies of pegmatites are in some cases incomplete. However, the system applied to the descriptive, paragenetic and geochemical classification within geological classes welcomes expansion upon further study, and so does the petrogenetic classification. The dominant current problem is a *lack of well-documented case-histories* that would permit (i) sound subdivision of the abyssal and muscovite – rare-element subclasses, (ii) rigorous genetic discrimination in the muscovite and muscovite – rare-element classes, and (iii) subdivision of the NYF and LCT families. Modern geochemical and petrogenetic documentation of the above cases should take precedence to attempts to create further descriptive subdivisions.

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References

Abella, P.A., Cordomí, M.C. & Melgarejo Draper, J.C. (1995): Nb–Ta-minerals from the Cap de Creus pegmatite field, eastern Pyrenees: distribution and geochemical trends. *Mineral. Petrol.* **55**, 53-69.

Adamson, O.J. (1942): The granite pegmatites of Hitterö, southeastern Norway. *Geol. Fören. Stockholm Förh.* **64**, 97-116.

Anderson, J.L. (1983): Proterozoic anorogenic granite plutonism of North America. *Geol. Soc. Am., Mem.* **161**, 113-154.

Anderson, S.D., Černý, P., Halden, N.M., Chapman, R. & Uher, P. (1998): The YITT-B pegmatite swarm at Bernic Lake, southeastern Manitoba: a geochemical and paragenetic anomaly. *Can. Mineral.* **36**, 283-301.

Andersson, U.B. & Wikström, A. (1989): Mafic–felsic plutonic interaction in the Transscandinavian Igneous Belt, southern Sweden. *Symp. Precambrian Granitoids* (*Helsinki*), *Abstr.*, 7-8.

Ayzderdzis, D.Ya. (1976): Pegmatites of the Urals Belt of micaceous pegmatites. *In* Fields of Rare-Metal Granitic Pegmatites. Nauka, Moscow, USSR (in Russ.).

Bergstøl, S. & Juve, G. (1988): Scandian ixiolite, pyrochlore and bazzite in granite pegmatite in Tørdal, Telemark, Norway. A contribution to the mineralogy and geochemistry of scandium and tin. *Mineral. Petrol.* **38**, 229-243.

Bilal, E., César-Mendes, J. & Correa-Neves, J.M. (1997): Chemistry of tourmalines in some granitic pegmatites of São José de Safira, Minas Gerais, Brazil. *In* Tourmaline 1997, Int. Symp. on Tourmaline (Nové Město na Moravě), Abstr. Vol., 7-10.

Bjørlykke, H. (1935): The mineral paragenesis and classification of the granite pegmatites of Iveland, Setesdal, southern Norway. *Norsk Geol. Tidsskr.* **14**, 241-255.

Bourret, W. (1988): Uranium-bearing pegmatites of the Antsirabe–Kitsamby district, Madagascar. *Ore Geol. Rev.* **3**, 177-191.

Breaks, F.W. & Moore, J.M., Jr. (1992): The Ghost Lake batholith, Superior Province of Northwestern Ontario: a fertile, S-type, peraluminous granite – rare element pegmatite system. *Can. Mineral.* **30**, 835-875.

________, Selway, J.B. & Tindle, A.G. (2005): Fertile peraluminous granites and related rare-element pegmatite mineralization, Superior Province of Ontario. *In* Rare-Element Geochemistry and Mineral Deposits (R.L. Linnen

& I.M. Samson, eds.). *Geol. Assoc. Can., Short Course Notes* **17**, 87-125.

Brown, C. (1999): Mineralogy of NYF granitic pegmatites. *In* The Eugene E. Foord Memorial Symposium on NYF-type Pegmatites (Denver). *Can. Mineral.* **37**, 848-849 (abstr.).

Bucher, K. & Frey, M. (1994): *Petrogenesis of Metamorphic Rocks* (6th ed.). Springer-Verlag, New York, N.Y.

Buck, H.M., Černý, P. & Hawthorne, F.C. (1999): The Shatford Lake pegmatite group, southeastern Manitoba: NYF or not? *In* The Eugene E. Foord Memorial Symposium on NYF-type Pegmatites (Denver). *Can. Mineral.* **37**, 830-831 (abstr.).

Bushev, A.G. (1975): Linkage of muscovite pegmatites with granites. *In* Muscovite Pegmatites of the USSR. Nauka, Leningrad, USSR (77-84; in Russ.).

________ & Koplus, A.V. (1980): Rare-earth pegmatites of the granulite facies of metamorphism. *Int. Geol. Rev.* **22**, 221-232.

Cameron, E.N., Jahns, R.H., McNair, A.H. & Page, L.R. (1949): Internal structure of granitic pegmatites. *Econ. Geol., Monogr.* **2**.

________ & Shainin, V.E. (1947): The beryl resources of Connecticut. *Econ. Geol.* **42**, 353-367.

Cempírek, J. & Novák, M. (2004): Abyssal pegmatite with olenite and dumortierite from Kutná Hora, Czech Republic: an example of fractionation in Li-poor Al, B-rich granitic system. *Geol. Assoc. Can. – Mineral. Assoc. Can., Program Abstr.* **29**, 225.

Černý, P. (1982a): Anatomy and classification of granitic pegmatites. *In* Granitic Pegmatites in Science and Industry (P. Černý, ed.). *Mineral. Assoc. Can., Short Course Handbook* **8**, 1-39.

________ (1982b): Petrogenesis of granitic pegmatites. *In* Granitic Pegmatites in Science and Industry (P. Černý, ed.). *Mineral. Assoc. Can., Short Course Handbook* **8**, 405-461.

________ (1989): Exploration strategy and methods for pegmatite deposits of tantalum. *In* Lanthanides, Tantalum and Niobium (P. Möller, P. Černý & F. Saupé, eds.). Springer-Verlag, Berlin, Germany (271-299).

________ (1990): Distribution, affiliation and derivation of rare-element granitic pegmatites in the Canadian Shield. *Geol. Rundschau* **79**, 183-226.

________ (1991a): Fertile granites of Precambrian rare-element pegmatite fields: is geochemistry controlled by tectonic setting or source lithologies? *Precamb. Res.* **51**, 429-468.

________ (1991b): Rare-element granitic pegmatites. I. Anatomy and internal evolution of pegmatite deposits. *Geosci. Can.* **18**, 49-67.

________ (1991c): Rare-element granitic pegmatites. II. Regional to global environments and petrogenesis. *Geosci. Can.* **18**, 68-81.

________ (1992): Geochemical and petrogenetic features of mineralization in rare-element granitic pegmatites in the light of current research. *Appl. Geochem.* **7**, 393-416.

________ (2000): Constitution, petrology, affiliations and categories of miarolitic pegmatites. *In* Mineralogy and petrology of shallow depth pegmatites. *In* Papers from the First International Workshop (F. Pezzotta, ed.). *Memorie Soc. It. Sci. Nat. Museo Civico Storia Nat. Milano* **30**, 5-12.

________ (2005): The Tanco rare-element pegmatite deposit, Manitoba: regional context, internal anatomy, and global comparisons. *In* Rare-Element Geochemistry and Mineral Deposits (R.L. Linnen & I.M. Samson, eds.). *Geol. Assoc. Can., Short Course Notes* **17**, 127-158.

________, Blevin, P.L., Cuney, M. & London, D. (2005a): Granite-related ore deposits. *Econ. Geol., 100th Anniv. Vol.*, 337-370.

________ & Brisbin, W.C. (1982): The Osis Lake pegmatitic granite, Winnipeg River district, southeastern Manitoba. *In* Granitic Pegmatites in Science and Industry (P. Černý, ed.). *Mineral. Assoc. Can., Short Course Handbook* **8**, 545-555.

