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TOWARD AN INTEGRATED DATABASE FOR NEWFOUNDLAND GRANITOID SUITES: A PROJECT OUTLINE AND PROGRESS REPORT

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SUMMARY

This report summarizes work completed, or in progress, as part of a project to integrate and interpret petrological and geochemical data from Newfoundland plutonic suites; it also provides an outline of future plans. The objectives are to develop and release a representative geochemical database for the island, to interpret these data in terms of petrogenesis and mineral potential, and to determine the relationships of plutonic associations to tectonic evolution. In this context, it is anticipated that integrated research involving isotopic and mineralogical studies can be continued in cooperation with outside researchers.

Information in Departmental computer archives has been assembled into a core database, and a variety of other data are collated for future incorporation. The core database is currently being checked and verified to eliminate errors in the location and classification of records. It is presently dominated by (mostly post-1980) data from southern Newfoundland, with lesser amounts of older data from eastern Newfoundland. Re-analysis of a subset of samples from a 1974 survey has raised doubts about the reliability of many of these older results; these samples have now been re-analyzed, with an expanded trace-element suite. Re-analysis will likely be required for other areas surveyed in the 1970's.

Under the Canada–Newfoundland Cooperation Agreement on Mineral Development 1990-1995, new field work and geochemical sampling is planned for many intrusions that are presently unrepresented, and to improve coverage in other areas. Re-analysis of older sample populations will continue as required, and acquisition of new data for a range of additional elements (e.g., REE) will be initiated. Multidisciplinary studies initiated over the last two years will be continued.

INTRODUCTION

Approximately one third of the island of Newfoundland is underlain by intrusive rocks that broadly form part of the 'granitoid clan', ranging in composition from diorite to alkali-feldspar granite. Geological mapping over the last 20 years, by various agencies, has resulted in coverage of large areas by 1:100,000- or 1:50,000-scale geological maps. A new 1:1,000,000-scale compilation map was recently released (Colman-Sadd *et al.*, 1990), replacing the earlier compilations by Williams (1967) and Hibbard (1983a).

The new map illustrates a number of changes in the classification of Newfoundland granitoid suites, but such are minor compared to revisions to volcanic and sedimentary sequences and their structural relationships. This reflects the 'natural' emphasis of geological mapping toward 'layered' rocks, which provide most information about structure, and the perception that sedimentary and volcanic sequences have a higher economic potential than many granitoid intrusions. Nevertheless, a considerable amount of petrological and geochemical information has been amassed from granitoid rocks in the course of regional mapping programs, particularly during the Canada–Newfoundland Mineral Development Agreement (MDA), and some Newfoundland granites are considered to have potential for economic mineralization.

With the signing of a new agreement (Canada–Newfoundland Cooperation Agreement on Mineral Development 1990-1995 = AMD 1990-1995) in late 1990, a project was initiated to compile, release and ultimately interpret the large volume of data collected by the Newfoundland Department of Mines and Energy (NDME). In addition to the collation of existing information, this project will also incorporate new work aimed at improving our understanding of the many areas where the present information base is cursory, and at providing a representative database for as much of the island as is feasible. The overall objective is to provide a basis for assessment of the petrogenesis, evolution and mineral potential of many of these suites, and to increase our understanding of their role in the geotectonic development of Newfoundland. This report contains a summary of work conducted on this project to date, and discusses some of the new directions planned for it under AMD 1990-1995, commencing in the 1991–1992 fiscal year. As only preliminary work has been undertaken to date, this

