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GEOCHEMICAL CHARACTERISTICS AND MINERAL POTENTIAL OF SPECIALIZED GRANITOID PLUTONS IN THE TRANS-LABRADOR BATHOLITH, EASTERN LABRADOR

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ABSTRACT

A number of small granitoid plutons in the eastern Trans-Labrador batholith host or are associated with Mo–Cu, Pb–Zn and F mineralization.

These granitoid rocks can be subdivided into the Monkey Hill intrusive suite, Strawberry intrusive suite, and Lanceground intrusive suite. Differences in major element geochemistry are subtle, but the Monkey Hill suite can be distinguished by peraluminous traits that contrast with the metaluminous to locally peralkaline compositions of the other two suites. The Monkey Hill suite is characterized by low levels of F, Ga, Nb, Zr, Y, Zn and REE whereas these are enriched in the Lanceground suite and, to a lesser extent, in the Strawberry suite. The Lanceground suite is distinguished from the Strawberry suite by hypersolvus characteristics, lesser F enrichment and higher Zr, Y and REE levels. Strawberry suite granites also contain anomalous levels of Sn. Patterns for large-ion lithophile elements are similar in all three suites, but absolute levels of Rb, Be, Li and Pb are lower than in Phanerozoic intrusive rocks of similar major element composition.

The Cape Strawberry granite of the Strawberry suite shows regular and unidirectional geochemical zonation related to distance from its outer contact. Silica, U, Rb, Th and Pb increase toward the contact, associated with complementary depletion of Ba, Sr and Li. This is interpreted to reflect in situ *vertical zonation in the roof of a much larger underlying magma chamber, similar to that inferred from compositionally zoned tuffs and widely considered to be a critical part of mineralizing systems in high-silica granites. Similar contactward enrichment of F suggests that a volatile phase played a role in developing zonation.*

The Strawberry and Lanceground suites are comparable in some respects to potassic, fluorine-enriched rocks that are variably termed 'anorogenic', 'A-type' or 'within-plate' granites, and are typically associated with Mo–Sn, F, U and Pb–Zn mineralization. The most promising units for exploration are those which preserve original intrusive contacts with their host rocks, and in which contactward geochemical enrichment patterns suggest significant mass transport of incompatible elements.

INTRODUCTION

Project Description

This project was initiated in 1984 to provide an assessment of the mineral potential of granitoid rocks throughout the eastern Central Mineral Belt and to develop an understanding of the evolution and petrogenesis of the ca. 1.65 Ga old Trans-Labrador batholith (Figure 1).

An important component of the project is a large-scale geological mapping and lithogeochemistry program utilizing a 2 by 2 km grid-cell approach similar to that employed in Newfoundland granitoid terranes (e.g., Dickson, 1983; Tuach *et al.*, 1986). Follow-up work has emphasized mapping and more detailed sampling with an average site spacing of 750 m to 1 km. This is intended to delineate possible specialized granitoids and to define geochemical zonation patterns in or around units that may pinpoint favourable loci for mineralization.

The study area is centred around the small village of Makkovik, and covers approximately 10,000 km^2. Northern and eastern portions are dominated by a deeply incised coastline and a rugged hinterland rising to 900 m above sea level. A monotonous drift-covered plateau is present in the southwest and southeast of the area. Access to the area is by scheduled air service (LABAIR) or Marine Atlantic coastal boat.

Previous Work

Compilation and synthesis of 1:50,000 and 1:100,000 scale mapping by the Newfoundland Department of Mines is presented by Gower *et al.* (1982) for the eastern part of the

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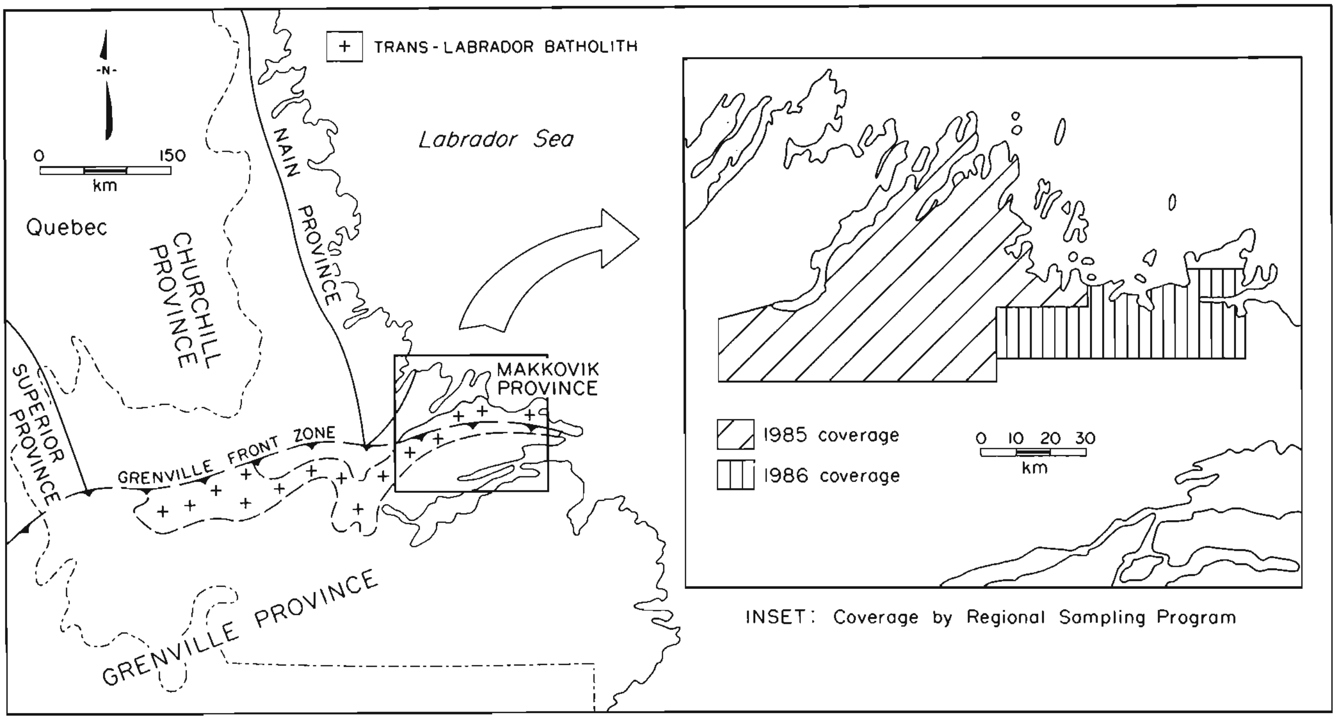


Figure 1. *Location map showing coverage by regional sampling and mapping programs carried out in 1985 and 1986.*

area, and by Bailey (1979) and Ryan (1985) for the west. These workers provide detailed reviews of geological work prior to the mid-1970's. Mineral exploration by Brinco was semicontinuous from 1955 to 1980, and was mostly directed at uranium, although some evaluation of Mo–Cu and Pb–Zn prospects took place.

Geological mapping during the 1985 field season led to the revision of existing subdivisions and establishment of new granitoid units (Kerr, 1986). Subsequent interpretation of geochemical data from the regional program allowed the identification of several granite plutons showing geochemical characteristics suggesting metallogenic specialization (Kerr, 1987a). This report subdivides these granites and gives an account of their petrology and geochemistry.

GEOLOGY AND PETROLOGY

Geological Overview

The geology of the area is reviewed in detail by Gower *et al.* (1982) and the distribution of granitoid units is summarized in previous reports (Kerr, 1986, 1987a). Figure 2 illustrates the distribution of specialized granitoid plutons and also the major geological divisions described below. Most of the area lies within the Makkovik structural province (Gower and Ryan, 1986), although the southeastern portion forms part of the Grenville Province. The boundary between the two structural provinces is marked by the major east-trending Benedict Fault system. Four geological assemblages are present within the Makkovik Province:

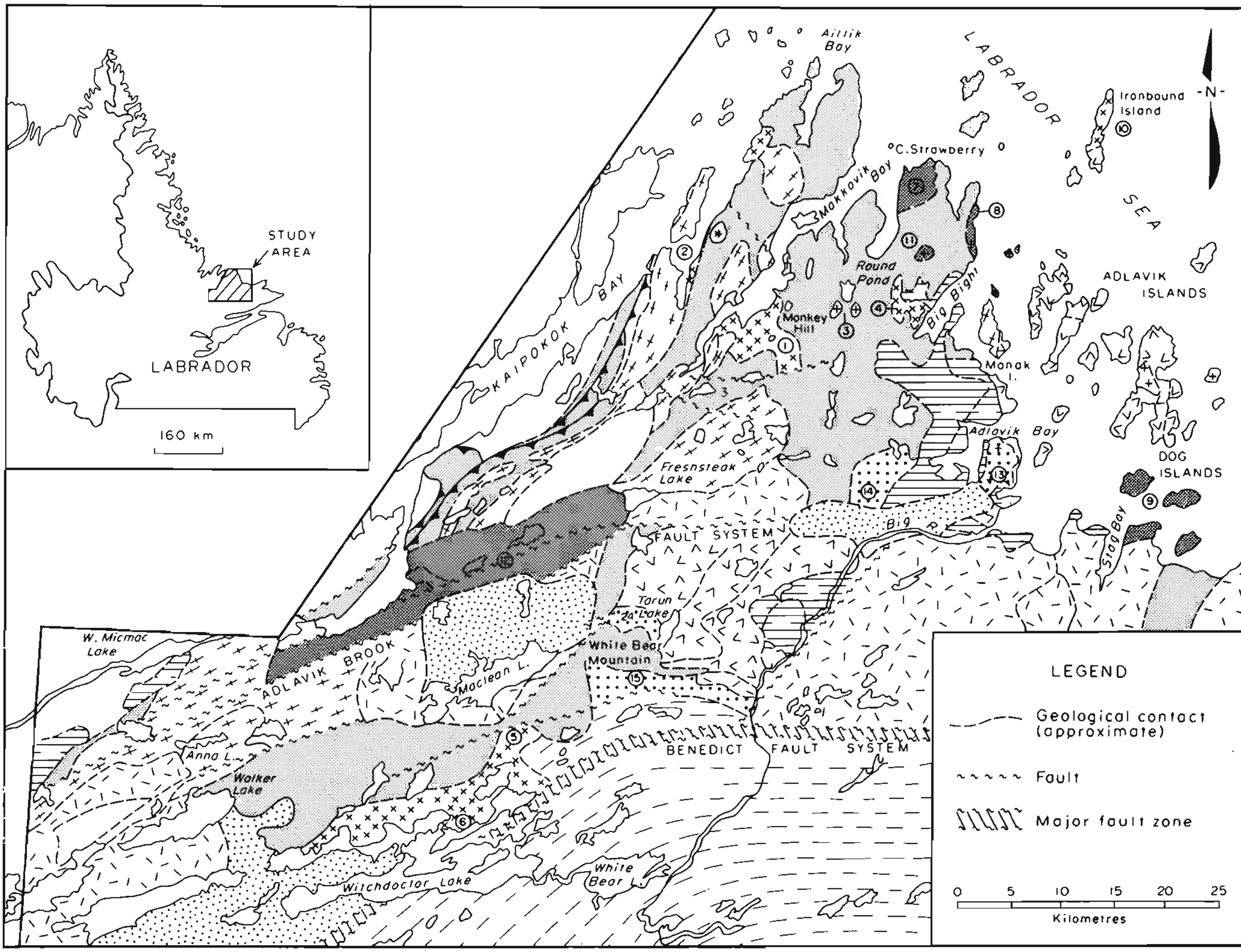
1) High-grade quartzofeldspathic gneisses of probable Archean age that underwent substantial reworking at ca. 1.85 Ga.

2) Supracrustal rocks of the *Aillik Group,* which structurally overlie the Archean, and were perhaps developed as a cover sequence upon it. They consist of a lower metasedimentary–mafic volcanic assemblage in a thrust belt along Kaipokok Bay, and a structurally overlying and much thicker upper felsic volcanic–volcaniclastic assemblage. Contacts between the two components are tectonic and they do not neccessarily represent a single stratigraphic sequence.

3) Foliated granitoid intrusive rocks of the *Makkovikian batholith,* which intrude the Aillik Group, but share at least the later portion of its deformational history. The batholith is thus broadly syntectonic with respect to the ca. 1.85 Ga Makkovikian Orogeny, which affected the Aillik Group and underlying basement.