________, Chapman, R., Ferreira, K. & Smeds, S.-A. (2004): Geochemistry of oxide minerals of Nb, Ta, Sn and Sb in the Varuträsk granitic pegmatite, Sweden: the case of an "anomalous" columbite–tantalite trend. *Am. Mineral.* **89**, 505-518.

________ & Ercit, T.S. (1985): Some recent advances in the mineralogy and geochemistry of Nb and Ta in rare-element granitic pegmatites. *Bull. Minéral.* **108**, 499-532.

________, Teertstra, D.K., Chapman, R., Fryer, B.J., Longstaffe, F.J., Wang, Xian Jue, Chackowski, L.E. & Meintzer, R.E. (1994): Mineralogy of extreme fractionation in rare-element granitic pegmatites at Red Cross Lake, Manitoba, Canada. *Int. Mineral. Assoc., 16th Gen. Meeting (Pisa), Abstr.*, 406.

________ & Kjellman, J. (1999): The NYF family of granitic pegmatites: simplistic past, fluid present, reformed future. *In* The Eugene E. Foord Memorial Symposium on NYF-type Pegmatites (Denver). *Can. Mineral.* **37**, 799-800.

________, Masau, M., Goad, B.E. & Ferreira, K. (2005b): The Greer Lake leucogranite, Manitoba and the origin of lepidolite-subtype granitic pegmatites. *Lithos* **80**, 305-321.

________ & Meintzer, R.E. (1988): Fertile granites in the Archean and Proterozoic fields of rare-element pegmatites: crustal environment, geochemistry and petrogenetic relationships. *In* Geology of Granite-Related Mineral Deposits (R.P. Taylor & D.F. Strong, eds.). *Can. Inst. Mining Metall., Spec. Publ.* **39**, 170-206.

________, Staněk, J., Novák, M., Baadsgaard, H., Rieder, M., Ottolini, L., Kavalová, M. & Chapman, R. (1995): Geochemical and structural evolution of micas in the Rožná and Dobrá Voda pegmatites, Czech Republic. *Mineral. Petrol.* **55**, 177-201.

________, Trueman, D.L., Ziehlke, D.V., Goad, B.E. & Paul, B.J. (1981): The Cat Lake – Winnipeg River and the Wekusko Lake pegmatite fields, Manitoba. *Manitoba Energy & Mines, Econ. Geol. Rep.* **ER80–1**.

Chackowsky, L.E. (1987): *Mineralogy, Geochemistry and Petrology of Pegmatitic Granites and Pegmatites at Red Sucker Lake and Gods Lake, Northeastern Manitoba*. M.Sc. thesis, Univ. of Manitoba, Winnipeg, Manitoba.

Christiansen, E.H., Stuckless, J.S., Funkholser-Marolf, M.J. & Howell, K.H. (1988): Petrogenesis of rare-metal granites from depleted crustal sources: an example from the Cenozoic of western Utah, U.S.A. *In* Recent Advances in the Geology of Granite-Related Mineral Deposits (R.P. Taylor & D.F. Strong, eds.). *Can. Inst. Mining Metall., Spec. Vol.* **39**, 307-321.

Cílek, V.G. (1989): *Industrial Minerals of Mozambique*. Geofyzika, Brno, Czech Republic.

Collins, W.J., Beams, S.D., White, A.J.R. & Chappell, B.W. (1982): Nature and origin of A-type granites with particular reference to southeastern Australia. *Contrib. Mineral. Petrol.* **80**, 180-200.

Cooper, D.G. (1964): The geology of the Bikita pegmatites. *In* The Geology of Some Ore Deposits in Southern Africa. **II**. Deposits of Some Minerals Outside the Witwatersrand Basin (S.H. Haughton, ed.). Geological Society of South Africa, Johannesburg, South Africa (441-462).

Cuney, M. (1980): Preliminary results on the petrology and fluid inclusions of the Rössing uraniferous alaskites. *Geol. Soc. S. Afr., Trans.* **83**, 39-45.

Ducharme, Y., Stevenson, R.K. & Machado, N. (1997): Sm–Nd geochemistry and U–Pb geochronology of the Preissac and Lamotte leucogranites, Abitibi Subprovince. *Can. J. Earth Sci.* **34**, 1059-1071.

Ehlmann, A.J., Walper, J.L. & Williams, J. (1964): A new, Baringer Hill-type rare-earth pegmatite from the Central Mineral Region, Texas. *Econ. Geol.* **59**, 1348-1360.

Einfalt, H.C., Leifeld, D., Wu, G.Y., Knabe, W. & Zhang, Y.Z. (1996): Tantalum – niobium – tin pegmatites in the Hengshan area, Guangdong Province, P.R. China. *Geowissensch.* **14**, 331- 332.

Ellsworth, H.V. (1932): Rare-element minerals of Canada. *Geol. Surv. Can., Econ. Geol. Ser.* **11**.

Ercit, T.S. (1992): Oxide mineralogy of the Mattawa pegmatite district – extreme Ta fractionation for muscovite-class pegmatites. *Geol. Assoc. Can. – Mineral. Assoc. Can., Program Abstr.* **17**, A32.

_______ (2005): REE-enriched granitic pegmatites. *In* Rare-Element Geochemistry and Mineral Deposits (R.L. Linnen & I.M. Samson, eds.). *Geol. Assoc. Can., Short Course Notes* **17**, 175-199.

________, Anderson, A.J., Černý, P, & Hawthorne, F.C. (1986): Bobfergusonite: a new primary phosphate mineral from Cross Lake, Manitoba. *Can. Mineral.* **24**, 599-604.

________, Groat, L.A. & Gault, R.A. (2003): Granitic pegmatites of the O'Grady batholith, N.W.T., Canada: a case study of the evolution of the elbaite subtype of rare-element granitic pegmatites. *Can. Mineral.* **41**, 117-137.

Falster, A.U., Simmons, W.B., Webber, K.L. & Buchholz, T. (2000): Pegmatites and pegmatite minerals of the Wausau complex, Marathon County, Wisconsin. *Memorie Soc. It. Sci. Nat. Museo Civico Storia Nat. Milano* **30**, 13-28.

Fersman, A.E. (1940): *Pegmatites* (3rd ed.). *In* Selected Works VI. Acad. Sci. USSR, Moscow, USSR (reprint 1970, in Russ.).

Foord, E.E. (1976): *Mineralogy and Petrogenesis of Layered Pegmatite–Aplite Dikes in the Mesa Grande District, San Diego County, California*. Ph.D. thesis, Stanford Univ., Stanford, California.

________ (1982): Amazonite-bearing pegmatites of the Lake George intrusive center. *Geol. Assoc. Can. – Mineral. Assoc. Can, Annual Meeting, Field Trip Guidebook* **12**, 51-56.

Ford, K.L. (1982): Uraniferous pegmatites of the Sharbot Lake area, Ontario. *Geol. Surv. Can., Pap.* **81–23**, 125-138.

Fowler, A.D. & Doig, R. (1983): The age and origin of Grenville Province uraniferous granites and pegmatites. *Can. J. Earth Sci.* **20**, 92-104.

Francis, C.A., Wise, M.A., Kampf, A.R., Brown, C.C. & Whitmore, R.W. (1993): Granitic pegmatites in northern New England. *In* Field Trip Guidebook for the Northeastern United States (J.T. Cheney & J.C. Hepburn, eds.). *Geol. Soc. Am., Annual Meeting, Guidebook* **1**, E1-E24.

Fransolet, A.-M., Keller, P. & Fontan, F. (1986): The phosphate mineral associations of the Tsaobismund pegmatite, Namibia. *Contrib. Mineral. Petrol.* **92**, 502-517.

Galliski, M.A. & Černý, P. (2006): Geochemistry and structural state of columbite-group minerals from granitic pegmatites of the Pampean Ranges, Argentina. *Can. Mineral.* **44** (in press).

________, Cooper, M.A., Hawthorne, F.C. & Černý, P. (1999): Bederite, a new pegmatite phosphate mineral from Nevados de Palermo, Argentina: description and crystal structure. *Am. Mineral.* **84**, 1674-1679.