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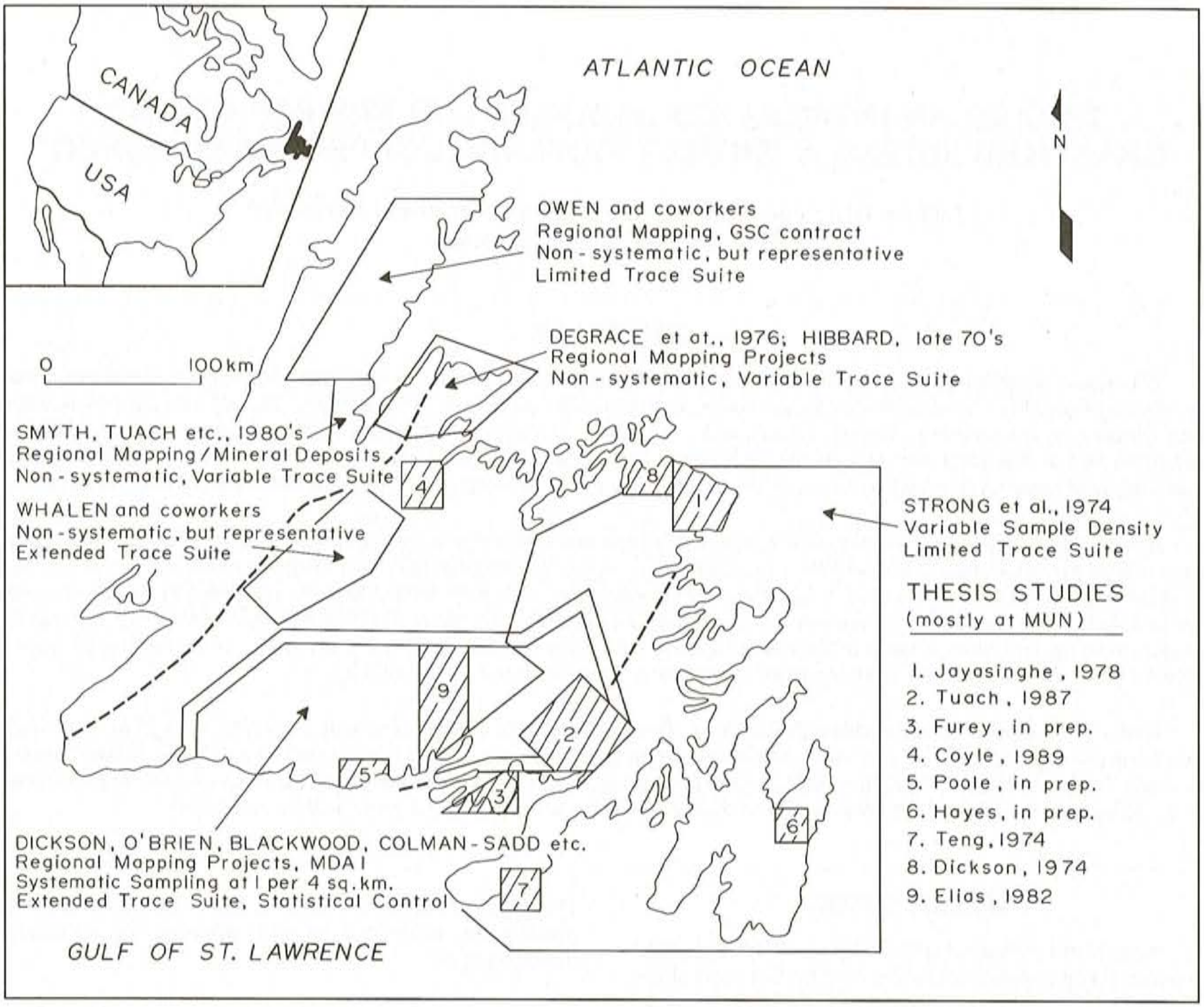

Figure 1. *Locations of and approximate areas covered by mapping projects that have contributed or are potential sources for geochemical data from Newfoundland granitoid rocks.*

article is a progress report and project outline, rather than a discussion of selected research topics. For preliminary discussion and interpretation of some of the geochemical data described here, see Dickson *et al.* (1990) and Kerr *et al.* (1990a). For a brief overview of the characteristics of Newfoundland granitoid intrusive suites, see Williams *et al.* (1989).

PREVIOUS STUDIES OF NEWFOUNDLAND GRANITOID ROCKS

Most systematic petrological and geochemical investigations incorporating geochemical studies have been conducted in the last two decades. Some of the most important contributions, and the approximate areas that they cover, are illustrated in Figure 1.

PROJECTS CONDUCTED DURING THE 1970'S

The survey of Strong *et al.* (1974) was the first large-scale application of geochemical and statistical methods to Newfoundland granitoid rocks, and was intended to provide a regional assessment of the mineral potential of those granitoid rocks in eastern Newfoundland. It was based on almost 1300 samples, collected mostly from coastal or roadside exposures. Although a few areas covered by this survey were later investigated in greater detail, the data of Strong *et al.* (1974) remain the only significant public-domain geochemical information for many eastern Newfoundland plutonic suites. The geochemical data were acquired mostly by X-ray fluorescence (XRF) methods, and include only a limited trace-element suite (Zr, Sr, Rb, Zn, Cu, Ba and F). Uranium was subsequently determined by neutron-activation (NAA) methods (Davenport, 1978).