4) Posttectonic intrusive rocks of the *Trans-Labrador batholith* (TLB), thought mostly to be of ca. 1.65 Ga age (Wardle *et al.*, 1986). These can be divided into 3 components:

    (i) the *Adlavik Intrusive Suite,* comprising layered gabbro and diorite, with spatially associated monzonite and syenite;



QUATERNARY

Drift deposits

MIDDLE PROTEROZOIC

TRANS-LABRADOR BATHOLITH

Unspecialized Granitoid Suites

Grenville Province gneisses: *strongly deformed granitoid rocks (probably equivalent to the Trans-Labrador batholith)*

Regional granitoid units: *quartz monzonite, granodiorite, granite*

Adlavik Intrusive Suite

Monzonite, quartz monzonite, syenite

Gabbro, diorite

Specialized Granitoid Suites

Lanceground intrusive suite: *medium to coarse grained, K-feldspar-porphyritic, quartz syenite to alkali-feldspar granite*

Strawberry intrusive suite: *coarse grained, K-feldspar-porphyritic, biotite granite and alkali-feldspar granite containing accessory fluorite*

Monkey Hill intrusive suite: *fine to medium grained leucocratic monzogranite and granite*

EARLY PROTEROZOIC

Aillik Group: *dominantly felsic volcanic and volcaniclastic rocks with subordinate mafic volcanic and metasedimentry rocks*

Makkovikian batholith: *variably foliated monzonite, quartz monzonite, granodiorite and granite.*

ARCHEAN

Quartzofeldspathic gneiss and migmatite

Figure 2. *Generalized geological map of the study area, showing the distribution of specialized granites and the locations of individual units discussed in this report. Circled numbers refer to units listed in Table 1.*

(ii) areally extensive *'regional'* granitoid units, comprising compositionally variable quartz monzonite, granodiorite and granite; and

(iii) *'smaller'* plutons, comprising discordant bodies of syenite, granite and alkali feldspar granite that commonly show well-preserved contacts with the Aillik Group. Several of these display specialization, and some are mineralized.

Smaller plutons associated with mineralization are mostly in the north, whereas regional granitoid units are mainly in the central portions of the area (Figure 2). This is interpreted to reflect the exposure of different levels of the TLB across a series of major east-trending faults of Grenvillian age. The northern portion of the area represents the uppermost surface of the batholith and enclosing country rocks, whereas progressively deeper levels are exposed southward.

Adjacent to and south of the Benedict Fault system, well-preserved intrusive rocks give way to foliated to gneissic granitoid rocks that are presumed to represent their deep-level deformed equivalents. North of this boundary, local east-trending fabrics and mylonitic zones suggest some Grenvillian deformation, but these effects are weak or absent in the northernmost structural blocks.

Definition and Classification of Specialized Granitoid Rocks in the Study Area

Several granitoid plutons within the TLB are considered to be 'specialized granites' (cf. Tischendorf, 1977). Specialization, as used in this study, is a *relative* characteristic, and is defined in terms of a contrast with regional geochemical background. As a whole, the TLB displays lower levels of incompatible and higher levels of compatible trace elements than younger rocks of equivalent major element composition (e.g., Tuach *et al.*, 1986); thus trace-element signatures of specialized rocks are less extreme. The definition employed for the TLB is as follows:

1) $SiO_2 > 71.5\%$, $(MgO + CaO) < 1.5\%$, $FeO(t) < 1.8\ \%$;

2) relatively enhanced Levels of F (1000-5000 ppm), Rb (180-500 ppm), Zr (250-2500 ppm), Th (15-60 ppm), and other lithophile trace elements;

3) relatively reduced levels of Sr (10-160 ppm), Ba (50-400 ppm), V (2-15 ppm), and other compatible trace elements;

4) relatively low K/Rb (50-150), high Rb/Sr (2-15), low Ba/Be (20-100) ratios; and

5) direct or spatial association with mineralization (this overrides the above).

Plutons in which most samples fit a majority of these charcteristics are considered to be specialized in terms of their regional environment. A feature that also appears to be associated with specialization is an extreme disorganization of trace-element patterns, particularly at SiO_2 contents of 72 percent and above. The geographic groupings established by these criteria do, however, include individual samples or areas that do not strictly meet this definition. Trace-element characteristics listed above are variably developed in the specialized rocks, and assist in their classification.

Three suites of specialized granites can be distinguished on both petrological and geochemical grounds. They are termed the Monkey Hill intrusive suite, Strawberry intrusive suite and Lanceground intrusive suite. Figure 2 shows the distribution of these suites and their individual components. They can be differentiated on both petrological and geochemical grounds, which are briefly summarized in Table 1. Showings related to these granites are located and described by Kerr (1987a).

Monkey Hill Intrusive Suite

Distribution. This suite is composed of eight discrete bodies, which lie in two main geographic zones. The type area is in the north, where the Monkey Hill, Duck Island, Round Pond and Little Monkey Hill granites, and a number of small unnamed bodies, intrude the Aillik Group. The similar Witchdoctor and Burnt Lake granites lie in the southwest of the area, within a downfaulted structural block that also exposes Aillik Group country rocks. The Kidlaluit granite, exposed on the larger of the Ironbound Islands, was grouped by Kerr (1987a) with the Cape Strawberry granite, but has been tentatively reassigned to the Monkey Hill suite on the basis of geochemistry.

Field relations and petrology. In its type area, the suite is characterized by fine grained, grey to pink or white, leucocratic monzogranite and alaskitic granite, locally containing small plagioclase phenocrysts. The main body is characterized by an overall textural and compositional homogeneity, and appears to consist of a single intrusive phase, although cognate inclusions are present in marginal areas (Plate 1a). Chlorite aggregates form the dominant mafic phase, and contain cores of pale biotite suggesting a largely secondary origin. Sparse accessory minerals include sphene, zircon, allanite and rare fluorite.

Other component units in the north of the area show similar characteristics to the type locality, and probably represent salients or cupolas on the upper surface of a larger interconnected plutonic body. The Round Pond granite and the Duck Island granite host, or are spatially related to mineralization, and are locally miarolitic and/or pegmatitic.

Contacts with the Aillik Group and Makkovikian batholith are well exposed in many locations, and appear as sharp, discordant intrusive contacts characterized by stoping

Table 1. Component bodies and general characteristics of the three suites of specialized granites in the Trans Labrador batholith

NAME	MONKEY HILL SUITE	STRAWBERRY SUITE	LANCEGROUND SUITE
COMPONENT INTRUSIVE BODIES	NORTHERN AREA: Monkey Hill granite (1) Duck Island granite (2) Round Pond Granite (3) Little Monkey Hill granite (4) Kidlaluit granite ? (10) assorted minor intrusions SOUTHERN AREA: Burnt Lake granite (5) Witchdoctor granite (6)	TYPE AREA: Cape Strawberry granite (7) October Harbour granite (8) Poodle Pond Granite (11) Kidlaluit granite ? (10) EASTERN AREA: Dog Island granite (9) SOUTHERN AREA: Bayhead granite (12)	ADLAVIK BAY AREA: Lanceground Hills granite (13) Pistol Lake granite (14) SOUTHERN AREA: Tarun granite (15)
GENERAL FEATURES	Fine- to medium-grained monzogranite and alaskitic granite. Locally plagioclase porphyritic.	Coarse grained pink to orange granite and alkali feldspar granite with K-feldspar phenocrysts.	Coarse grained buff to pink quartz syenite to alkali-feldspar porphyritic granite.
MAFIC MINERALOGY	Chlorite, derived from biotite. Muscovite/garnet in southern area.	Biotite, variably altered to chlorite. Accessory fluorite, lesser zircon and allanite.	Biotite with lesser hornblende Accessory zircon and allanite, with lesser fluorite.
REPORTED MINERALIZATION	Endocontact disseminated Mo. Exocontact vein-style Mo–Cu, also Pb–Zn, U, F and Au	Endocontact disseminated Cu-Pb exocontact Pb–Zn–Ag veins, and stockwork-type Mo.	Uncertain. Possible spatial association with vein-style Cu–Ag–U mineralization.

NOTE: Numbers in parentheses refer to locations on Figure 2.

and net veining of the country rocks. Narrow (<50cm) 'tuffisite' breccia zones with biotite-rich matrix (Plate lb) indicate violent exsolution of dissolved volatile components and a relatively high level of emplacement. Contact metamorphic effects are minimal or nonexistent. However, this may largely be a reflection of the unreactive nature of the surrounding felsic volcanic and granitoid rocks. Calcic skarn assemblages with orange calcite, diopside, andradite garnet and local specularite are developed where amphibolitic rocks are adjacent to contacts.

The southern zone of the Monkey Hill suite is represented by the Burnt Lake and Witchdoctor granites, which form a continous body within a structural block dominated by Aillik Group felsic volcanic rocks. This is inferred to represent a downfaulted area where higher levels of the TLB are locally preserved. The Burnt Lake granite is a fine grained, equigranular, grey to pink, alaskitic leucogranite containing biotite, chlorite, muscovite and minor garnet. It displays a sharp intrusive contact with metarhyolites of the Aillik Group in some areas (MacKenzie and Wilton, 1987), but has also been described as showing gradational contacts (Bailey, 1979). The Witchdoctor granite is a poorly exposed unit that consists largely of medium grained, equigranular leucogranite and alkali feldspar granite containing minor muscovite and garnet in addition to biotite. The mineralogical and chemical similarities suggest a close relationship between the two, and the Burnt Lake granite is interpreted to be a fine grained roof phase to the Witchdoctor granite.

Mineralization. Both geographic zones are associated with mineralization. In the north, the most significant deposits are associated with the Round Pond granite, which has a halo of hydrothermal quartz and carbonate veins containing Mo, Cu, Zn, Pb, U and F, and minor Ba and W. Distribution and mineralogy of the vein swarm appear to be zoned with distance from the easternmost of the two stocks in the area. Detailed descriptions of this mineralization are presented by MacDougall *(in preparation)* and MacDougall and Wilton (1987). Disseminated molybdenum mineralization (up to 0.5–1.0 percent Mo) is also present in miarolitic granites of the Duck Island stock (Gower *et al.*, 1982; Kerr, 1987a). This small (500 by 500 m) body represents a cupola intruding deformed Makkovikian granitoids, and is at the centre of an extensive area of granitoid veins and sheets that suggest a larger body is close to surface over several square kilometres.

In the southern zone, a similar small but high-grade molybdenum showing is hosted by the Burnt Lake granite at its contact with the Aillik Group, and MacKenzie and Wilton (1987) suggest that a phase of Pb–Zn–F mineralization within adjacent Aillik Group rocks may also be related to the granite.

Significant molybdenum mineralization at the Cape Aillik prospect, which contains some 2 million tonnes of 0.25 percent Mo, is considered by Wilton *et al.* (1986) and Wilton and Wardle (1987) to be of 'granophile' aspect, as it is formed by discordant veins and fracture fillings within an older