Garrison, J.R., Long, L.E. & Richmann, D.L. (1979): Rb–Sr and K–Ar geochronologic and isotopic studies, Llano Uplift, central Texas. *Contrib. Mineral. Petrol.* **69**, 361-374.

Garson, M.S., Bradshaw, N. & Rattawong, S. (1969): Lepidolite pegmatites in the Phangnga area of peninsular Thailand. *In* 2nd Technical Conference on Tin **1** (W. Fox, ed.). *Int. Tin Council and Dept. of Mines and Res. Thailand*, 328-339.

Ginsburg, A.I. & Rodionov, G.G. (1960): On the depth of formation of granitic pegmatites. *Geol. Rudn. Mestorozhd.*, 45-54 (in Russ.).

________, Timofeyev, I.N. & Feldman, L.G. (1979): *Principles of Geology of the Granitic Pegmatites*. Nedra, Moscow, USSR (in Russ.).

Goad, B.E. (1990): Granitic pegmatites of the Bancroft area, southeastern Ontario. *Ont. Geol. Surv., Open File Rep.* **5717**.

Göd, R. (1989): The spodumene deposits at "Weinebene", Koralpe, Austria. *Mineral. Deposita* **24**, 270-278.

Gordiyenko, V.V. (1996): *Granitic Pegmatites*. SPGU, St. Petersburg State Univ., St. Petersburg, Russia (in Russ.).

________ & Leonova, V.A., eds. (1976): *Mica-Bearing Pegmatites of Northern Karelia*. Nedra, Leningrad, USSR (in Russ.).

Gorlov, N.V. (1975): Structural principles of exploration for pegmatite deposits in northwestern White Sea region. *In* Muscovite Pegmatites of the USSR. Nauka, Leningrad, USSR (146-153; in Russ.).

Grew, E.S. (1998): Boron and beryllium minerals in granulite-facies pegmatites and implications of beryllium pegmatites for origin and evolution of the Archean Napier Complex of east Antarctica. *Mem. Nat. Inst. Polar Research, Spec. Issue* **53**, 75-92.

________, Yates, M.G., Barbier, J., Shearer, C.K., Sheraton, J.W., Shiraishi, K. & Motoyoshi, Y. (2000): Granulite-facies beryllium pegmatites in the Napier Complex in Khmara and Amundsen bays, western Enderby Land, East Antarctica. *Polar Geosci.* **13**, 1-40.

________, ________, Huijsmans, J.P.P., McGee, J.J., Shearer, C.K., Wiedenbeck, M. & Rouse, R.C. (1998): Werdingite, a borosilicate new to granitic pegmatites. *Can. Mineral.* **36**, 399-414.

Griffitts, W.R. & Olson, J.C. (1953): Mica deposits of the southeastern Piedmont. 5. Shelby–Hickory district, North Carolina. *U.S. Geol. Surv., Prof. Pap.* **248–D**, 203-281.

Groat, L.A., Mulja, T., Mauthner, M.H.F., Ercit, T.S., Raudsepp, M., Gault, R.A. & Rollo, H.A. (2003): Geology and mineralogy of the Little Nahanni rare-element granitic pegmatites, Northwest Territories. *Can. Mineral.* **41**, 139-160.

Halleran, A.A.D. & Russell, J.K. (1993): Rare-earth element bearing pegmatites in the Wolverine metamorphic complex: a new exploration target (93N/93E, 93O/12W, 5W). *British Columbia Geol. Surv. Branch, Geol. Fieldwork 1992, Pap.* **1993–1**, 301-306.

Hanley, J.B., Heinrich, E.W. & Page, R.L. (1950): Pegmatite investigations in Colorado, Wyoming, and Utah 1942–1944. *U.S. Geol. Surv., Prof. Pap.* **227**.

Hanson, S.L., Simmons, W.B. & Falster, A.U. (1998): Nb–Ta–Ti oxides in granitic pegmatites from the Topsham pegmatite district, southern Maine. *Can. Mineral.* **36**, 601-608.

________, ________, Webber, K.L. & Falster, A.U. (1992): Rare-earth-element mineralogy of granitic pegmatites in the Trout Creek Pass district, Chaffee County, Colorado. *Can. Mineral.* **30**, 673-686.

________, ________, ________, ________ & Buchholz, T. (1999): Trace-element chemistry of micas in "NYF" and "NY" pegmatites. *In* The Eugene E. Foord Memorial Symposium on NYF-type Pegmatites (Denver). *Can. Mineral.* **37**, 849-852 (abstr.).

Harris, N.B.W. & Marriner, G.F. (1980): Geochemistry and petrogenesis of a peralkaline granite complex from the Midian Mountains, Saudi Arabia. *Lithos* **13**, 325-337.

Heinrich, E.W. (1967): Micas of the Brown Derby pegmatites, Gunnison County, Colorado. *Am. Mineral.* **52**, 1110-1121.

________ (1975): Economic geology and mineralogy of petalite and spodumene pegmatites. *Ind. J. Earth Sci.* **2**, 18-29.

Henderson, M. (1982): Lithological and structural setting of uraniferous pegmatites near Mekoos, Mont-Laurier, Québec. *Geol. Surv. Can., Pap.* **82–1A**, 261-264.

Hewitt, D.F. (1955): Geology of Monteagle and Carlow townships. *Ont. Dept. Mines, Annu. Rep.* **62**(5), 1-101.

________ (1967a): Geology and mineral deposits of the Parry Sound – Huntsville area. *Ont. Dept. Mines, Geol. Rep.* **52**.

________ (1967b): Uranium and thorium deposits of Southern Ontario. *Ont. Dept. Mines, Mineral Res. Circ.* **4**.

Hogarth, D.D. (1972): The Evans–Lou pegmatite, Québec: a unique yttrium – niobium – bismuth – vanadium mineral assemblage. *Mineral. Rec.* **3**, 69-77.

Huijsmans, J.P.P., Barton, M. & van Bergen, M.J. (1982): A pegmatite containing Fe-rich grandidierite, Ti-rich dumortierite and tourmaline from the Precambrian, high-grade metamorphic complex of Rogaland, S.W. Norway. *Neues Jahrb. Mineral., Abh.* **143**, 249-261.

Jackson, N.J., Walsh, J.N. & Pegram, E. (1984): Geology, geochemistry and petrogenesis of late Precambrian granitoids in the central Hijaz Region of the Arabian Shield. *Contrib. Mineral. Petrol.* **87**, 205-219.

Jacobson, M.I., Calderwood, M.A. & Grguric, B. (2005): *A Guidebook to the Pegmatites of Western Australia*. Hesperion Press, Victoria Park, Western Australia, Australia (in press).

Jahns, R.H. (1953): The genesis of pegmatites. II. Quantitative analysis of lithium-bearing pegmatite, Mora County, New Mexico. *Am. Mineral.* **38**, 1078-1112.

________ (1955): The study of pegmatites. *Econ. Geol., 50th Anniv. Vol.*, 1025-1130.

________ (1982): Internal evolution of granitic pegmatites. *In* Granitic Pegmatites in Science and Industry (P. Černý, ed.). *Mineral. Assoc. Can., Short Course Handbook* **8**, 293-346.

________ & Ewing, R.C. (1976): The Harding mine, Taos County, New Mexico. *New Mexico Geol. Soc. Guidebook, 27th Field Conf.* (*Vermejo Park*), 273-276.

________, Griffitts, W.R. & Heinrich, E.W. (1952): Mica deposits of the southeastern Piedmont. 1. General features. *U.S. Geol. Surv., Prof. Pap.* **248–A**, 1-99.

Joo', J. (1970): Étude géologique et prospection des feuilles Miandrarivo–Mandoto (LM. 48). *Repoblika Malagasy, Direction des Mines et de l'Énérgie, Rapport Annuel du Service Géologique pour l'Année* **1970**, 29-39.