During a similar time-period, a regional mapping project in the Baie Verte area (summarized by DeGrace *et al.*, 1976) produced 180 analyses of volcanic and plutonic rocks, using similar analytical methods to those of Strong *et al.* (1974). With the exception of a small number of analyses, presented by Hibbard (1983b), this 1976 database is the only significant public-domain source of geochemical data from granites in what has subsequently become an important exploration area. In the late 1970's, Elias (1979, 1980) conducted extensive geochemical sampling of granites in south-central Newfoundland, in conjunction with NDME mapping and a thesis study. This project was the first to employ a structured approach to geochemical sampling and mapping large areas of granitoid rocks. In contrast to sporadic sampling patterns determined largely by access (e.g., roads and coastlines), it produced a fairly constant sample density of about 1 per 4 km^2. Geochemical data were released (Colman-Sadd *et al.*, 1981) and are summarized by Colman-Sadd and Swinden (1982). They include a wider range of trace elements than the earlier studies.

PROJECTS CONDUCTED DURING THE 1980'S

The structured approach to sampling developed in the late 1970's was used during mapping of the Ackley granite (Dickson, 1983). The large volume of geographically representative data was used to supplement traditional unit divisions based on petrography, and to assess geochemical zonation patterns within the intrusion (Tuach, 1987).

Throughout the 1980's, much geological mapping under the MDA was focussed on the south coast of Newfoundland (e.g., O'Brien *et al.*, 1986; Dickson *et al.*, 1989). Most of this area is underlain by granitoid rocks, and mapping techniques were similar to those employed in the Ackley granite project. Extensive grid-based geochemical sampling of granitoid rocks accompanied and supplemented mapping programs throughout this area, and also in parts of the central Gander Zone (Blackwood, 1983). As a result of these projects, granitoid plutons in southern Newfoundland are now covered by systematic lithogeochemical sampling, and are probably better known than many in more accessible parts of the province.

OTHER RELEVANT GEOCHEMICAL SURVEYS

The Geological Survey of Canada (GSC) has also examined Newfoundland granitoid rocks. In the 1980's, their focus was the Topsails Intrusive Suite, described by Whalen and Currie (1983). Geochemical data were partially released as part of an open-file report on 'A-type' granites (Whalen *et al.*, 1987). Although the sampling methods differ from that employed by recent NDME projects, there has been a similar emphasis on coupled lithological mapping and the geochemical data are of high quality. Mapping in the Long Range Mountains of western Newfoundland by Owen (1988) as part of a MDA research contract, has recently provided the first regional information on Precambrian granites of this Grenville inlier. Small amounts of geochemical data were also acquired by other GSC and NDME mapping projects in various areas of the province (e.g., Chorlton, 1980).

A number of thesis studies based on Newfoundland granites have been conducted at Memorial University and other institutions. Most have been at the B.Sc or M.Sc level, and are consequently of local emphasis, being focussed on a single intrusion or a portion thereof. Others (e.g., Tuach, 1987; Poole, *in preparation*) mostly utilize geochemical data collected via Departmental mapping programs. However, some studies conducted during the late 1980's (e.g., Furey, *in preparation;* Coyle, 1989) promise to be sources of new high-quality geochemical data for some plutons and/or correlative felsic volcanic suites.

VARIATIONS IN THE SPECTRUM AND QUALITY OF GEOCHEMICAL DATA

The changes in sampling methods over the years are mirrored by changes in analytical techniques and capabilities. Most major- and trace-element data are now acquired by atomic absorption (AA) and inductively-coupled plasma (ICP) spectroscopic methods via the NDME laboratory, which allows precision and accuracy to be monitored closely from year to year. Trace elements include several of economic significance (e.g., Mo, Li, Be, F, U and Ag) and some used in classification and modelling (e.g., Ga, Y, Nb, Th, Ce). Few, if any, of these elements were determined on a routine basis during the early 1970's, when most analytical work was contracted to outside agencies. Surveys conducted in the late 1970's and earliest 1980's fall between these extremes, and typically include a mixture of NDME and external contract data. The range of analytical techniques and their precision create some problems in comparison of data, and steps must be taken to upgrade some of the early analyses to current standards (see below).