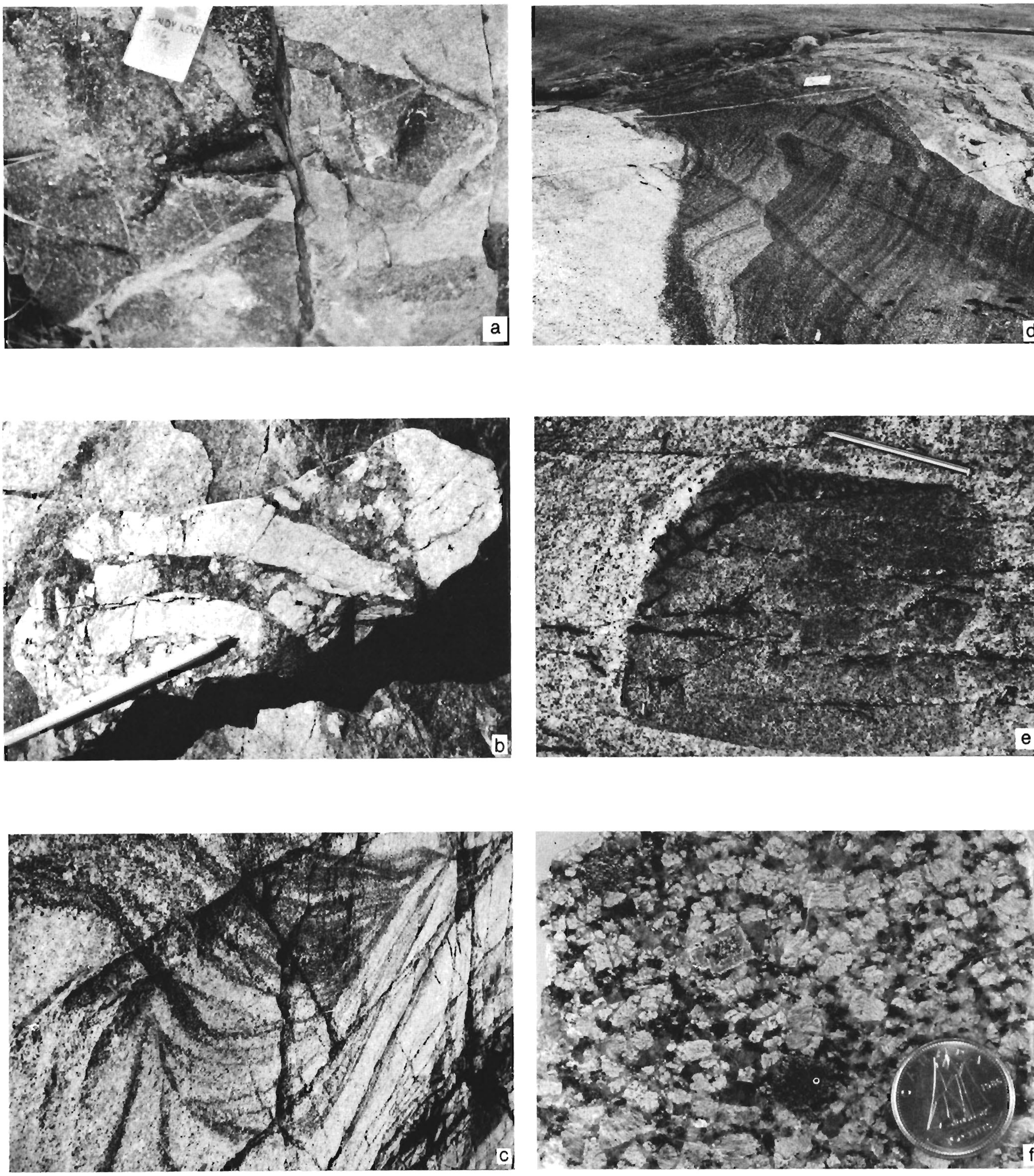


Plate 1. *Field characteristics of specialized granitoid plutons in the Trans-Labrador batholith; (a) cognate xenoliths (dark) disrupted by the main phase of the Monkey Hill granite; (b) 'tuffisite' breccia from the Monkey Hill granite; (c) distinctive trough crossbedded mafic layers of cumulate origin, Cape Strawberry granite; (d) megaxenolith of rhythmically layered granite in the Cape Strawberry granite; (e) xenolith of fine grained phase in Cape Strawberry granite, note breccia veinlet; (f) typical feldspar-porphyritic texture of the Pistol Lake granite, part of the Lanceground intrusive suite.*

stratiform shear zone. They suggest that an apophysis of the Cape Strawberry granite (see below) might be present beneath the prospect. A number of granitoid sheets and dykes exposed within the deposit area attest to the proximity of a magma chamber, but these minor intrusions bear a closer resemblance to the Monkey Hill suite. Wilton and Wardle (1987) suggest a similar origin for a number of disseminated and skarn-like U–Mo–F showings around Makkovik. These could be related to granites of either the Monkey Hill or Strawberry suites.

Strawberry Intrusive Suite

Distribution. The Strawberry intrusive suite is the most widespread and distinctive of the three suites. It consists of at least six discrete bodies within the area covered by Figure 2, and also probably includes rocks present as far as Cape Harrison, some 75 km to the east. The type area is on the peninsula north-east of Makkovik, where the Cape Strawberry, October Harbour and Poodle Pond granites, together with numerous similar veins and dykes, intrude Aillik Group metavolcanic rocks. About 20 km to the east, the Dog Island granite underlies a number of islands, and may be continous eastward with the Tukialik granite of the Benedict Mountains (Gower, 1981; Kerr, 1987b).

The largest individual body within the suite is the Bayhead granite, which outcrops around the inner reaches of Kaipokok Bay. This was previously grouped with the 'regional' granitoid units by Kerr (1987a), and is unspecialized or marginally specialized by the criteria listed above. It is, however, very similar in mineralogy and texture to northern components of the suite, and is inferred to represent a deeper level section through a magma chamber typical of the suite. It has thus been retained as part of the Strawberry intrusive suite.

Field relations and petrology. The Strawberry intrusive suite is predominantly medium- to coarse-grained, pink to orange, quartz-rich granite and alkali feldspar granite that commonly displays porphyritic to megacrystic textures. The most common phenocryst phase is perthitic microcline, but parts of the Dog Island granite are variably quartz porphyritic. Plagioclase is present as a discrete (usually groundmass) phase and as lamellae in coarse perthite. The dominant mafic phase is biotite, which is variably altered to chlorite. A few samples contain relict grains of pale-green amphibole rimmed by biotite aggregates. Some finer grained granites near contact zones contain blue reibeckitic or arfvedsonitic amphibole, as do (metasomatised ?) lithologies that may have been originally Aillik Group metavolcanic rocks. Purple fluorite is present in interstitial patches, along fractures, and intergrown with biotite–chlorite–zircon–iron oxide aggregates. Accessory phases include euhedral apatite, sphene, zircon and allanite.

The Strawberry suite exhibits considerable local textural variety, including both fine grained granite and rocks with very coarse pegmatitic textures, in addition to the dominant coarse grained facies. Such variety is most evident in the type area at Cape Strawberry, whereas the Bayhead and Dog Island granites are more homogeneous. Two phases of coarse grained granite can be distinguished locally in the Cape Strawberry granite, but there is little textural or mineralogical contrast away from their mutual contacts; they probably represent minor chilling effects. Mafic mineral accumulations indicative of cumulate processes (Plate 1c) are found in the Cape Strawberry, Dog Island and Bayhead granites. These consist of trough crossbedded accumulations of euhedral amphibole and biotite, and lesser amounts of euhedral zircon and allanite. The Cape Strawberry granite also contains a large (cognate ?) block of rhythmically layered granite (Plate 1d) showing similar characteristics. These features suggest a low viscosity during crystallization of Strawberry suite magmas.

Intrusive contacts with the Aillik Group are best exposed in the type area, where they vary from clean, sharp, discordant contacts to zones of extensive interaction and hybridization. Fine grained, miarolitic phases are developed close to the contacts, but rarely exceed a few tens of metres in thickness. Xenolith-rich zones are also developed, with xenoliths of unaltered Aillik Group, fine grained granite and rock types that appear to represent 'granitized' Aillik Group. Margins of the October Harbour granite are particularily xenolith rich, and granite adjacent to the contact contains a green-brown (calcic ?) garnet probably derived by assimilation of skarnoid patches developed in local amphibolitic country rocks. Brecciated zones, indicative of volatile exsolution, are developed in xenoliths and outcrops adjacent to contacts (Plate 1e). Aillik Group lithologies near contacts are variably recrystallized and fluoritic, and are locally difficult to distinguish from fine grained phases of the granite. Alteration, bleaching and pyritization are evident, and suggest the passage of hydrothermal fluids. Amphibolitic units develop calcite–diopside–garnet skarn zones, some of which contain up to 2 percent fluorine.

The distribution of granite bodies in the type area suggests that a more extensive body lies just below the surface, and the small Poodle Pond granite consists of a composite sill or laccolith of fine grained granite above a feeder dyke presumably connected to this body at depth.

Numerous minor intrusions are present between Makkovik and the Adlavik Islands, and include a variety of single phase and composite dykes, pegmatites, aplites and quartz–feldspar porphyries. Many are fluorite bearing or show geochemical patterns suggesting that they are part of the Strawberry suite and provide evidence of a more continous body at depth. Porphyry dykes are also associated with the Dog Island granite, and fresh rhyolite and felsite sills are present within the Bayhead granite. Some of these minor intrusions may represent feeders to cogenetic volcanic sequences now removed by erosion.

Mineralization. Most of the mineralization associated with the Strawberry intrusive suite is external to its contacts. The Cape Strawberry granite itself is associated with a number of low-grade molybdenum showings and pyritic gossans around its southern contact (Figure 2) and on the peninsula west of Ford's Bight (Wilton *et al.*, 1986; Wilton and Wardle, 1987). Some of these display a stockwork style of deposition and are associated with pyrite, fluorite and molybdenite-bearing pegmatites and aplites that are probably offshoots of the granite. Irregular vein-like siliceous and/or biotite-rich zones near contacts of the granite contain elevated but uneconomic levels of Mo, Zn and F over narrow widths. Significant Pb, Zn, Ag and Au mineralization, associated with fluorite and barite, is present in a group of discordant carbonate-hosted veins east of Big Bight, (Wilton and Wardle, 1987). The mineralized zone is equidistant from contacts of the Cape Strawberry, October Harbour and Poodle Pond granites, and is presumably underlain at shallow depths by granite, although none is exposed in trenches.

The Dog Island granite hosts a small, low-grade, disseminated Cu–Pb–F occurrence associated with the margins of an aplitic vein cutting coarse-grained granite. Anomalous levels of Sn (116 g/t) are also present in this showing.

The Bayhead granite is bounded mostly by faults and is not known to host mineralization. It contains irregular zones of moderate to locally intense hematization that suggest mild hydrothermal activity. Fine grained fluoritic phases are present at the southeastern extremity of the unit, and may suggest the presence of an intrusive contact with older Makkovikian granitoid rocks in this area.

Lanceground Intrusive Suite

Distribution. The Lanceground intrusive suite consists of three discrete bodies. The Lanceground Hills and Pistol Lake granites are located east and west of Adlavik Bay respectively, whereas the Tarun granite is inland, south of White Bear Mountain. All three geographic zones of the Lanceground suite are spatially associated with gabbro, monzonite and syenite assigned to the Adlavik Intrusive Suite.

Field relations and petrology. The characteristics of the suite are best known from the Adlavik Bay area, where deformation is relatively minor. In the Tarun granite, Grenvillian deformation variably obliterates original textures and relationships. The Lanceground Hills and Pistol Lake granites consist of medium- to coarse-grained grey to buff-pink quartz syenite to alkali felspar granite, containing phenocrysts of coarse perthite (Plate 1f). Both are hypersolvus granites commonly lacking discrete plagioclase, and are richer in mafic phases than granites of the Monkey Hill and Strawberry suites. The dominant mafic phase is red-brown biotite, although hornblende is usually present. A few samples contain relict fayalitic olivine, extensively altered to amorphous iron oxide–hydroxide (iddingsite). Samples lacking fayalite often contain irregular red-brown patches that may be pseudomorphs after it. Abundant accessory phases include interstitial fluorite and large (1 to 2 mm) euhedral sphene, zircon and allanite. Reibeckitic amphibole is present in some examples, and a red-brown prismatic phase (aenigmatite?) is locally associated with it. The Tarun granite is strongly recrystallized in places; the best preserved examples resemble granites from the Adlavik Bay area, but lack fayalite.

The Lanceground Hills granite intrudes diorite and quartz monzonite of the Adlavik Intrusive Suite. Most coastal exposures correspond with a complex polyphase agmatitic zone in the older rocks, and it is difficult to distinguish individual intrusive components. However, dykes of buff quartz syenite and granite, which cut this zone, clearly belong to the Lanceground granite. The Pistol Lake granite is in contact with the Aillik Group for over 10 km, but much of this is obscured by drift. The contact is sharp and intrusive in the few locations where it has been observed, and the granite has a finer groundmass than normal, suggesting marginal chilling. The Tarun granite is in contact with the Aillik Group around White Bear Mountain, but contacts have not been observed. East-trending faults related to the Benedict Fault system are prominent in this area, and it is likely that some of these contacts are tectonic.

Mineralization. The three component bodies of the Lanceground intrusive suite lie outside the areas explored in detail by BRINCO Limited, and data concerning mineralization are scanty. A U–Cu–Ag showing within the Aillik Group (7-11 showing) lies close to the contact of the Pistol Lake granite. This is reported to have a discordant vein-like form (Wilton *et al.*, 1987), and may be related to the granite. Analysis of samples by Wilton *et al.* (1987) and recent work by Cuvier Mines Limited suggest some potential for gold in this occurrence. A number of uranium showings in the area are also close to the contact of the Pistol Lake body. A dyke of fine- to medium-grained granite near the entrance to Adlavik Bay, probably related to the Lanceground Hills granite, contains 2400 ppm Zr and 170 ppm Y. No mineralization is known in or around the Tarun body.

DESCRIPTIVE GEOCHEMISTRY

Analytical Methods

Samples were analyzed for major elements and a range of trace elements in the Department of Mines laboratory, and also by Bondar-Clegg Limited. The element suite and methods are listed in Table 2. Numerical data and analyses of precision and reproducibility are presented in Kerr *(in preparation).*

Table 2 shows the average compositions of the three specialized suites described above, and also the average composition of regional units inferred to represent deeper levels of the batholith. The Bayhead granite has been separated from other members of the Strawberry suite as it shows a significantly different major-element composition. Median values representing the 50th percentile are also shown to give a better measure of 'average' levels of trace elements, which mostly have strongly log-normal distributions. For some major elements, notably SiO_2 and MgO, medians are also significantly different from arithmetic means.