Jutz, D. (1986): *Erzmineralparagenese Sn–Nb–Ta-führender Pegmatite, Finnis River, Area, Northern Territories/Australien.* M.Sc. thesis, Institut für Mineralogie und Lagerstättenlehre, Rhein-Westfählische Technische Hochschule, Aachen, Germany.

Kesler, T.L. (1976): Occurrence, development and long-range outlook of lithium-pegmatite ore in the Carolinas. *U.S. Geol. Surv., Prof. Pap.* **1005**, 45-50.

Kjellman, J., Černý, P. & Smeds, S.-A. (1999): Diversified NYF pegmatite populations of the Swedish Proterozoic: outline of a comparative study. *In* The Eugene E. Foord Memorial Symposium on NYF-type Pegmatites (Denver). *Can. Mineral.* **37**, 832-833 (abstr.).

Köhler, H. & Müller-Sohnius, D. (1981): Rb–Sr areal isochrons. *Terra Cognita,* 95 pp.

Kunász, I. (1982): Foote Mineral Company – Kings Mountain operation. *In* Granitic Pegmatites in Science and Industry (P. Černý, ed.). *Mineral. Assoc. Can., Short Course Handbook* **8**, 505-511.

Lahti, S. (1981): On the granitic pegmatites of the Eräjärvi area in Orivesi, southern Finland. *Geol. Surv. Finland, Bull.* **314**.

________ & Kinnunen, K.A. (1993): A new gem beryl locality: Luumäki, Finland. *Gems and Gemmology* **29***,* 30-37.

Laurs, B.M., Dilles, J.H. & Snee, L.W. (1996): Emerald mineralization and metasomatism of amphibolite, Khaltaro granitic pegmatite – hydrothermal vein system, Haramosh Mountains, northern Pakistan. *Can. Mineral.* **34**, 1253-1286.

________, ________, Wairrach, Y., Kausar, A.B. & Snee, L.W. (1998): Geological setting and petrogenesis of symmetrically zoned, miarolitic granitic pegmatites at Stak Nala, Nanga Parbat – Haramosh Massif, northern Pakistan. *Can. Mineral.* **36**, 1-47.

Lazarenko, E.K., Pavlishin, V.I., Latysh, V.T. & Sorokin, Y.G. (1973): *Mineralogy and Genesis of Chamber Pegmatites of Volynia.* Lvov State Univ. publishing house, Lvov, USSR (in Russ.).

Leonova, V.A. & Polezhaeva, L.I. (1975): Accessory minerals as indicators of the geochemical specialization of muscovite and ceramic pegmatites (Chupa and Yena fields, White Sea area). *Vestnik Leningradskogo Universiteta* **12**, 43-52 (in Russ.).

Lesure, F.G. (1968): Mica deposits of the Blue Ridge in North Carolina. *U.S. Geol. Surv., Prof. Pap.* **577**.

Lockett, N.H. (1979): The geology of the country around Dett, Rhodesia. *Geol. Surv. Bull.* **85**.

London, D. (1982): Stability of spodumene in acidic and saline fluorine-rich environments. *Carnegie Inst. Wash., Yearbook* **81**, 331-334.

________ (1984): Experimental phase equilibria in the system $LiAlSiO_4$–SiO_2–H_2O: a petrogenetic grid for lithium-rich pegmatites. *Am. Mineral.* **69**, 995-1004.

________ (1986): Formation of tourmaline-rich gem pockets in miarolitic pegmatites. *Am. Mineral.* **71**, 396-405.

________ (1987): Internal differentiation of rare-element pegmatites: effects of boron, phosphorus, and fluorine. *Geochim. Cosmochim. Acta* **51**, 403-420.

________ (1992): The application of experimental petrology to the genesis and crystallization of granitic pegmatites. *Can. Mineral.* **30**, 499-540.

________ (1995): Geochemical features of peraluminous granites, pegmatites, and rhyolites as sources of lithophile metal deposits. *In* Magmas, Fluids, and Ore Deposits (J.F.H. Thompson, ed.). *Mineral. Assoc. Can., Short Course Ser.* **23**, 175-202.

________ (2005): Granitic pegmatites: an assessment of current concepts and directions for the future. *Lithos* **80**, 281-303.

________ & Burt, D.M. (1982): Lithium minerals in pegmatites. *In* Granitic Pegmatites in Science and Industry (P. Černý, ed.). *Mineral. Assoc. Can., Short Course Handbook* **8**, 99-133.

Lu, H.Z. & Wang, Z.G. (1997): Geology and fluid inclusion studies on Keketuohai No. 3 rare-element pegmatite, Xinjiang, northwest China. *30th Int. Geol. Congress, Proc.* **16**, 277-297.

Lunts, A.Ya. (1972): *Mineralogy, Geochemistry and Origin of the Rare-Earth Pegmatites of Alkaline Granites, Northwestern USSR.* Nauka, Moscow, USSR (in Russ.).

Lyckberg, P. (1997): Shallow depth granitic pegmatites of the Baltic Shield. *First Int. Workshop on Petrology, Rare Minerals and Gemstones of Shallow-Depth Pegmatites* (*Milan*), *Abstr.*, 9.

________ & Rosskov, A. (1997): Prediction of pockets in shallow depth pegmatites in the Alabashka area, Mursinka intrusion, Ural Mountains, Russia. *First Int. Workshop on Petrology, Rare Minerals and Gemstones of Shallow-Depth Pegmatites* (*Milan*), *Abstr.*, 13.

Martin, R.F. (1989): Metasomatic "ground preparation" and the origin of anorogenic granites. *Symp. Precambrian Granitoids, Helsinki, Abstr.,* 87.

________ (1999): Petrogenetic considerations: A-type granites, NYF granitic pegmatites, and beyond….. *In* The

Eugene E. Foord Memorial Symposium on NYF-type Pegmatites (Denver). *Can. Mineral.* **37**, 804-805 (abstr.).

________ & De Vito, C. (2004): Where do LCT and NYF pegmatites fit in? A contribution to a revised classification of granitic pegmatites. *Geol. Soc. Am., Abstr. Program* **36**(5), 44.

________ & Piwinskii, A.J. (1972): Magmatism and tectonic settings. *J. Geophys. Res.* **77**, 4966-4975.

________ & ________ (1974): The contrasting origin of orogenic and non-orogenic granitoid rocks. *Proc. Andean and Antarctic Volc. Probl. Symp.* (*Santiago*), 482-496.

Martin-Izard, A., Paniagua, A., Moreiras, D., Acevedo, R.D. & Marcos-Pascual, C. (1995): Metasomatism at a granitic pegmatite – dunite contact in Galicia; the Franqueira occurrence of chrysoberyl (alexandrite), emerald, and phenakite. *Can. Mineral.* **33**, 775-792.

McMath, J.C., Gray, N.M. & Ward, H.J. (1953): The geology of the country about Coolgardie, Coolgardie Goldfield, W.A. *Western Australia Geol. Surv., Bull.* **107**.

Meintzer, R.E. (1987): *The Mineralogy and Geochemistry of the Granitoid Rocks and Related Pegmatites of the Yellowknife Pegmatite Field, Northwest Territories.* Ph.D. thesis, Univ. of Manitoba, Winnipeg, Manitoba, Canada.

Menzies, M.A. & Boggs, R.C. (1993): Minerals of the Sawtooth batholith, Idaho. *Mineral. Rec.* **10**, 129-133.

Minakawa, T., Momoi, H. & Noto, S. (1978): Rare element minerals from pegmatites in the Ryoke belt, western Shikoku, Japan. *Mem. College of Sci., Ehime Univ., Ser. D* (*Earth Sci.*) **8**(3), 15-25 (in Japanese).