ASSEMBLY OF A GEOCHEMICAL DATABASE FOR NEWFOUNDLAND GRANITOID ROCKS

OVERVIEW OF CONTENTS

Commencing in 1987, data held in various NDME archives were assembled into a single, large computer file, using the SPSS-X software package. This task was completed in 1988 (Butler, 1988) and the resultant database of about 4500 records is the starting point for this project. The initial priorities were to develop a standardized file format and classification system, and problems inherent in the data themselves were largely set aside for later resolution. Data are presently stored on the Departmental microcomputer.

The data collected from southern Newfoundland intrusions in the late 1970's and early 1980's far outweigh all other material. The data from Strong *et al.* (1974) are the second largest contributor and are the only source for much of eastern Newfoundland. All other sources are minor contributors, and some of the mapping projects located in Figure 1 are presently unrepresented in the database. This is because, prior to the late 1970's, relatively small amounts of geochemical data were not routinely transferred to the computer archives. Figure 2 shows the distribution of the

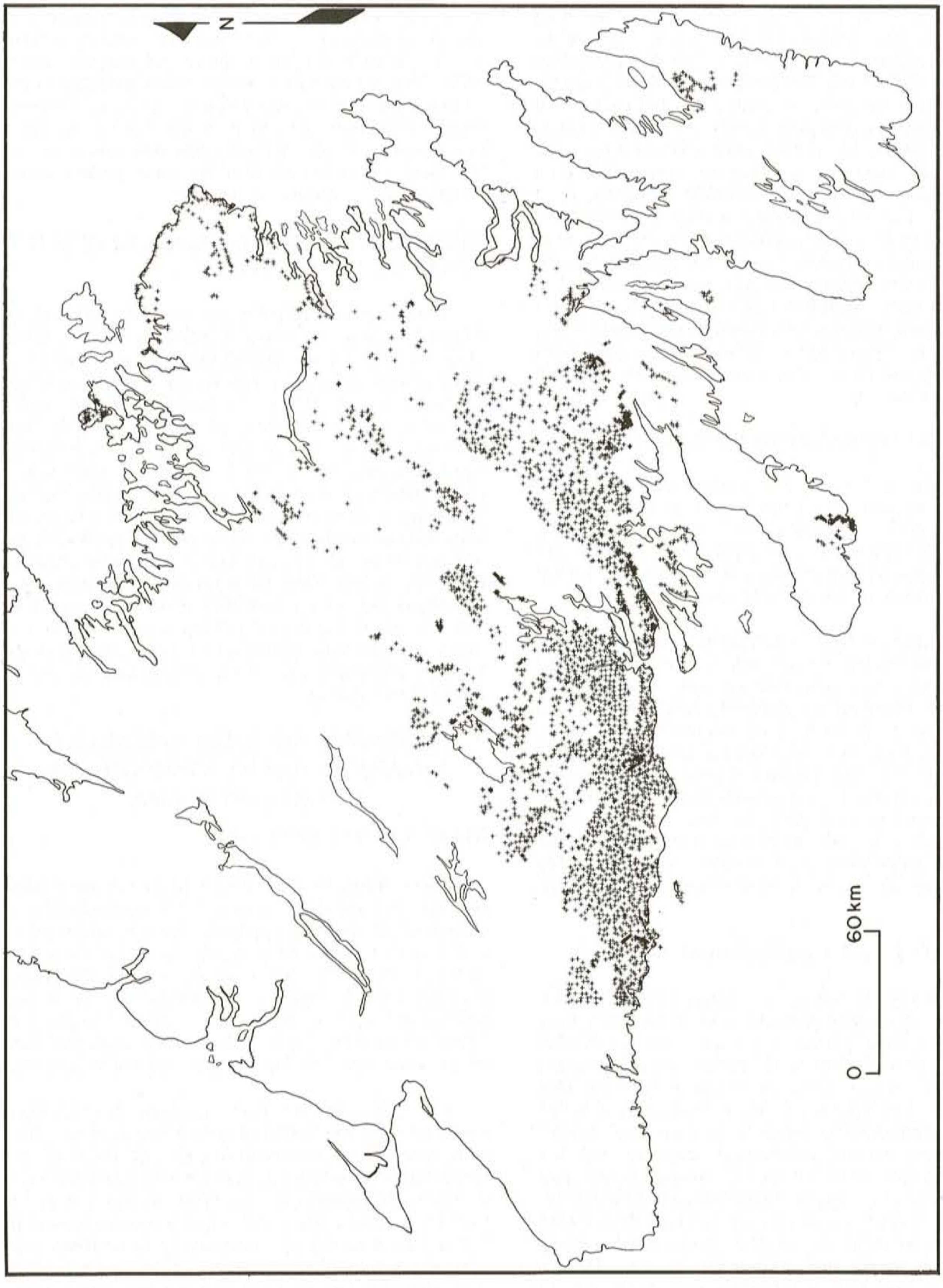

Figure 2. *A computer-generated map showing the geographic distribution of records currently held in the core granitoid database. Note the dominance of data from southern and parts of eastern Newfoundland.*