Table 2. Average major- and trace-element compositions of granitoid rocks discussed in this report

Oxide weight percent	Regional Units (n=131 or n=32)* MEAN	MEDIAN	S.D.	Monkey Hill Intrusive Suite (n=85 or n=51)* MEAN	MEDIAN	S.D.	Strawberry Intrusive Suite (Excluding Bayhead Granite) (n=82 or n=50)* MEAN	MEDIAN	S.D.	Strawberry Intrusive Suite (Bayhead Granite Only) (n=47 or n=11)* MEAN	MEDIAN	S.D.	Lanceground Intrusive Suite (n=64 or n=26)* MEAN	MEDIAN	S.D.
SiO_2	67.33	68.20	5.61	73.87	74.20	2.47	72.62	73.35	2.93	69.90	71.40	5.42	72.13	72.22	2.98
TiO_2	0.53	0.47	0.30	0.13	0.12	0.10	0.23	0.22	0.11	0.43	0.30	0.34	0.34	0.30	0.20
Al_2O_3	15.15	15.12	1.65	13.65	13.50	1.15	13.47	13.50	1.40	13.87	13.69	1.34	13.06	12.90	1.23
Fe_2O_3	1.43	1.31	0.81	0.66	0.50	0.50	0.97	0.72	0.68	1.05	0.79	0.73	1.26	1.25	0.58
FeO	2.11	1.68	1.38	0.52	0.47	0.33	1.28	1.14	0.76	2.37	2.03	1.44	1.54	1.36	0.92
MnO	0.07	0.07	0.03	0.05	0.04	0.03	0.05	0.04	0.03	0.07	0.05	0.05	0.07	0.06	0.04
MgO	0.91	0.70	0.99	0.17	0.14	0.12	0.22	0.18	0.25	0.52	0.22	0.65	0.20	0.15	0.18
CaO	2.24	1.82	1.66	0.74	0.64	0.35	0.84	0.79	0.46	1.52	1.08	1.16	0.92	0.75	0.51
Na_2O	4.15	4.18	0.59	4.17	4.09	0.87	4.15	3.95	0.93	3.87	3.78	0.60	3.92	3.97	0.51
K_2O	4.78	4.88	1.00	4.96	4.87	0.83	5.12	5.16	0.98	5.12	5.23	0.92	5.48	5.40	0.54
P_2O_5	0.16	0.13	0.11	0.03	0.02	0.02	0.04	0.04	0.03	0.10	0.04	0.11	0.05	0.04	0.05
LOI	0.70	0.67	0.33	0.54	0.53	0.21	0.60	0.57	0.27	0.57	0.57	0.18	0.55	0.55	0.21
Element (ppm)															
Li	21.1	19.0	12.0	20.6	16.0	15.9	28.2	20.5	23.5	23.2	16.0	19.4	14.0	11.0	12.6
Rb	129.0	129.0	47.7	189.9	182.0	66.0	188.4	185.0	52.7	156.7	143.0	61.8	172.4	169.0	40.0
Cs	2.9	2.0	2.4	2.0	2.0	1.3	1.3	1.0	0.5	1.7	2.0	0.9	1.3	1.0	0.5
Be	3.6	3.6	1.1	4.8	4.6	1.4	4.9	5.1	1.1	3.7	3.0	1.7	5.5	4.9	2.1
Sr	295.6	218.0	209.2	119.1	85.0	191.3	83.7	77.5	69.1	119.3	76.0	114.7	61.2	35.5	69.3
Ba	944.4	881.0	467.0	444.6	340.0	502.9	382.0	427.0	232.6	673.7	661.0	436.1	333.1	258.0	267.7
Ga	16.4	17.0	5.1	11.8	11.0	5.5	18.3	19.0	6.9	17.6	20.0	6.3	21.8	22.5	10.2
Sn	2.8	2.0	2.6	1.9	1.0	1.6	5.5	5.0	3.6	4.3	4.0	2.5	3.7	3.0	2.6
Pb	18.7	16.0	12.1	24.2	24.0	9.7	25.2	24.5	12.7	24.8	24.0	7.3	24.9	23.0	14.6
As	1.6	1.0	1.4	1.3	1.0	0.8	1.8	1.0	2.0	1.3	1.0	0.5	1.5	1.0	0.9
Sb	0.3	0.2	0.2	0.2	0.2	0.1	0.3	0.2	0.2	0.3	0.2	0.1	0.3	0.2	0.1
F	695.4	696.0	377.6	377.5	225.0	386.6	1491.9	1412.0	965.6	970.0	797.0	761.5	1327.5	1213.0	921.8
Sc	4.8	3.7	3.3	1.7	1.3	1.3	2.7	2.4	2.0	2.4	1.6	1.8	4.5	2.6	7.1
V	35.0	22.0	39.5	11.3	11.0	9.7	11.5	10.0	9.8	15.9	10.0	21.7	8.4	7.0	8.4
Cr	6.3	3.0	13.8	3.0	2.0	2.8	4.2	2.0	6.1	4.8	3.0	5.0	4.0	4.0	2.5
Co	6.5	3.0	11.1	1.1	1.0	0.3	1.8	1.0	1.8	3.8	1.0	4.7	1.4	1.0	0.7
Ni	2.5	1.0	4.3	1.3	1.0	1.4	1.5	1.0	3.3	2.3	1.0	3.8	1.5	1.0	1.4
Cu	17.4	6.0	72.7	6.8	2.0	16.1	8.6	3.0	36.8	4.6	3.0	4.4	6.5	4.0	10.3
Zn	61.8	56.0	28.3	30.9	31.0	15.0	71.0	57.0	65.7	73.6	73.0	31.9	93.2	85.0	56.3
Y	38.2	37.0	17.3	27.3	22.0	24.0	55.5	44.5	40.0	55.0	54.0	21.6	78.1	80.5	32.3
Zr	200.1	189.0	102.8	148.0	138.0	69.1	314.0	255.0	213.0	246.1	240.0	97.0	416.9	377.5	284.4
Nb	16.1	15.0	7.2	18.7	17.0	11.2	27.4	22.0	26.8	25.1	25.0	9.9	29.8	29.0	11.0
Mo	3.6	3.0	2.1	80.3	2.0	531.8	3.3	3.0	1.9	4.4	4.0	1.8	4.3	4.0	2.3
La	58.9	54.0	27.0	25.1	19.0	22.6	85.1	91.5	45.2	91.4	76.0	56.3	128.1	117.5	61.0
Ce	115.8	103.0	53.8	51.1	39.0	46.4	167.1	179.0	79.9	180.5	143.0	102.8	257.8	248.5	120.1
Sm	9.9	9.3	4.0	4.1	3.6	2.6	12.6	11.5	5.9	12.8	11.0	7.6	20.1	19.9	11.7
Tb	1.5	1.0	0.7	1.2	1.0	0.6	1.8	1.5	1.1	2.3	2.0	1.1	3.1	3.0	1.9
Yb	5.4	5.0	0.8	5.1	5.0	0.4	7.1	6.0	3.5	6.5	6.0	1.8	9.0	8.5	4.8
Lu	1.0	1.0	.0	1.0	1.0	.0	1.2	1.0	0.4	1.1	1.1	0.2	1.4	1.3	0.6
Hf	10.9	8.0	12.4	5.1	5.0	1.7	12.5	11.0	5.2	10.3	10.0	4.8	21.5	21.0	14.6
Ta	1.5	1.0	0.7	1.5	1.0	0.8	1.7	1.5	0.9	2.0	2.0	1.1	1.8	2.0	0.9
W	2.0	2.0	0.2	2.0	2.0	0.0	2.0	2.0	0.0	2.2	2.0	0.6	4.2	2.0	7.7
Th	12.5	10.0	10.8	15.3	16.0	9.3	21.9	17.0	23.6	17.4	14.0	16.9	18.5	20.0	7.2
U	4.2	3.7	2.3	6.4	4.7	5.3	6.7	5.2	8.3	4.7	3.5	4.1	5.4	5.3	2.0
K/Rb	330	320	85	241	221	86	240	235	67	304	293	110	275	264	60
Rb/Sr	1	0.5	1.6	3.9	2.2	4.8	4.6	2.5	5.2	5.3	2.2	16.5	7.3	4.5	9.4
Ba/Rb	9	7	7.1	3.2	1.7	5.3	2.6	2.2	4.4	5.4	3.53	4.9	2.1	1.5	1.8
Ga/Al_2O_3	1.1	1.1	0.4	0.9	0.8	0.4	1.4	1.4	0.6	1.3	1.4	0.4	1.7	1.7	0.8

* n–number of samples; S.D.–standard deviation; ppm–parts per million. Major elements and Ba, Cu, Zn, Pb, Sr, Ni, Li, Rb, Cr, V, Be, Mo and Cu analyzed by atomic absorption. ICP spectroscopy used for Ga, Nb, Zr, Th, Y, La and Ce, INAA for U and ion-selective electrode for F. Data for Sc, As, Cd, Sb, Cs, Sm, Tb, Yb, Lu, Hf, Ta, W and Sn obtained by Bondar-Clegg Limited by INAA (XRF for Sn). Values for these elements obtained on a smaller data set than for internal analysis. The smaller of the two figures for number of observations at the head of each column refers to this data set.

Major-Element Variation Patterns

Figure 3 shows the distribution of selected major elements and derived ratios for the three suites, which are each subdivided to show different bodies or geographic areas. Differences in major-element geochemistry between the specialized rocks are very subtle. The northern zone of the Monkey Hill suite shows the highest SiO_2 content, but all groups overlap in the range 70 to 75 percent SiO_2. The Bayhead granite shows the lowest mean SiO_2 values and the highest CaO, FeO and TiO_2. The Monkey Hill suite shows the lowest FeO content and also significantly lower FeO / FeO + Fe_2O_3 ratios (labelled FERAT), suggesting that it is more oxidized. MgO levels are similar in all units except the Bayhead granite, and uniformly low, showing median values below 0.2 percent. MgO also has a log-normal frequency distribution similar to that of trace elements. The strongly differentiated nature of all three groups is emphasized by comparison with the average for regional granitoid units in Table 2.

Parameters such as the agpaitic index (AGP.I = molecular Na_2O + K_2O / molecular Al_2O_3) and the alumina or I-S ratio (A/CNK = molecular Al_2O_3 / molecular Na_2O + K_2O + CaO) are useful in distinguishing the three suites. None of the suites are wholly peralkaline, but the Lanceground suite and the Cape Strawberry granite both stray into the peralkaline field and show mean agpaitic index values above 0.95. They contrast with granites of the Monkey Hill suite, which are wholly subalkaline and show mean agpaitic index values below 0.9. Agpaitic index values for the Strawberry suite show considerable variation; the Bayhead granite is less agpaitic than other members of the suite.

The A/CNK ratio reveals a complementary grouping. The Monkey Hill suite is mildly peraluminous, with average values in excess of 1.0. The Lanceground suite shows the lowest values (<.95), and the Strawberry suite falls between these extremes. These differences are not dramatic, but they characterize the Monkey Hill suite very clearly, and suggest a closer association between the Strawberry and Lanceground suites.

Trace-Element Patterns

Table 2 shows average values for 34 trace elements. The most obvious feature of all groups is relatively high Ba and Sr and relatively low Rb, Li, Be and Pb, especially when compared to Phanerozoic granitoids of equivalent major-element composition (e.g., Tuach *et al.*, 1986). Such features are characteristic of the TLB as a whole and may be a reflection of depleted source materials or a high degree of partial melting in the source region of the batholith. However, Table 2 suggests significant relative enrichment–depletion of some of these parameters between regional and specialized units. Figure 4 shows the distribution (log transformed) of selected elements and ratios that exemplify patterns shown by different groups of trace elements as discussed below.

Patterns for Rb and Sr resemble those for U, Th, Li, Be, Pb and Ba in that they reveal little or no coherent variation or distinction. The Cape Strawberry granite and both areas of the Lanceground suite show low levels of Sr and Ba, which is often considered to be an indication of extreme differentiation. The fluorine content shows a clear distinction between the Monkey Hill suite and the other two suites, which both show mean F contents in excess of 1200 ppm, compared to less than 400 ppm in the Monkey Hill suite. Zr shows a similar contrast, and exemplifies the behaviour of other high-field strength (HFS) elements such as Ga, Nb and Hf, and the rare-earth elements (REE). In addition to separation of the Monkey Hill suite, these elements suggest that the Lanceground suite is enriched significantly in comparison to the Strawberry suite.

Trace-element ratios shown in Figure 4 illustrate patterns displayed by a number of such parameters. The K/Rb ratio, widely used as a differentiation index, shows little or no distinction between the three suites, but is highest (>300) in the Bayhead granite. Lanceground suite granites show slightly higher K/Rb than most Monkey Hill or Strawberry suite granites. Other trace-element ratios used as differentiation indices (e.g., Rb/Sr, Rb/Ba, Y/Ba) show minimal variation and inconsistent patterns, with the exception of Rb/Sr, which is highest in the Lanceground suite, largely as a function of Sr depletion.

La/Ce ratios are close to 0.5 in all components of the TLB, and the three suites show essentially identical mean values, narrow ranges and small standard deviations. The northern zone of the Monkey Hill suite and, to a lesser extent, the Cape Strawberry granite, show asymmetric distributions with high outlying values suggesting disturbance of this relatively constant parameter. The Bayhead granite also shows more variable La/Ce than other units, but appears to have a normal frequency distribution.