Mineyev, D.A. & Salye, M.E. (1971): Some characteristics of the geochemistry of ultrametamorphogenic mica-bearing pegmatites of northern Karelia. *In* Pegmatitic Rare-Metal Deposits **4**, 59-82 (in Russ.).

Moller, W.P. (1995): Minerals of the Pacoima pegmatite. *Rocks and Minerals* **70**, 36-39.

Montagne, D.G. (1964): An interesting pegmatite deposit in northeastern Surinam. *Geol. Mijnbouw* **43**, 360-374.

Mulja, T., Williams-Jones, A.E., Wood, S.A. & Boily, M. (1995): The rare-element-enriched monzogranite – pegmatite – quartz vein systems in the Preissac – Lacorne batholith, Quebec. II. Geochemistry and petrogenesis. *Can. Mineral.* **33**, 817-822.

Mulligan, R. (1965): Geology of Canadian lithium deposits. *Geol. Surv. Can., Econ. Geol. Rep.* **21**.

Murphy, J.B., Anderson, A.J. & Archibald, D.A. (1998): Postorogenic alkali feldspar granite and associated pegmatites in West Avalonia: the petrology of the Neoproterozoic Georgeville Pluton, Antigonish Highlands, Nova Scotia. *Can. J. Earth Sci.* **35**, 110-120.

Neuvonen, K.J. & Vesasalo, A. (1960): Pollucite from Luolamäki, Somero, Finland. *Comm. Géol. Finlande, Bull.* **188**, 133-148.

Nizamoff, J.W., Falster, A.U., Simmons, W.B. & Webber, K.L. (1999): Phosphate mineralogy of NYF-, LCT- and mixed-type granitic pegmatites. *In* The Eugene E. Foord Memorial Symp. on NYF-type Pegmatites (Denver). *Can. Mineral.* **37**, 853-854 (abstr.).

Norton, J.J., Page, R.L. & Brobst, D.A. (1962): Geology of the Hugo pegmatite, Keystone, South Dakota. *U.S. Geol. Surv., Prof. Pap.* **297–B**, 49-128.

________ and others (1964): Geology and mineral deposits of some pegmatites in the southern Black Hills, South Dakota. *U.S. Geol. Surv., Prof. Pap.* **297–E**, 293-341.

Novák, M., Černý, P. & Selway, J.B. (1999): The zinnwaldite – masutomilite – elbaite pegmatite at Kracovice from the Třebíč durbachite massif – a complex pegmatite related to the NYF family. *In* The Eugene E. Foord Memorial Symp. on NYF-type Pegmatites (Denver). *Can. Mineral.* **37**, 815-816 (abstr.).

________, ________ & Uher, P. (2003): Extreme variation and apparent reversal in columbite-group minerals from the Scheibengraben beryl–columbite granitic pegmatite, Marsikov, Czech Republic. *Eur.J. Mineral.* **15**, 565-574.

________ & Povondra, P. (1995): Elbaite pegmatites in the Moldanubicum: a new subtype of the rare-element class. *Mineral. Petrol.* **12**, 159-176.

Öhlander, B. & Zuber, J. (1988): Genesis of the Feelingsbro granites: evidence from gravity measurements and geochemistry. *Geol. Fören. Stockholm Förh.* **110**, 39-54.

Olson, J.C. (1944): Economic geology of the Spruce Pine pegmatite district, North Carolina. *North Carolina Dep. of Conservation and Development, Div. of Mineral Resources, Bull.* **43**(1).

Oyarzábal, J.C. & Galliski, M.A. (1993): Geología del yacimiento San Luis: un caso de yuxtaposición de tipologías diferentes en pegmatitas de clase elementos raros. *Actas 12° Congreso Geológico Argentino* **5**, 167-174.

Pehrman, G. (1945): Die Granitpegmatite von Kimito (S.W. Finnland) und ihre Minerale. *Acta Acad. Aboensis, Mat. Phys.* **15**.

Pezzotta, F. (2000): Internal structures, paragenesis and classification of the miarolitic Li-bearing complex pegmatites of Elba Island (Italy). *Memorie Soc. It. Sci. Nat. Museo Civico Storia Nat. Milano* **30**, 29-44.

________ (2001): Madagascar, a mineral and gemstone paradise. *Extralapis English* **1**.

________, Diella, V. & Guastoni, A. (1999): Sc–Y–REE minerals and evolution of miarolitic cavities in the NYF pegmatites in the western southern Alps, Italy. *In* The Eugene E. Foord Memorial Symp. on NYF-type Pegmatites (Denver). *Can. Mineral.* **37**, 805-806 (abstr.).

Propach, G. (1978): Granitization by mixing of crustal rocks and subduction-derived magma. *Neues Jahrb. Mineral., Monatsh.*, 537-549.

________ (1989): The origin of a conformable Variscan granite in Bavaria – results of geochemical and geochronological investigation. *In* Magma–Crust Interactions and Evolution (M. Bonin, ed.). Theophrastus, Athens, Greece (193-210).

RANOROSOA, N. (1986): *Étude minéralogique et microthermométrique des pegmatites du champ de la Sahatany, Madagascar.* Thèse de doctorat, Univ. Paul Sabatier, Toulouse, France.

RIMŠAITE, J. (1981): Petrochemical and mineralogical evolution of radioactive rocks in the Baie-Johan-Beetz area, Quebec; a preliminary report. *Geol. Surv. Can., Pap.* **81–1A**, 115-131.

ROBIE, R.A. & HEMINGWAY, B.S. (1984): Entropies of kyanite, andalusite and sillimanite: additional constraints on the pressure and temperature of the Al_2SiO_5 triple point. *Am. Mineral.* **69**, 299-306.

ROSSOVSKYI, L.N. & CHMYREV, V.M. (1977): Distribution patterns of rare-metal pegmatites in the Hindu Kush (Afghanistan). *Int. Geol. Rev.* **19**, 511-520.

RUGGERI, G. & LATTANZI, L. (1992): Fluid inclusion studies on Mt. Capanne pegmatites, Isola d'Elba, Tuscany, Italy. *Eur. J. Mineral.* **4**, 1085-1096.

SCHNEIDERHÖHN, H. (1961): *Die Erzlagerstätten der Erde. II. Die Pegmatite.* Gustav Fischer Verlag, Stuttgart, Germany.

SELWAY, J.B., NOVÁK, M., ČERNÝ, P. & HAWTHORNE, F.C. (1999): Compositional evolution of tourmaline in lepidolite-subtype pegmatites. *Eur. J. Mineral.* **11**, 560-584.

SHEARER, C., PAPIKE, J.J. & JOLLIFF, B.L. (1992): Petrogenetic links among granites and pegmatites in the Harney Peak rare-element granite – pegmatite system, Black Hills, South Dakota. *Can. Mineral.* **30**, 785-810.

SHERIDAN, D.M., STEPHENS, H.G., STAATZ, M.H. & NORTON, J.J. (1957): Geology and beryl deposits of the Peerless pegmatite, Pennington County, South Dakota. *U.S. Geol. Surv., Prof. Pap.* **297–A**.

SHMAKIN, B.M. (1976): *Muscovite and Rare Metal – Muscovite Pegmatites.* Nauka, Novosibirsk, USSR (in Russ.).

________ (1992): Mineralogy and geochemistry of REE in granitic pegmatites, Baikal region, eastern Siberia, Russia. *Appl. Geochem.* **7**, 459-468.

________ & MAKAGON, V.M. (1972): Physicochemical conditions of formation of the muscovite-bearing pegmatites. *Proc. Int. Geol. Congress* (*Moscow*) **3**(2), 591-599.

SIMMONS, W.B. & HEINRICH, E.W. (1980): Rare-earth pegmatites of the South Platte district, Colorado. *Colo. Geol. Surv., Res. Ser.* **11**.

________, LEE, M.T. & BREWSTER, R.H. (1987): Geochemistry and evolution of the South Platte granite–pegmatite system, Jefferson County, Colorado. *Geochim. Cosmochim. Acta* **51**, 455-471.