samples across the Island (compare with Figure 1). It illustrates, in a striking manner, the contrasts in both sample density and sampling patterns between earlier and more recent projects.

Each record in the database consists of identification (both laboratory number and original field number), location and field information, and available geochemical results. Records are grouped using a classification variable, termed the 'pluton number', which denotes the intrusion or plutonic suite in question. This number is derived from the empirical numbering system utilized by Hayes *et al.* (1987) in their summary map of Newfoundland granites.

The term 'pluton' is not used in a literal sense, as the scale of such divisions varies greatly and, in many respects, it is an unsatisfactory term for this classification variable. However, it is retained (in quoted format) in this report. The numbering system has itself developed over several years of informal usage, and hence has little geographic or stratigraphic 'order'. Table 1 lists all the 'plutons' currently numbered and the number of records available for each. For locations of these 'plutons', see the summary map of Hayes *et al.* (1987).

As mentioned above, there are many variations in the spectrum and quality of geochemical data. This applies mostly to trace-element data, but there are also many inconsistencies in major-element analyses; e.g., discrete FeO and Fe_2O_3 analyses versus total iron as either FeO or Fe_2O_3. No distinction is made between analytical methods, although there are large variations in the precision and accuracy of some elements; e.g., Ce (XRF) is well known to be intrinsically less reliable than Ce (ICP). Although UTM coordinates are ubiquitous, other information such as texture, mineralogy, colour, alteration etc., have been recorded to different degrees in different projects. Some recent projects have subdivided records by map unit. Most older data are not subdivided beyond the 'pluton' level.

In the initial concept for this project, incorporation of data collected from Geological Survey of Canada projects and university researchers was proposed. However, the consistency problems noted above, based on the authors' experiences, are likely to be formidable. At present, all external information of this type is being maintained as separate files.

The database discussed above will form the core for all future assembly of geochemical data. Some existing Departmental data has already been assembled as separate files (e.g., Baie Verte Peninsula and White Bay area data) but this will not be added until the core database has passed an exhaustive checking procedure. Similarly, data from limited sampling and mapping conducted during the 1989 and 1990 field seasons (Kerr, 1989, 1990; see below) are also being held in reserve as separate files. Data continue to accumulate from a variety of sources; for example, 1990 field work in several areas of peralkaline igneous rocks (Miller, 1990) will soon fill some significant gaps in our information base.

WORK CURRENTLY IN PROGRESS

The first priority is to eliminate, as far as is possible, all problems related to sample identification and classification. Some are obvious and easily rectified. For example, suspicions were quickly aroused when the very small Piccaire granite of the Baie d'Espoir area was apparently represented by over 100 records, and it was soon established that most belonged to another suite, which had been miscoded. However, not all classification problems are as glaring as this example.

The present checking procedure involves producing sample location maps (corresponding to 1:250,000-scale NTS sheets) where individual 'plutons' are represented by discrete symbols and/or colours. This allows their locations to be checked against the outcrop patterns of their units, and also helps to eliminate any errors in UTM coordinates. Some intensively studied and sampled areas will probably eventually require location checking at a scale of 1:100,000 or greater. In the process, one of us (JH) is developing plotting routines that will be of use in future assessment of spatial geochemical variations (see below).

For these data to be useful on the scale of an individual intrusion or plutonic suite, division into lithological and/or geographical subunits is important. The second phase of the checking procedure involves the plotting of data for a specific 'pluton' at a scale that allows verification of subunits, or their introduction if not already present. Naturally, some 'plutons' cannot be subdivided on either basis. A related problem involves the methodology of unit definition, as some workers (e.g., Tuach, 1987) have utilized definitions based on geochemistry, rather than the lithological and geographical features that are the foundation of stratigraphic nomenclature.