F/Zr ratios illustrate the F-enriched nature of the Strawberry suite compared to the other suites, and also show that the enrichment of HFS elements and REE in the Strawberry and Lanceground suites is not proportional to F content. Ga/Al_2O_3 ratios again emphasize contrasts between the Monkey Hill and other suites, and are particularly high in the Lanceground suite. This ratio is commonly used as an indicator of so-called 'A-type' granites (Collins *et al.*, 1982, Whalen *et al.*, 1987), and is accompanied by enrichment in F, Zr and REE.

Figure 5 shows the distribution of several ore and ore-indicator trace elements. Y and Zn show groupings similar to F and Zr, and are signifcantly higher in the Strawberry and Lanceground suites. Data for Sn indicates significant enrichment in these suites relative to the Monkey Hill suite, and also relative to 'average' crustal rocks (typically < 2 ppm).

Mo, Cu and Ta do not show coherent patterns; Mo and Cu data for the Monkey Hill suite and the Cape Strawberry granite are slightly biased by the retention of a few weakly mineralized samples in the database (most were screened out). Median values (Table 2) suggest that these elements are

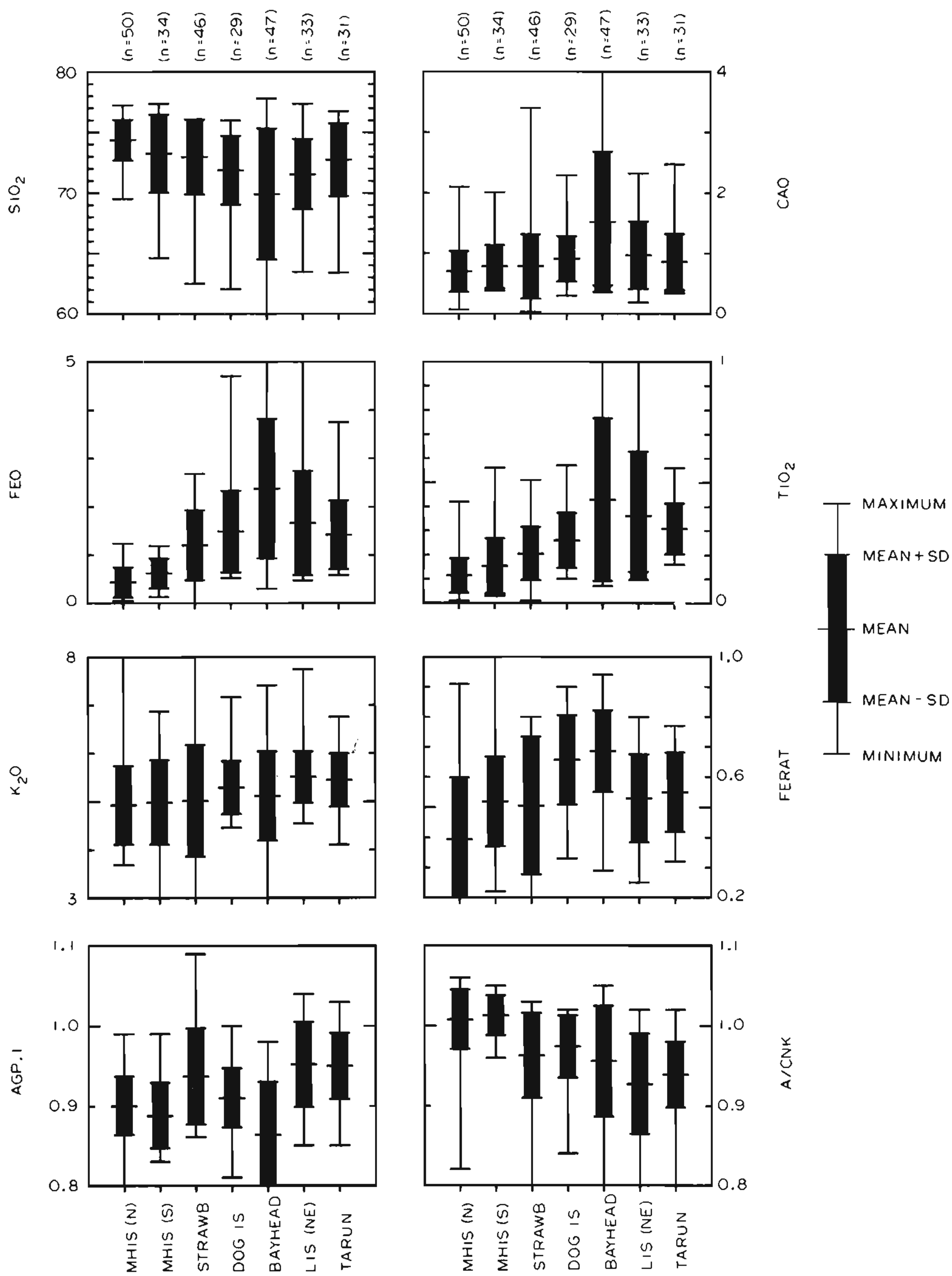


Figure 3. *Distribution of major elements and derived ratios in the three suites of specialized granitoids. MHIS–Monkey Hill intrusive suite; LIS–Lanceground intrusive suite; STRAWB–Cape Strawberry granite; DOG IS.–Dog Island granite; BAYHEAD–Bayhead granite; TARUN–Tarun granite.*

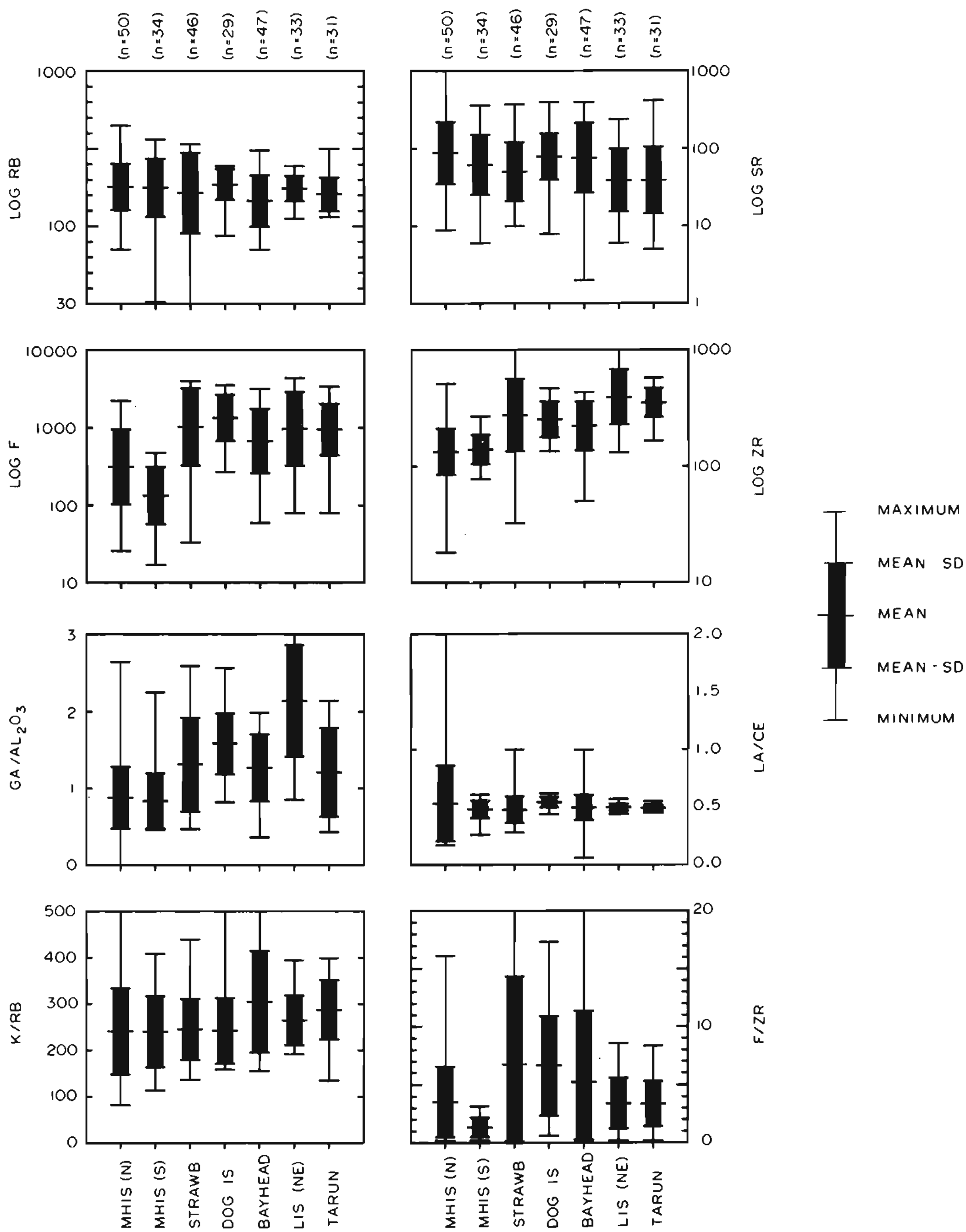


Figure 4. *Distribution of trace elements and derived ratios in the three suites of specialized granitoids. Abbreviations as for Figure 3.*

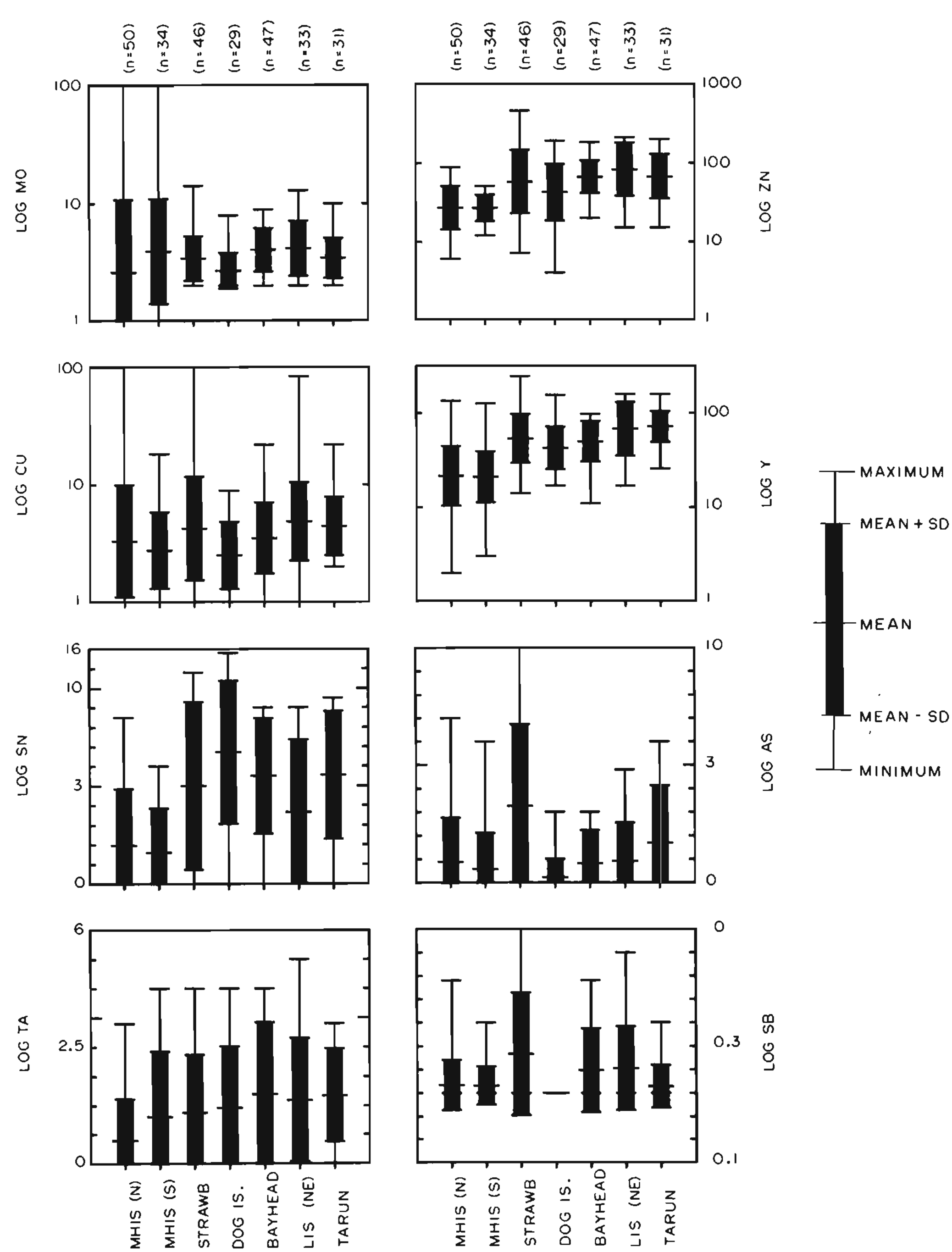


Figure 5. *Distribution of selected 'ore elements' in the three suites of specialized granitoids. Abbreviations as for Figure 3.*

Table 3. Element groupings defined by factor analysis

Factor	Elements Showing Strong Correlation (r > 0.60)	Elements Showing Moderate Correlation (r=0.45-0.60)	Elements Showing Weak Correlation (r=0.30-0.45)
1	Ce, La, Zr, Y, Nb	Mo, Zn, Ga	F
2	U, Th	Rb, Nb, TTDI, Pb	
3	Ba, Sr		
4	Li	F, (-TTDI), Zn	Rb
5	V	Ga	(-TTDI)

Note: Analysis was performed with the FACTOR subprogram of SPSS (Nie *et al.*, 1975) using principal component extraction and varimax rotation.

uniformly low in all groups. Sb and As show little coherent variation but show higher mean values and ranges in the Cape Strawberry granite compared to all other bodies. Median values suggest that this may not be significant, but scattergrams confirm that it is not simply a function of a few high outlying values. Data for W are available, but are almost all at the detection limit (2 ppm), except for a single sample from the Lanceground suite containing 40 ppm.