________, PEZZOTTA, F., FALSTER, A.U. & WEBBER, K.L. (2001): Londonite, a new mineral species: the Cs-dominant analogue of rhodizite from the Antandrokomby granitic pegmatite, Madagascar. *Can. Mineral.* **39**, 747-755.

SIMPSON, E.S. (1951): *Minerals of Western Australia* **II**. Hesperion Press, Carlysle, Australia.

SMEDS, S.-A. (1990): Regional trends in mineral assemblages of Swedish Proterozoic granitic pegmatites and their geological significance. *Geol. Fören. Stockholm Förh.* **112**, 227-242.

________, UHER, P., ČERNÝ, P., WISE, M.A., GUSTAFFSON, L. & PENNER, P. (1998): Graftonite–beusite in Sweden: primary phases, products of exsolution and distribution in zoned populations of granitic pegmatites. *Can. Mineral.* **36**, 377-394.

SOKOLOV, Y.M., KRATZ, K.O. & GLEBOVITSKYI, V.A. (1975): Regularities in the formation and distribution of the muscovite and muscovite – rare metal pegmatite formations in metamorphic belts. *In* Muscovite Pegmatites of the USSR. Nauka, Leningrad, Russia (5-15; in Russ.).

SOLODOV, N.A. (1962): *Internal Structure and Geochemistry of Rare-Element Granitic Pegmatites.* Academy Sci. USSR, Moscow, USSR (in Russ.).

________ (1971): *Scientific Principles of Perspective Evaluation of Rare-Element Pegmatites.* Nauka, Moscow, USSR (in Russ.).

SOMAN, K., NAIR, N.G.K. & DRUZHNIN, A.V. (1986): Chrysoberyl pegmatites of South Kerala and their metallogenic implications. *J. Geol. Soc. India* **27**, 411-418.

SPENCE, H.S. (1932): Feldspar. *Can. Dep. Mines, Mines Branch Rep.* **731**.

STANĚK, J. (1991): The mineral paragenesis of the Dolní Bory – Hatě pegmatite dykes, western Moravia, Czechoslovakia. *Acta. Mus. Moraviae, Sci. Nat.* **76**, 19-49 (in Czech with English summary).

STEWART, D.B. (1978): Petrogenesis of lithium-rich pegmatites. *Am. Mineral.* **63**, 970-980.

STOREY, C.C. & VOSS, M.A. (1981): Industrial minerals of the Pembroke – Renfrew area **2**. *Ont. Geol. Surv., Mineral Dep. Circ.* **22**.

STRUNZ, H., FORSTER, A. & TENNYSON, C. (1975): Die Pegmatite in der nördlichen Oberpfalz. A. Geologie und Genese; B. Mineralführung. *Der Aufschluss* **26**, 117-189.

SWEETAPPLE, M.T. & COLLINS, P.L.F. (2002): Genetic framework for the classification and distribution of Archaean rare metal pegmatites in the North Pilbara Craton, Western Australia. *Econ. Geol.* **97**, 873-895.

SWITZER, G. (1939): Granite pegmatites of the Mt. Antero region, Colorado. *Am. Mineral.* **24**, 791-809.

TAIT, K.T., HAWTHORNE, F.C., ČERNÝ, P. & GALLISKI, M.A. (2004): Bobfergusonite from the Nancy pegmatite, San Luis Range, Argentina: crystal-structure refinement and composition. *Can. Mineral.* **42**, 705-716.

Tatekawa, M. (1955): The pegmatites of the Oku–Tango district of Kyoto Prefecture researched chiefly from the viewpoint of trace elements. *Mem. of the College of Sci., Univ. of Kyoto, Ser. B* **22**, 199-212.

Taylor, M.C., Williams, A.E., McKibben, M.A., Kimbrough, D.L. & Novák, M. (1993): Miarolitic elbaite subtype of complex rare-element pegmatite, Peninsular Ranges batholith, southern California. *Geol. Soc. Am., Abstr. Program* **25**(6), A321.

Thoreau, J. (1950): La pegmatite stannifère de Manono, Katanga. *C.R. de Travaux, Congrès Scientifique Elisabethville* **41**, 1-33.

Thurston, W.R. (1955): Pegmatites of the Crystal Mountains district, Larimer County, Colorado. *U.S. Geol. Surv., Bull.* **1011**.

Tomascak, P.B., Wise, M.A., Černý, P. & Trueman, D.L. (1994): Reconnaissance studies of four pegmatite populations in the Northwest Territories. *In* Studies of Rare-Metal Deposits in the Northwest Territories (W.D. Sinclair & D.G. Richardson, eds.). *Geol. Surv. Can., Bull.* **475**, 33-62.

Tremblay, L.P. (1978): Uranium subprovinces and types of uranium deposits in the Precambrian rocks of Saskatchewan. *Geol. Surv. Can., Pap.* **78–1A**, 427-435.

Varlamoff, N. (1972): Matériaux pour l'établissement des types et de la zonéographie des pegmatites granitiques à métaux rares de Madagascar. *Académie Royale des Sciences d'Outre-Mer, Sciences Naturelles, Médicinales, N.S.* **18–6**.

Vejnar, Z. (1968): The genesis of pegmatites and its relationship to the metamorphic and magmatic development of the West-Bohemian crystalline complexes. *Rozpravy Českoslov. Akad. Věd* **78**, 1-70.

Vesasalo, A. (1959): On the petalite occurrences of Tammela, SW-Finland. *Comm. Géol. Finlande, Bull.* **184**, 59-74.

Vladykin, N.V., Dorfman, M.D. & Kovalenko, V.I. (1974): Mineralogy, geochemistry and genesis of rare-element topaz–lepidolite–albite pegmatites of the Mongolian People's Republic. *Trudy Mineral. Museya Akad. Nauk SSSR* **23**, 6-49 (in Russ.).

Vocke, R.D., Jr. & Welin, E. (1987): Origin of the Middle to Late Proterozoic granitoids of SW Sweden in light of their Nd and Sr isotope systematics. *Proterozoic Geochemistry Symp.* (*Lund*), *Abstr.*, 90.

Vorma, A., Ojanperä, P., Hoffrén, V., Siivola, J. & Löfgren, A. (1966): On the rare earth minerals from the Pyörönmaa pegmatite in Kangasala, SW-Finland. *C.R. Soc. Géol. Finlande* **38**, 241-274.

Walker, R.J., Hanson, G.N., Papike, J.J. & O'Neil, J.R. (1986): Nd, O and Sr isotopic constraints on the origin of Precambrian rocks, southern Black Hills, South Dakota. *Geochim. Cosmochim. Acta* **50**, 2833-2846.

Wang, X.-J., Zou, T.-R., Xu, J.-G., Yu, X.-Y. & Qiu, Y.-Z. (1981): *Study of Pegmatite Minerals from the Altai Region*. Scientific Publishing House, Beijing, China (in Chinese).

Webber, K.L., Simmons, W.B., Falster, A.U. & Foord, E.E. (1999): Cooling rates and crystallization dynamics of shallow level pegmatite–aplite dikes, San Diego County, California. *Am. Mineral.* **84**, 708-717.

Whalen, J.B., Currie, K.L. & Chappell, B.W. (1987): A-type granites: geochemical characteristics, discrimination and petrogenesis. *Contrib. Mineral. Petrol.* **95**, 407-419.

White, A.J.R. (1979): Sources of granite magma. *Geol. Soc. Am., Abstr. Programs* **11**, 539.

Wilson, M.R. (1980): Granite types in Sweden. *Geol. Fören. Stockholm Förh.* **102**, 167-176.

________, Fallick, A.E., Hamilton, P.J. & Persson, L. (1986): Magma sources for some mid-Proterozoic granitoids in SW Sweden: geochemical and isotopic constraints. *Geol. Fören. Stockholm Förh.* **108**, 79-91.