There is also a need to eliminate samples of rock types that do not strictly belong in a database mainly composed of plutonic rocks. The principal rock types are migmatites, hornfelses and assorted country-rock types, which have been sampled during regional mapping and included with granitoid data. Fortunately, the variable 'Rocktype', comprising a 4-letter code, is present for most records and is fairly standard in usage. It is also desirable to identify samples that are strongly mineralized; some of these can be picked out via coded rock type (e.g., 'vein' or 'greisen'), but others may have to be identified via strongly anomalous geochemistry and then verified by original field descriptions.

Once basic questions of identification and classification are resolved, it will be necessary to locate and correct problems with the geochemical data themselves. Post-1978 data has already gone through double-entry verification, during keypunching at Newfoundland and Labrador Computer Services (NLCS), and most geologists working with such data perform their own checks. In the case of older data, substantial re-analysis is planned, and verification prior to incorporation of replacement data will be possible.

Table 1. A listing of all the 'plutons' currently assigned classification numbers, and the number of records presently contained in the core granitoid database. Note that many of the names, introduced by Hayes *et al.* (1987), are of an informal nature (regardless of any capitalization) and subject to revisions

Pluton Number	Name of Unit or Plutonic Suite	Valid Records	Percent of Data
1	Piccaire Granite	21	0.45
2	Gaultois Granite	150	3.21
3	Northwest Cove Granite	24	0.51
4	Straddling Granite	26	0.56
5	Northwest Brook Complex	200	4.28
6	Dolland Bight Granite	31	0.66
7	North Bay Granite Suite	793	16.98
8	Missing Island Granodiorite	6	0.13
9	Long Pond Diorite	4	0.09
10	Rocky Bottom Tonalite	15	0.32
11	Matthews Pond Granodiorite	19	0.41
12	Round Pond Gabbronorite	10	0.21
13	Partridge Berry Hill Granite	73	1.56
14	Through Hill Granite	23	0.49
15	Ackley Granite Suite	587	12.57
16	Eastern Meelpaeg Complex	26	0.56
17	Mt. Sylvester Granite	99	2.12
18	Avalon Straddling Granite	7	0.15
19	Burgeo Intrusive Suite	711	15.22
20	Avalon meta-igneous rocks		
21	Simmons Brook Batholith	24	0.51
22	Kepenkeck Granite		
23	Tolt Granite		
24	Meta Granite		
25	Hungry Grove Granite		
26	Koskaecodde Pluton		
27	Middle Ridge Granite	109	2.33
28	Third Berry Pond Granite	4	0.09
29	Sall the Maid Granite		
30	Gull Lake Intrusive Suite		
31	Devils Room Granite		
32	Laughlins Hill Gabbro		
33	Seal Cove Gabbro		
34	Anchor Drogue Granodiorite		
35	Cape Roger Mountain Batholith	18	0.39
36	Swift Current Granite	61	1.31
37	Berry Hills Granite	5	0.11
38	St. Lawrence Granite	189	4.05
39	Grole Diorite		
40	Furbys Cove Granite		
41	Harbour Breton Granite	33	0.71
42	Pass Island Granite	15	0.32
43	Belleoram Granite	14	0.30
44	Cross Hills Complex	111	2.38
45	Holyrood Granite	79	1.69
46	Rencontre Lake Granite		
47	Sage Pond Granite		
48	Francois Granite	180	3.85
49	Chetwynd Granite	48	1.03
50	Otter Point Granite		
51	Roti Granite East		
52	Hawkes Nest Pond Porphyry		
53	Petites Granite		
54	Strawberry Granite		
55	Windowglass Hill Granite		
56	Rose Blanche Granite	12	0.26
57	Ironbound Monzonite	34	0.73
58	Peter Snout Granite		
59	Cochrane Pond Granite	5	0.11
60	Buck Lake Granite		
61	Baggs Hill Granite		
62	Rotten Brook Granodiorite	10	0.21
63	Roti Granite West	16	0.34
64	Nitty Gritty Brook Granite		
65	Isle aux Morts Brook Granite		
66	Mollyguajeck Pluton		
67	Aspen Brook Pluton	9	0.19
68	Barren Lake Gabbro		
69	Belle Island Granite		
70	Big Round Pond Granite		
71	Brighton Gabbro		
72	Burlington Granodiorite		
73	Business Cove Granite		
74	Cape Brule Porphyry		
75	Cape Freels Granite	31	0.66
76	Cape Ray Granite		
77	Causeway Diorite		
78	Cinq Cerf Complex		
79	Clarenville Granite	8	0.17
80	Coaker Porphyry		
81	Colchester Granodiorite		
82	Cripple Back Lake Quartzdiorite		
83	Deadmans Bay Granite	83	1.78
84	Dolland Arm Head Quartzdiorite		
85	Dolland Quartzdiorite		
86	Dover Fault Granite		
87	Dunamagon Granite		
88	Ernie Pond Gabbro		
89	Feeder Granodiorite		
90	Fogo Diorite–Gabbro Complex		
91	Fogo Granite		
92	Fogo Island Batholith		
93	Fredrickton Pluton	21	0.45
94	Gander Lake Pluton	19	0.41
95	Goose Hill Granite		
96	Grapnel Gabbro		
97	Gull Pond Granite		
98	Hare Hill Granite		
99	McCallum Granite	66	1.41
100	Harpoon Hill Gabbro		
101	Hodges Hill Granite		
102	Hungry Hill Gabbro		
103	Hungry Mtn Complex		
104	Indian Head Complex		
105	Indian Point Complex		
106	Iona Islands Intrusion		
107	Island Pond Pluton		
108	La Poile Batholith		
109	LaScie Granite		
110	LaScie Igneous Suite		
112	Lloyds River Intrusive Suite		
113	Lockers Bay Granite		
114	Loon Bay Granite		
115	Louil Hills Granite		
116	Maccles Lake Granite	27	0.58
117	Mansfield Head Granodiorite		
118	Middle Brook Granite	47	1.01
119	Moose Lake Granite		
120	Mt. Margaret Gabbro		
121	Mt. Peyton Intrusive Suite	64	1.37
122	Newport Granite	19	0.41
123	North Pond Granite		
124	Northern Granite		
125	Overflow Pond Granite	9	0.19
125	Overflow Pond Granite		
126	Partridge Point Granite		
127	Port aux Basques Granite		
128	Powder Horn Diorite Complex		
129	Puncheon Diorite		
130	Ragged Harbour Pluton	11	0.24