Table 2 shows that, with the exception of Sn, these elements do not discriminate well between regional and specialized granites in the Trans-Labrador batholith.

Factor Analysis of Trace-Element Data

Factor analysis has been used to clarify patterns and reduce the number of variables required to characterize suites and assess spatial variation within them. This method reduces a large number of variables to a much smaller number of 'factors' (typically < 6) which each represent a group of variables displaying mutually sympathetic or antipathetic behaviour. It was conducted with a subset of data comprising the Thornton-Tuttle Differentiation Index (TTDI—Sum of normative orthoclase, albite, quartz and feldspathoids) and 20 trace elements for which complete data were available. Trace-element data were log-transformed to compensate for asymmetric frequency distributions, and data for Cr, Ni, Cu and Ag subsequently removed as most values were at or near detection limits. The five-factor model employed explains 72 percent of the variance, and produces the element groupings listed in Table 3. The distributions of Factors 1 to 4 are shown in Figure 6. Factor scores are standardized variables that are expressed in terms of standard deviations. Each has a mean of 0 and a standard deviation of 1.0 for the *entire* population, but significant differences exist between suites.

Factor 1 [Ce, La, Zr, Y, Nb, Mo, Zn, Ga, F]. Factor 1 accounts for almost 30 percent of the total variance. The dominance of this element group comes as no surprise as HFS elements and REE provide the best discriminator of the three suites. All are trace elements whose enrichment is commonly associated with 'alkalic' or 'A-type' tendencies in igneous rocks, and this factor is thus considered to be a measure of such traits. There is no significant correlation with major-element composition, as represented by TTDI.

Factor 1 provides by far the best discrimination of the three suites. Peraluminous Monkey Hill suite granites show negative values compared to positive values for the Lanceground and Strawberry suites. The Lanceground suite has the highest values.

Factor 2 [U, Th, Rb, Pb, Nb, TTDI]. Factor 2 accounts for 18 percent of the total variance and represents a familiar association of large-ion-lithophile (LIL) trace elements and TTDI. In contrast to the HFS element and REE association of Factor 1, it does not provide a good discriminator between suites. However, within individual suites, it should provide a good measure of differentiation, especially when considered in conjunction with Factor 3 (below).

Factor 3 [Ba, Sr]. Factor 3 represents 10 percent of the variance and is confined to two elements that substitute in feldspars and therefore behave as compatible elements in felsic magmas. It can therefore be considered as an inverse measure of differentiation reflecting depletion of Ba and Sr by feldspar fractionation or hydrothermal processes. The Cape Strawberry granite and the Lanceground suite show the lowest values; other units are comparable.

Factor 4 [Li, F, -TTDI, Zn]. The significance of this association, which accounts for 7.5 percent of the variance, is unclear. Zn and F are also part of the Factor 1 association, and TTDI is part of the Factor 2 association. The distribution pattern, however, does not resemble either of these associations. It is highest in the northern zone of the Monkey Hill suite and the Strawberry suite, but reduced in the Lanceground suite. It may reflect variations in the amount of biotite, which concentrates these elements. The slight negative loading with TTDI suggests an association with (relatively) melanocratic rocks.

Factor 5 [V, Ga, -TTDI]. This accounts for only 6.6 percent of the variance, and is of uncertain significance. Ga is part of the Factor 1 association, but V is not present in other associations. The presence of a negative correlation with TTDI suggests that it is primarily a measure of the compatible trace element V, and thus not particularily useful. In four factor models with the same data, V is included with the Factor 3 association.

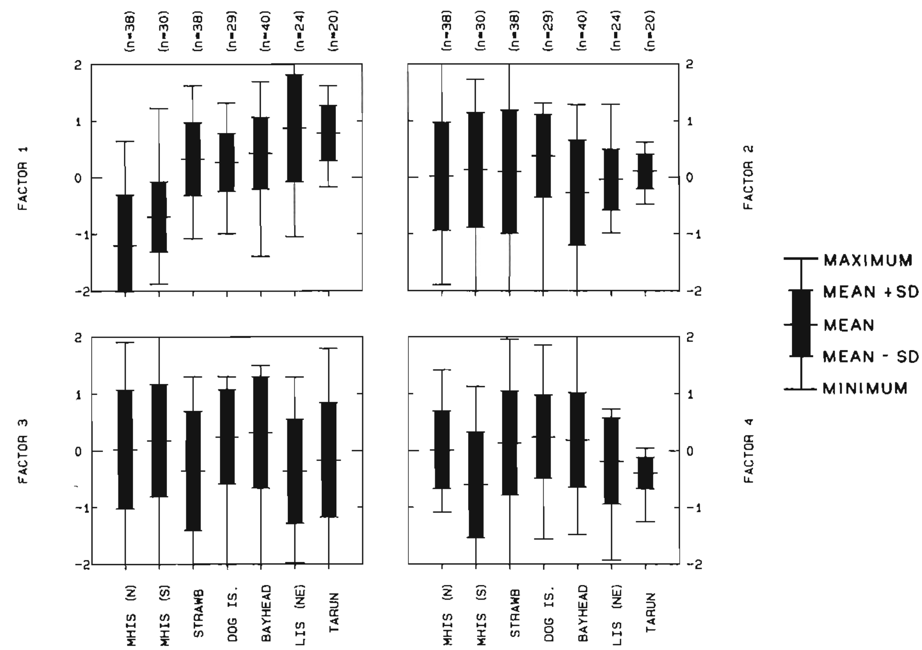


Figure 6. *Distribution of Factors 1 to 4 in the three suites of specialized granitoids. See Table 3 for the element associations represented by each Factor. Abbreviations as for Figure 3.*

SPATIAL GEOCHEMICAL VARIATIONS

An Example from the Strawberry Intrusive Suite

Recognition of geochemical zonation patterns in and around specialized units is an approach that may be valuable in the location of exocontact or near-contact mineralization. Roofward or contactward enrichment of a number of ore elements and indicator trace elements is a feature of many granites associated with mineralization (e.g., Tischendorf, 1977; Ramsay, 1986; Tuach *et al.*, 1986), and commonly culminates at or near ore deposits.

Figure 7 shows the spatial variation of a number of chemical parameters within the Cape Strawberry granite (see Figure 2 for location). This body provides an ideal test case as uniform exposure allows a regular sampling pattern, and a well-defined intrusive contact is present. Samples to the south and east of this contact are mostly from small intrusive bodies (veins, dykes) which may act as 'windows' on the underlying granite. The shape of the contact suggests that the 'roof' of the granite dips southeast and may imply that the entire body has been tilted by later tectonism. This may also be implied by the subvertical attitude of cumulate layering. The exposed area of the granite may thus represent as much as a 3- to 4-km vertical profile through the magma chamber. Contour maps in Figure 7 were prepared by a computer program, and a moderate amount of 'smoothing' has been applied. Visual checks of maps for SiO_2 and Zr against the actual values indicate a good correspondance. Ornamentation patterns reflect values above the 65th percentile (approximately), except for Factor 3, which has been inverted to highlight the lowest values.

Enrichment toward the contact is shown by several elements, such as SiO_2 and U, whereas others (e.g., Mo) show an inverse zonation in which the interior of the body is enriched. The distribution of fluorine is more diffuse, but also suggests contactward enrichment. Variation patterns for trace elements are best summarized by the distributions of Factors 1, 2 and 3 derived from the above analysis.

Factor 1, representing an association of HFS elements and REE, shows strong enrichment toward the contact zone in the northeast of the body, but not toward the southern contact. Minor enrichment is seen in the centre. Examination of single-element distributions for various HFS elements and REE suggests that this may be a hybrid pattern, and that the two groups of elements may behave differently on a local scale. *Factor 2,* representing incompatible LIL elements and major element differentiation, shows very clear enrichment along the southern contact, but lesser enrichment in the northeast. Factor 2 and U distributions are closely similar, but both are subtly different to the SiO_2 pattern, which highlights all areas of the contact. *Factor 3,* representing Ba and Sr, displays an inverse zonation pattern where central parts of the granite are enriched relative to its margins. It is comparable to single-element distributions for Mo and V, and shows some correspondance to Li, which also appears to be depleted near the contact.

An effective measure of *combined* enrichment and depletion is provided by the ratio of *Factor 2* to *Factor 3,* which highlights areas enriched in TTDI, U, Th, Rb, Pb *and* depleted in Ba and Sr. The combined distribution highlights the entire contact zone, but accentuates the northeastern area

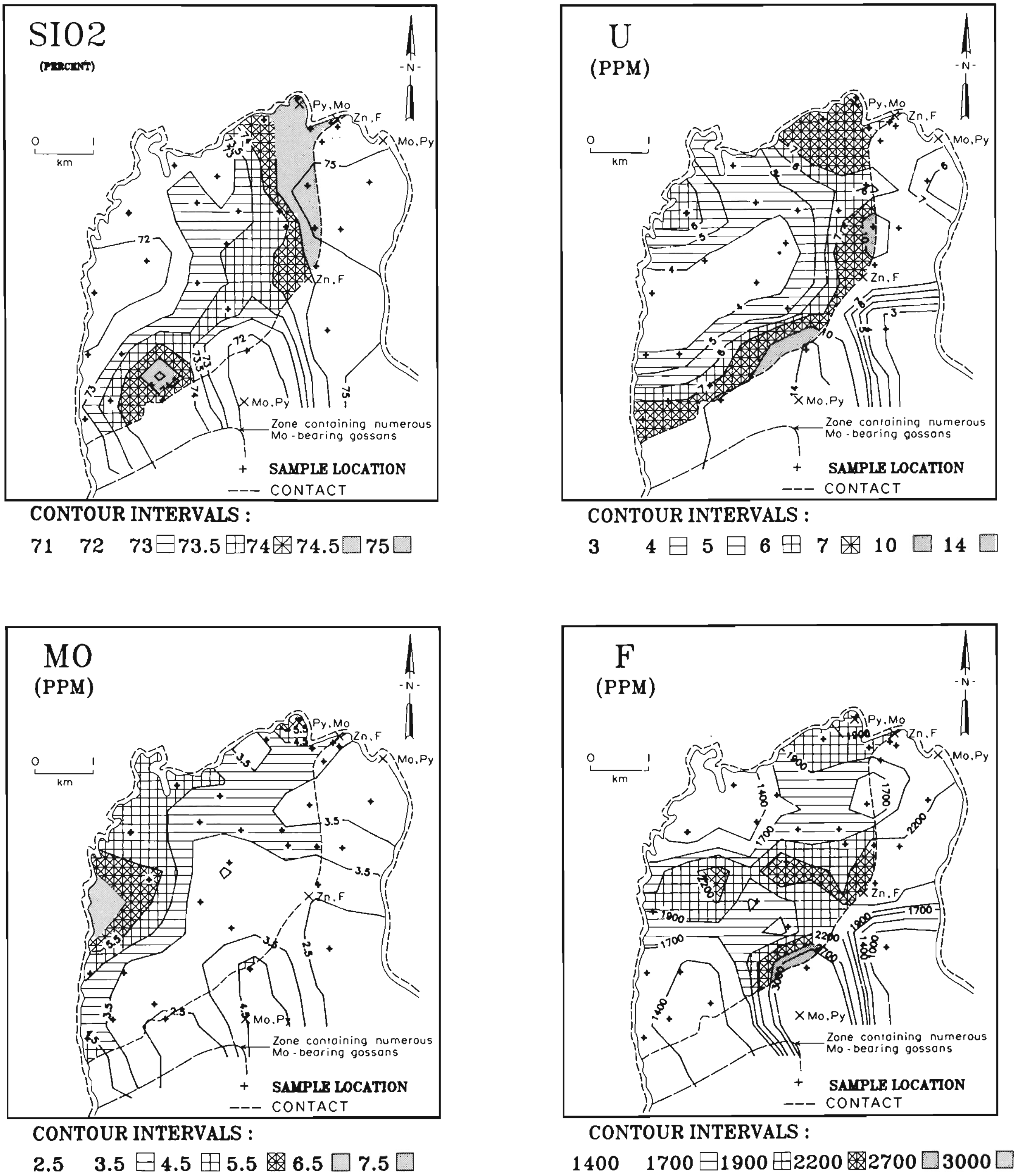


Figure 7. *Spatial distribution of a number of chemical parameters in the Cape Strawberry granite. Contouring performed by the USGS PLOTGEN program with search radius=1500 m, weighting factor=10 and number of nearest neighbours considered=4. For location of this body, refer to Figure 2.*