Wise, M.A. (1987): *Geochemistry and Crystal Chemistry of Nb, Ta and Sn Minerals from the Yellowknife Pegmatite Field, N.W.T.* Ph.D. thesis, Univ. of Manitoba, Winnipeg, Manitoba, Canada.

________ (1999), Characterization and classification of NYF-type pegmatites. *In* The Eugene E. Foord Memorial Symp. on NYF-type Pegmatites (Denver). *Can. Mineral.* **37**, 802-803 (abstr.).

Wood, P.A. (1996): *Petrogenesis of the Spruce Pine Pegmatites, North Carolina*. M.Sc. thesis, Virginia Polytechnic Institute, Blacksburg, Virginia, USA.

Wright, J.E. & Haxel, G. (1982): A garnet – two-mica granite, Coyote Mountains, southern Arizona: geologic setting, uranium–lead isotopic systematics of zircon, and nature of the granite source region. *Geol. Soc. Am., Bull.* **93**, 1176-1188.

Yardley, B.W.D. (1989): *An Introduction to Metamorphic Petrology*. Longman, Harlow, U.K.

Žáček, V. & Vrána, S. (2002): Iron-rich chrysoberyl from Kalanga Hill, Muyombe District, northeastern Zambia. *Neues Jahrb. Mineral., Monatsh.*, 529-540.

Zagorskyi, V.Ye., Makagon, V.M. & Shmakin, B.M. (2003): Systematics of granitic pegmatites. *Russ. Geol. Geophys.* **44**, 422-435.

________ & Peretyazhko, I.S. (1992): *Gem Pegmatites of Central Transbaikalia*. Nauka, Novosibirsk, Russia (in Russ.).

Zou, T.-R. & Xu, J.-G. (1975): The genesis and type-classification of the granite pegmatites. *Geochimica* **9**, 161-174 (in Chinese).

________, Yang, U., Guo, Y. & Ni, Y. (1985): China's crust- and mantle-source pegmatites and their discriminating criteria. *Geochemistry* **4**, 1-17.

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Appendix 2

Mercator Support Documents

Brazil Lake Property
Drill Hole Location

Hole	UTM_E*	UTM_N*	Elev_DEM**	Length	Azi	Dip	Year	Latitude	Departure	Dyke
BZL-93-1	260104	4875172	74	97.54	145	-50	1993			N
BZL-93-2	260119	4875163	73	92.6	145	-50	1993			N
BZL-93-3	260094	4875167	74	153.1	145	-50	1993			N
BZL-93-4	260069	4875123	74	120.6	145	-50	1993			N
BZL-93-5	260038	4875101	76	112.8	145	-50	1993			N
BZ-02-1	259845	4874737	69	29	340	-45	2002	3+15S	0+17W	S
BZ-02-2	259871	4874689	69	82	340	-45	2002	3+52S	0+24E	S
BZ-02-3	259983	4875066	76	69	140	-45	2002	0+07N	1+12W	N
BZ-02-4	260009	4875088	76	100	140	-45	2002	0+44N	1+05W	N
BZ-02-5	260223	4875106	67	104	320	-45	2002	1+88N	0+48E	N
BZ-02-6	260255	4875140	61	95	320	-45	2002	2+35N	0+45E	N
BZ-02-7	260005	4874969	74	93	320	-45	2002	0+56S	0+40W	N
BZ-02-8	260148	4874865	65	120	320	-45	2002	0+58S	1+32E	reg
BZ-02-9	260111	4874913	67	98	320	-45	2002	0+40S	0+75E	reg
BZ-02-10	260111	4874913	67	40	140	-45	2002	0+40S	0+75E	reg
BZ-02-11	260282	4874878	62	120	160	-45	2002	0+30N	2+30E	reg
BZ-02-12	259921	4874745	70	150	340	-45	2002	2+75S	0+24E	S
BZ-02-13	260019	4875077	76	50	140	-45	2002	0+37N	0+91W	N
BZ-02-14	259986	4874996	76	57	320	-45	2002	0+45S	0+72W	N
BZ-02-15	260130	4875099	71	59	320	-45	2002	1+30N	0+23W	N
BZ-02-16	260173	4875130	70	59	320	-45	2002	1+76N	0+05W	N
BZ-02-17	259744	4874640	70	26.7	320	-45	2002	4+72S	0+54W	S
BZ-02-18	259764	4874648	70	51	320	-45	2002	4+54S	0+43W	S
BZ-02-19	259792	4874665	69	57.5	320	-45	2002	4+24S	0+31W	S
BZ-02-20	259812	4874681	68	35	320	-45	2002	4+00S	0+25W	S
BZ-02-21	259836	4874703	69	71	320	-45	2002	3+68S	0+18W	S
BZ-02-22	259807	4874699	70	22	320	-45	2002	3+88S	0+39W	S
BZ-03-23	260101	4875069	72	57.5	320	-45	2003	0+80N	0+24W	N
BZ-03-24	260059	4875050	74	54.5	320	-45	2003	0+41N	0+46W	N
BZ-03-25	260007	4875014	75	45	320	-45	2003	0+18S	0+66W	N
BZ-03-26	260195	4875145	70	50	320	-45	2003	1+96N	0+05E	N
BZ-03-27	260218	4875176	68	60	320	-55	2003	2+34N	0+05E	N
BZ-03-28	260259	4875204	64	59	320	-45	2003	2+80N	0+21E	N

Hole	UTM_E*	UTM_N*	Elev_DEM**	Length	Azi	Dip	Year	Latitude	Departure	Dyke
BZ-03-29	260300	4875236	64	50	320	-45	2003	3+29N	0+34E	N
BZ-03-30	259535	4874293	53	75	305	-45	2003	8+80S	0+19W	regional
BZ-03-31	259535	4874293	53	40	123	-45	2003	8+80S	0+19W	regional
BZ-03-32	259463	4874347	54	47	123	-45	2003	8+80S	1+09W	regional