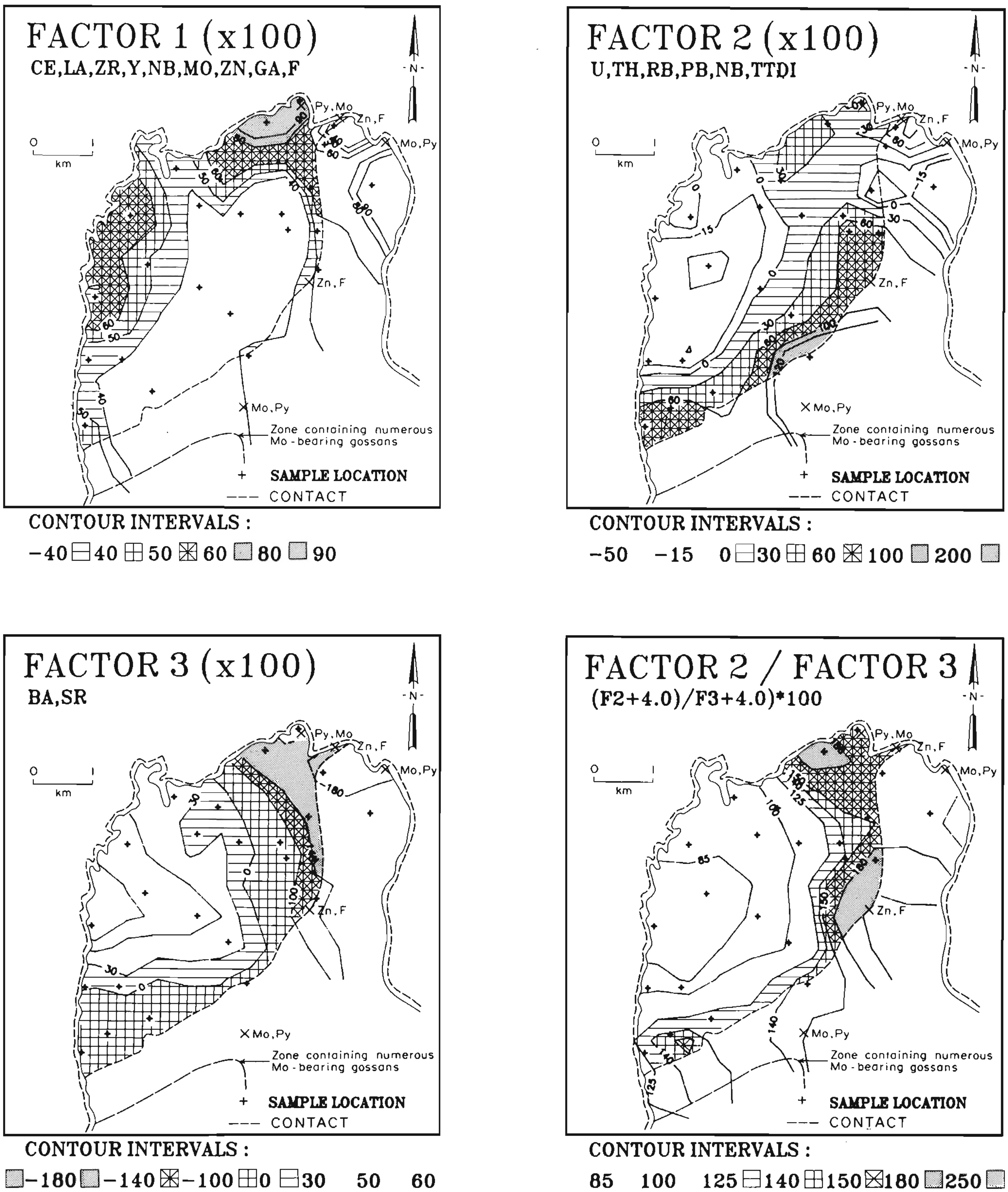


Figure 7. *(Continued)*

most strongly, largely due to extreme depletion in Factor 3. Mineralization adjacent to the southwestern contact is associated with a culmination of several trends, and the striking patterns in the northeast suggest that this area may also be worthy of investigation.

SUMMARY AND DISCUSSION

Petrological and geochemical data indicate that specialized granitoid rocks in the TLB can be grouped into three suites. The greatest contrast is between the Monkey Hill suite, consisting of fine grained, peraluminous granite and monzogranite, and the coarse grained metaluminous to slightly peralkaline granites of the Strawberry and Lanceground suites. Trace-element patterns provide a more subtle but consistent contrast between the latter suites. Factor analysis techniques provide the best discriminators between the three suites, and also yield composite variables that are useful measures of 'alkalinity' and 'differentiation' within each. The Cape Strawberry granite shows regular geochemical zonation relative to distance from its outer contact and some geochemical trends highlight areas proximal to known alteration and mineralization.

The following sections of this report discuss the significance of geochemical patterns summarized above, and also the possible affinities of the TLB specialized granites in terms of tectonic setting and economic element associations.

Interpretation of Geochemical Patterns

Major- and trace-element patterns suggest a clear distinction between the Monkey Hill suite and the other suites. The Strawberry and Lanceground suites show some features in common and clearly have a closer chemical affinity. There are, however, some significant differences, the most obvious of which is fluorine content. It has been suggested that HFS element and REE enrichment in A-type and peralkaline granites is largely a function of F enrichment, and Watson (1979) has demonstrated that high F levels enhance the solubility of zirconium in magmas. However, the Lanceground suite shows the highest levels of these elements, but *without* the extreme F enrichment of the Strawberry suite; this contrast is shown well by F/Zr ratios (Figure 4). This suggests that the higher levels of HFS elements and REE in the Lanceground suite are not a function of fluorine enrichment alone. Other features of the suite that suggest a separate origin from the Strawberry suite are common hypersolvus characteristics and spatial association with the Adlavik Intrusive Suite.

It is apparent from Figure 2 that the Monkey Hill and the Strawberry suites coincide in space over a considerable area, whereas the Lanceground suite is geographically distinct from them. Spatial coincidence of two suites showing contrasting compositions could imply that there is a significant age difference between them, and that they represent end-products of two different magmatic lineages. However, available geochronological data suggest very similar K/Ar ages for the two suites, indicating that cooling and hydrothermal activity were contemporaneous, at least in the north (Gower *et al.*, 1982).

These data suggest an alternative interpretation, namely that the Monkey Hill and Strawberry suites are variants or derivatives of a single magma, and observed differences in composition reflect late-stage processes such as hydrothermal activity in the roof zone of the magma chamber. The contrasting fluorine contents of the two suites could reflect loss of fluorine from the Monkey Hill suite, as suggested by Bailey (1977) for some fluorine-enriched magmas. The presence of fluorite and zircon in some veins associated with the Round Pond granite (MacDougall and Wilton, 1987; MacDougall, personal communication) may indicate some loss of F and Zr. Deuteric effects within Monkey Hill suite granites are indicated by chloritization of biotite, and also by disturbance of the La/Ce ratio (Figure 4). The principal argument against this interpretation is that transitional rock types are not present, and that (aside from chlorite) petrographic evidence for pervasive alteration of Monkey Hill suite granites is not present in the main body, which has a composition closely comparable to that of the mineralized Round Pond granite. Igneous textures are well preserved for the most part, and the remarkable homogeneity of the main body over almost a kilometer of vertical relief argues against any progressive alteration in the roof zone of this magma chamber. Preliminary analysis suggests that cryptic trace-element zonation is also absent.

In contrast, the Cape Strawberry granite shows a disorganized trace-element pattern suggesting redistribution of mobile elements, and also displays regular chemical zonation suggesting the concentration of silica and lithophile elements toward the upper or sidewall contact. A similar zonation pattern was suggested by MacKenzie and Wilton (1987) in the Burnt Lake granite, where it culminates near endocontact molybdenum mineralization. Patterns of this type appear to be characteristic of high-silica and specialized granitoid systems, and have been recognized *in situ* (Ackley granite; Tuach *et al.*, 1986) and in eruptive products (Hildreth, 1981). The Cape Strawberry body is small compared to these examples, but is simply a protrusion on the upper surface of a body with comparable overall dimensions. Zonation may reflect a number of processes, including fractional crystallization and liquid-state mechanisms such as convective fractionation or volatile fluxing. The high fluorine content of the Strawberry suite granites would act to reduce viscosity and enhance liquid-state fractionation (Dingwell, 1985) and also provide a volatile phase that could complex and transport elements.

At the present time, the preferred interpretation is that all three suites represent magmas of separate origin, and that there may be an age difference between the Monkey Hill and Strawberry suites. Zircon and/or sphene U—Pb dating would help to resolve this problem, and is currently underway.

Identification of Precursor Suites

'Precursor granites' are bodies that are spatially associated with and may precede metallogenetically specialized granites (Tischendorf, 1977) The spatial association between the Lanceground intrusive suite and the Adlavik Intrusive Suite suggests that it may represent the end product of this lineage. Parts of the Lanceground suite are compositionally and texturally similar to syenites of the Adlavik Intrusive Suite. A mineralogical link is provided by the presence of relict fayalite in the Lanceground Suite, which is also a component of Adlavik syenites. These syenites also show moderately high Zr, Y, La and Ce contents.

There is no obvious spatial association between members of the Strawberry suite and any one regional granitoid unit. However, geochemical data suggest that the Bayhead granite or similar rocks may have been precursors to the more highly differentiated Cape Strawberry and Dog Island granites. It is consistently less evolved yet displays strong mineralogical and textural similarities. The principal difference between the Bayhead granite and other members of the suite is level of exposure. The geochemical differences suggest vertical zonation within Strawberry suite magma chambers, and imply that in this case the 'precursor' may simply be a portion of an equivalent magma chamber below compositionally stratified levels represented by the Cape Strawberry unit.

Assigning precursor units for the Monkey Hill suite is more difficult as there are no regionally extensive peraluminous granitoid rocks within the area. The most comparable unit is the Crooked River granite of Ryan (1985), which is well removed geographically from the Monkey Hill suite.

Affinities and Mineral Potential of TLB Specialized Granitoid Rocks

Figure 8 shows discrimination diagrams commonly employed in the study of granitoid rocks, with broad fields for the three specialized suites, regional granitoid units and the Adlavik Intrusive Suite.

The K_2O vs Na_2O diagram illustrates the similarity of major-element compositions; the three specialized suites occupy essentially identical fields. Regional granitoid units show a tendency to higher soda, which is also echoed by the Bayhead granite of the Strawberry suite. All three groups plot along the upper edge of the A-type granite field defined by White and Chappel (1983). Ga vs Al_2O_3 shows a clearer separation, with higher Ga and Ga/Al ratios displayed by the Strawberry and Lanceground suites, and a restricted low-Ga field for the Monkey Hill suite. Strawberry and Lanceground suite granites are A-type granites in this plot, whereas the Monkey Hill suite lies in the field of I- and S-type granites. The (Y+Nb) vs Rb plot (Pearce *et al.*, 1984) places the Monkey Hill suite in the volcanic arc and syn-collisional field, and the Strawberry and Lanceground suites in the field of within-plate granites. Regional granitoid units and the Adlavik Intrusive Suite are equally distributed between these fields and that of volcanic-arc granites. Ti/Zr vs Nb/Y, commonly used in the classification of felsic volcanic rocks (Winchester and Floyd, 1977), shows a smooth trend from the Adlavik Intrusive Suite to regional granitoid units, and then divergence amongst the three specialized suites. The Strawberry intrusive suite has the most variable composition, and strays into the field occupied by peralkaline volcanic rocks such as comendite and pantellerite.

The results of this study suggest an empirical similarity between the Strawberry and Lanceground suites and A-type, anorogenic or within-plate granites, and between the Monkey Hill suite and volcanic-arc or syn-collisional granites. It seems unlikely that the two groupings represent radically different tectonic environments as they seem to be of broadly similar age. The contrasts in affinity may instead be a reflection of different source materials within the crust.

From an economic point of view, A-type granitoid rocks are associated with Pb–Zn, Sn, Nb–Ta, U, F and, in strongly peralkaline variants, with Zr–Y–REE deposits. Sn data for the Strawberry suite is clearly anomalous relative to average crust, and these granites may have some potential for tin in addition to known potential for Mo, Cu, Pb and Zn. The Lanceground suite is the most enriched in Zr, Y and REE, but falls well short of levels in peralkaline intrusives elsewhere in Labrador (Miller, *this volume)*. However, values of up to 2400 ppm Zr and 160 ppm Y in a dyke assigned to the Lanceground Suite are of interest. Biotite-rich cumulate zones in Strawberry suite granites contain up to 2400 ppm Zr, 400 ppm Y and 2300 ppm Ce.

Monkey Hill suite granites are not S-type granites in the strict sense of the term (Chappel and White, 1974), but have peraluminous traits. They resemble 'plumasitic' specialized granites associated with Sn–W–Ta–F mineralization from the Arabian shield (Ramsay, 1986), but have lower F. There is some evidence of tungsten (up to 160 ppm) in the Round Pond vein swarm, and potential might exist for tungsten-bearing skarns in addition to molybdenum and copper. There is, however, no sign of tin or tungsten enrichment in Monkey Hill suite granites.

Mineral Potential of Individual Bodies

The highest potential lies in rocks with known mineralization including the Cape Strawberry granite (Strawberry intrusive suite), the Round Pond granite and Burnt Lake granite (Monkey Hill intrusive suite). The exocontact nature of mineralization suggests that first priority should be given to those plutons that have well-defined intrusive contacts with their host rocks, and in which geochemical zonation patterns indicate significant mass transport of incompatible elements. Culminations of geochemical trends similar to those illustrated in Figure 7 provide the best indication of promising areas. In addition to the established targets listed above, the Dog Island granite and Pistol Lake granite may have potential. The Monkey Hill suite includes a number of small cupolas and stocks that have not been explored. The area around the Duck Island granite lies above one that contains endocontact molybdenum, and is worth further investigation.

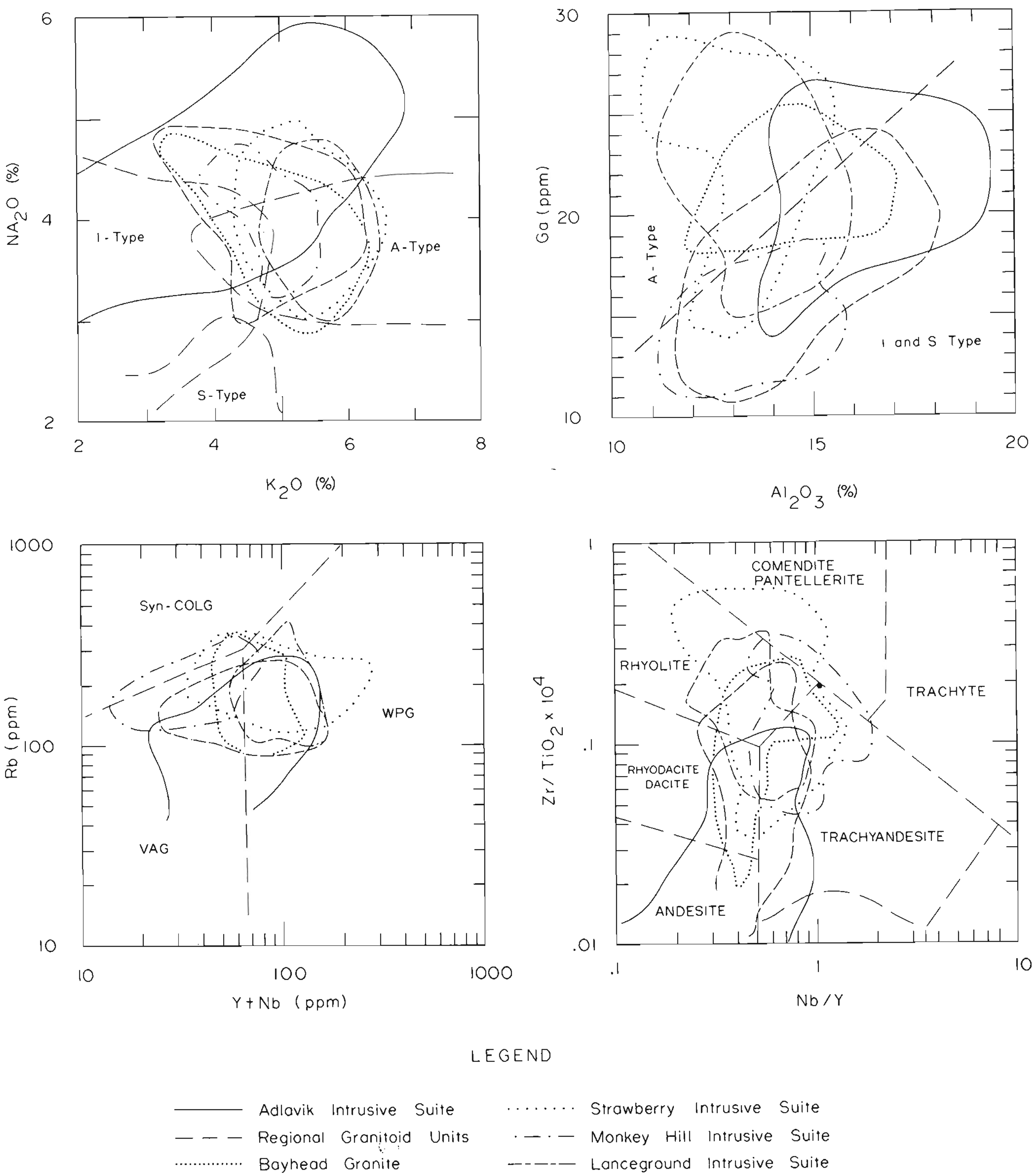


Figure 8. *Selected major and trace-element discrimination plots. Field boundaries from Pearce* et al. *(1984), White and Chappel (1983), Winchester and Floyd (1977), and Collins* et al., *1982.*

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REFERENCES

Bailey, D.G.
1979: The geology of the Walker Lake—MacLean Lake area, Central Mineral Belt, Labrador. *In* Report of Activities. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 78-1, pages 1-8.

Bailey, J.C.
1977: Fluorine in granitic rocks and melts: A review. Chemical Geology, Volume 19, pages 1-42.

Chappell, B.W. and White, A.J.R.
1974: Two contrasting granite types. Pacific Geology, Volume 8, pages 173-174.

Collins, W.J., Beams, S.D. and White, A.J.R.
1981: Nature and origin of A-type granites with particular reference to S.E. Australia. Contributuions to Mineralogy and Petrology, Volume 80, pages 189-200.

Dickson, W.L.
1983: Geology, geochemistry and mineral potential of the Ackley granite and parts of the Northwest Brook and Eastern Meelpaeg Complexes, southeast Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 83-6, 129 pages.

Dingwell, D.B.
1985: The structure and properties of F-rich silicate melts: implications for granite petrogenesis. *In* Granite-related Mineral Deposits. *Edited by* R.P. Taylor and D.F. Strong. CIM Geology Division, pages 72-82.

Gower, C.F.
1981: The geology of the Benedict Mountains, Labrador. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 81-3, 26 pages.

Gower, C.F., Flanagan, M.J., Kerr, A. and Bailey, D.G.
1982: Geology of the Kaipokok Bay—Big River Area, Central Mineral Belt, Labrador. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 82-7, 77 pages.

Gower, C.F. and Ryan, A.B.
1986: Proterozoic evolution of the Grenville Province and adjacent Makkovik Province in eastern and central Labrador. *In* The Grenville Province. *Edited by* J.M. Moore, A. Davidson and A.J. Baer. Geological Association of Canada, Special Paper 31, pages 281-296.

Hildreth, E.W.
1981: Gradients in silicic magma chambers: implications for lithospheric magmatism. Journal of Geophysical Research, Volume 86, pages 10153-10192.

Kerr, A.
1986: Plutonic rocks of the eastern Central Mineral Belt, Labrador: General geology and description of regional granitoid units. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 86-1, pages 89-100.

1987a: Plutonic rocks of the eastern Central Mineral Belt: Lithogeochemical patterns and the identification of potential specialized granitoids. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 87-1, pages 161-181.

1987b: Geochemistry and mineral potential of evolved granitoid rocks and layered mafic intrusions within the Trans-Labrador batholith, eastern Labrador. *In* Report of Activities. Newfoundland Department of Mines, Mineral Development Division, pages 39-42.

In preparation: Geochemical data from granitoid rocks of the Makkovikian and Trans-Labrador batholiths, eastern Central Mineral Belt, Labrador. Newfoundland Department of Mines, Mineral Development Division, Open File.

MacDougall, C.S.
In preparation: Granite-related mineralization in the Round Pond area, Makkovik Province, eastern Labrador. M.Sc Thesis. Memorial University of Newfoundland.

MacDougall, C.S. and Wilton, D.H.
1987: Middle Proterozoic granite-related mineralization in the Round Pond area, Labrador. *In* Current Research, Part A. Geological Survey of Canada, Paper 87-1A, pages 457-466.

MacKenzie, L.M. and Wilton, D.H.C.
1987: Uranium, molybdenum and base metal sulphide mineralization in the Burnt Lake area, central Labrador; three different styles of ore formation. *In* Current Research, part A. Geological Survey of Canada, Paper 87-1A, pages 467-477.

Miller, R.R.
This volume: Yttrium (Y) and other rare metals (Be, Nb, REE, Ta, Zr) in Labrador.

Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K. and Bent, D.H.
1975: SPSS. Statistical package for the social sciences. Second Edition, McGraw-Hill, 675 pages.

Pearce, J.A., Harris, N.B.W. and Tindle, A.G.
1984: Trace element discrimination diagrams for the tectonic interpretation of granitoid rocks. Journal of Petrology, Volume 25, pages 956-983.

Ramsay, C.R.
1986: Specialized felsic plutonic rocks of the Arabian Shield and their precursors. Journal of African Earth Sciences, Volume 4, pages 153-168.

Ryan, A.B.
1985: Regional geology of the central part of the Central Mineral belt, Labrador. Newfoundland Department of Mines and Energy, Mineral Development Division, Memoir 3, 185 pages.

Taylor, R.P. and Strong, D.F.
1985: Granite-related mineral deposits: Geology, petrogenesis and tectonic setting. Extended Abstracts of papers presented at the CIM conference in Halifax, 1985 CIM Geology Division.

Tischendorf, G.
1977: Geochemical and petrographic characteristics of silicic magmatic rocks associated with acid magmatism. *In* Metallization Associated with Acid Magmatism. *Edited by* M. Stemprok. Geological Survey of Czechoslovakia, pages 41-96.

Tuach, J., Davenport, P.H., Dickson, W.L. and Strong, D.F.
1986: Geochemical trends in the Ackley granite, southeast Newfoundland: Their relevance to magmatic/metallogenic processes in high-silica granitoid systems. Canadian Journal of Earth Sciences, Volume 23, pages 747-765.

Wardle, R.J. Rivers, T., Gower C.F., Nunn, G.A.G. and Thomas, A.
1986: The northeastern Grenville Province: new insights. *In* The Grenville Province. *Edited by* J.M. Moore, A. Davidson and A.J. Baer. Geological Association of Canada, Special Paper 31, pages 13-31.

Watson, E.B.
1979: Zircon saturation in felsic liquids: experimental results and applications to trace element geochemistry. Contributons to Mineralogy and Petrology, Volume 70, pages 407-419.

Whalen, J.B., Currie, K.L. and Chappel, B.W.
1987: A-type granites: geochemical characteristics, discrimination and petrogenesis. Contributons to Mineralogy and Petrology, Volume 95, pages 407-419.

White, A.J.R. and Chappel, B.W.
1983: Granitoid types and their distribution in the Lachlan Fold Belt, Southeastern Australia. Geological Society of America, Memoir 159, pages 21-34.

Wilton, D.H.C. and Wardle, R.J.
1987: Two contrasting metallogenic styles in the early Proterozoic Upper Aillik Group, Central Mineral Belt, Labrador, Canada. Mineralium Deposita, Volume 22, pages 198-206.

Wilton, D.H.C., MacDougall, C.M. and MacKenzie, L.M.
1986: Final report on 1985 field work in the Central Mineral Belt of Labrador. Geological Survey of Canada Internal Report, 149 pages.

Wilton, D.H.C., MacDougall, C.M., MacKenzie, L.M. and North, I.N.
1987: Final report on 1986 field work in the Central Mineral Belt of Labrador. Geological Survey of Canada Internal Report, 121 pages.

Winchester, J.A. and Floyd, P.A.
1977: Geochemical distinction of different magma series and their differentiation products, using immobile elements. Chemical Geology. Volume 20, pages 325-313