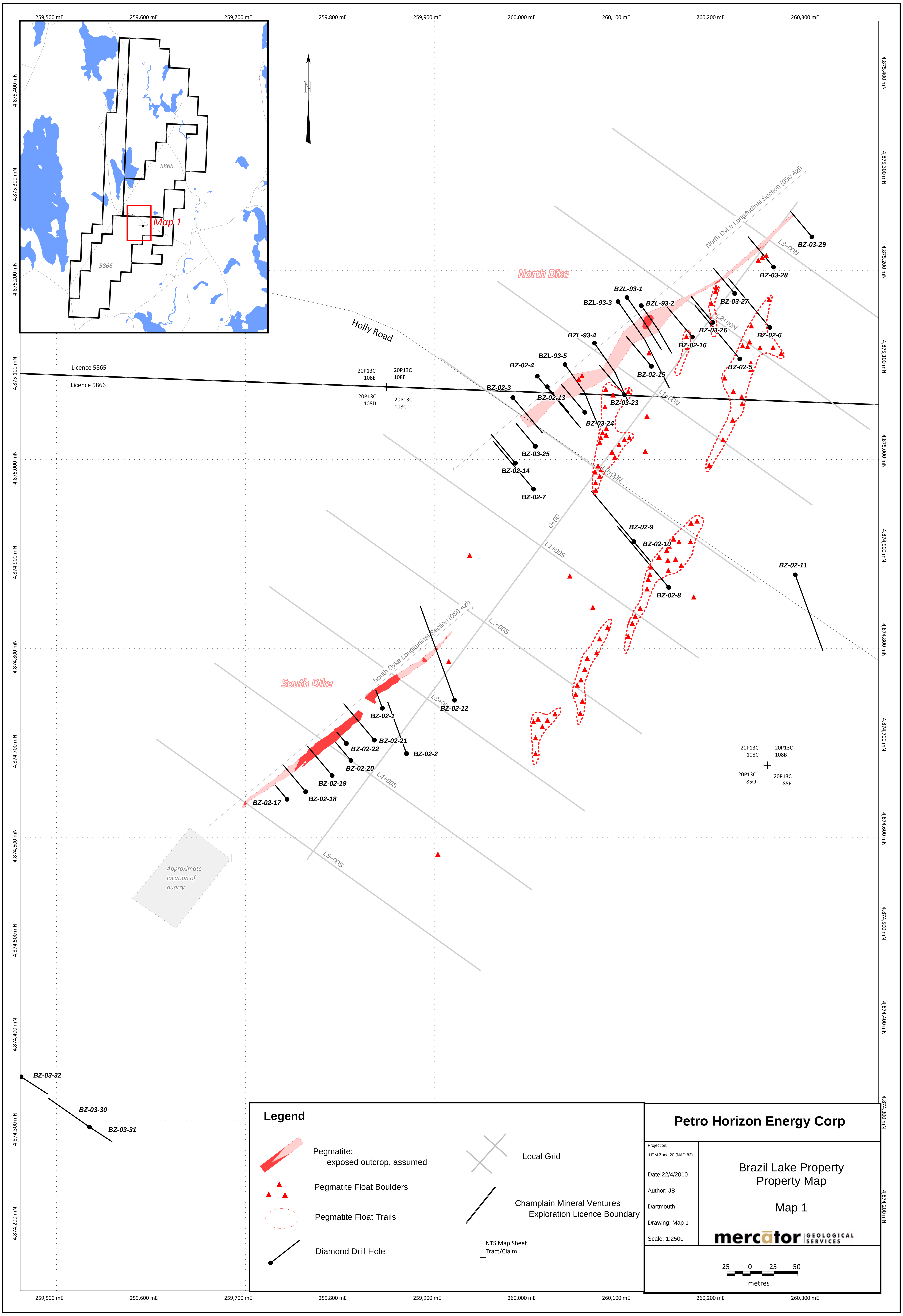
Total 2702.84 m

* UTM co-ordinates are based on Assessment Maps from Champlain Mineral Ventures Ltd

** Elevation data has been extracted from Nova Scotia provincial DEM

Appendix 3

Drilling Longitudinal Sections and Base Map



Legend

🟥	Pegmatite: exposed outcrop, assumed
▲	Pegmatite Float Boulders
◯	Pegmatite Float Trails
●	Diamond Drill Hole
✕	Local Grid
╱	Champlain Mineral Ventures Exploration Licence Boundary
+	NTS Map Sheet Tract/Claim

Petro Horizon Energy Corp

Projection:
UTM Zone 20 (NAD 83)

Date:22/4/2010

Author: JB

Dartmouth

Drawing: Map 1

Scale: 1:2500

Brazil Lake Property
Property Map

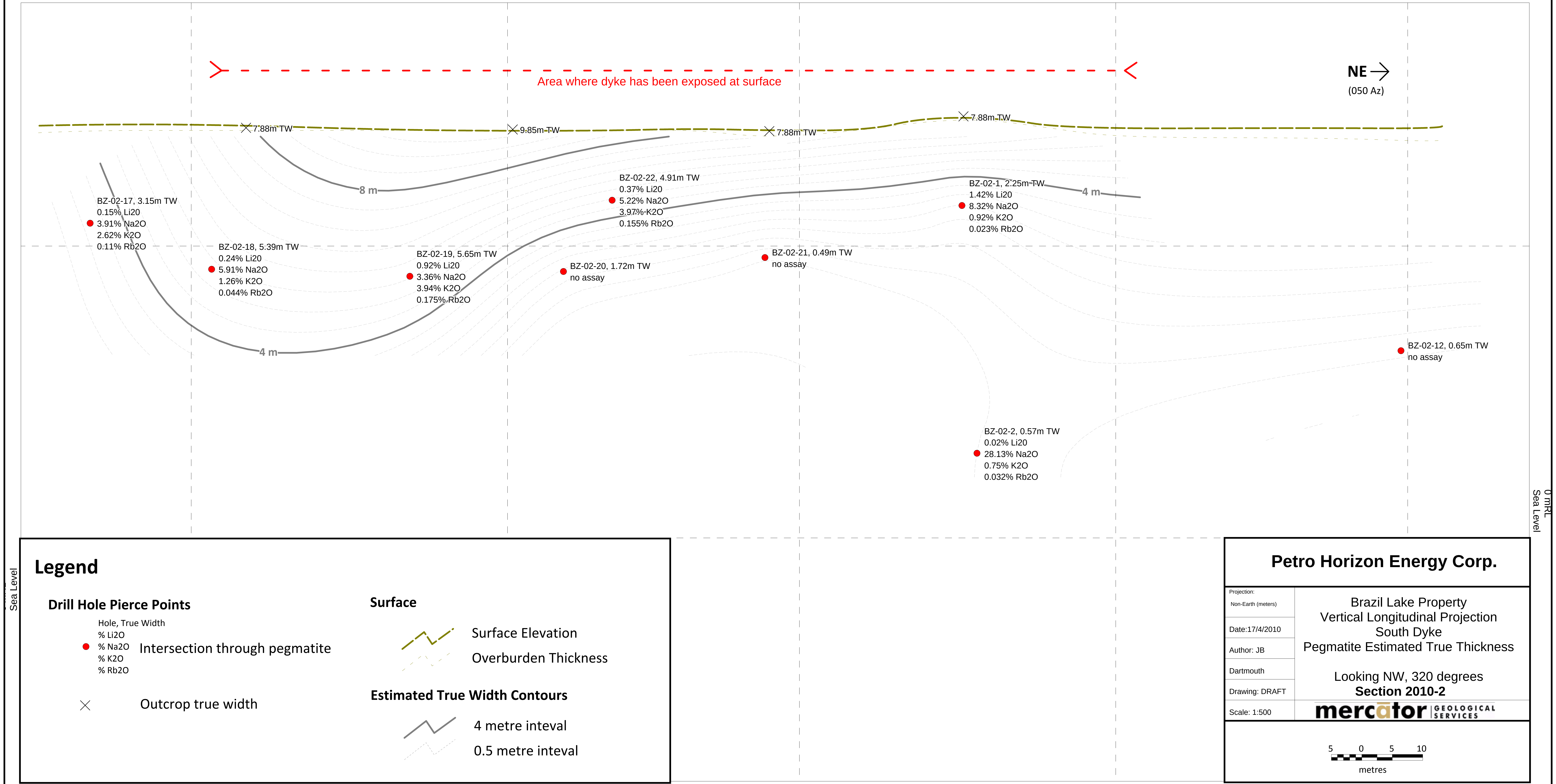
Map 1

mercator GEOLOGICAL SERVICES

25 0 25 50
metres

Petro Horizon Energy Corp.

Projection: Non-Earth (meters)	Brazil Lake Property Vertical Longitudinal Projection North Dyke Pegmatite Estimated True Thickness
Date:17/4/2010	
Author: JB	
Dartmouth	Looking NW, 320 degrees
Drawing: DRAFT	**Section 2010-1**
Scale: 1:500	mercator GEOLOGICAL SERVICES



Legend

Drill Hole Pierce Points

Hole, True Width
% Li2O
● % Na2O Intersection through pegmatite
% K2O
% Rb2O

× Outcrop true width

Surface

Surface Elevation

Overburden Thickness

Estimated True Width Contours

4 metre inteval

0.5 metre inteval

Petro Horizon Energy Corp.

Projection: Non-Earth (meters)	Brazil Lake Property Vertical Longitudinal Projection South Dyke Pegmatite Estimated True Thickness Looking NW, 320 degrees **Section 2010-2**
Date:17/4/2010	
Author: JB	
Dartmouth	
Drawing: DRAFT	
Scale: 1:500	mercator GEOLOGICAL SERVICES

5 0 5 10
metres