Table 1. *(continued)*

Pluton Number	Name of Unit or Plutonic Suite	Valid Records	Percent of Data
131	Red Island Granite	11	0.24
132	Red Rocks Granite		
133	Reddits Cove Gabbro		
134	Rocky Bay Pluton	8	0.17
135	Rodeross Lake Troctolite		
136	Seal Island Bight Syenite		
137	Seal Nest Cove Tonolite		
138	Skull Hill Granite		
139	South Lake Igneous Complex		
140	South Pond Granite		
141	South Pond Pluton		
142	Southwest Brook Intrusive Suite		
143	Tacks Beach Pluton		
144	Forche Harbour Pluton	11	0.24
145	Terra Nova Granite	24	0.51
146	Terra Nova River Pluton	6	0.13
147	Terra Nova River West	4	0.09
148	Cat Arm Granite		
149	Tilting Igneous Complex		
150	Topsails Granite		
151	Topsails Intrusive Suite		
152	Tulks Hill Granite		
153	Tulks Pond Syenite		
154	Twillingate Granite	55	1.18
155	Twin Lakes Diorite Complex		
156	Valentine Lake Quartz Monzonite		
157	Wadsworth Gabbro		
158	Wareham Granite		
159	Wellmans Cove Diorite		
160	Coney Head Complex		
161	Whaleback Gabbro		
162	White Point Pluton		
164	Kings Point Complex		
165	Wild Cove Pond Igneous Suite		
166	Winterland Porphyry		
167	Cloud River Pluton		
168	Hooping Harbour Pluton		
169	Hooping Harbour Pluton II		
170	Horse Chops Pluton		
171	Lake Michel Pluton		
172	Leg Pond Pluton		
173	Budgell Harbour Gabbro		
174	Great Burnt Lake Granite	53	1.13
175	North Bay Granite (part)	21	0.45
176	Unassigned		
177	Steel Pond Gabbro	38	0.81
178	Ebbegunbaeg Granite	22	0.47
179	Georges Pond Granite		
180	Potato Hill Diorite		
181	Taylor Brook Gabbro Complex		
182	North Branch Brook Granite		
183	Killdevil Hill Granodiorite		
184	Lomond River Granodiorite		
185	Deadwolf Brook Granite		
186	Unassigned		
187	Unassigned		
188	Main Gut Gabbro		
189	Boogie Lake Monzonite		
190	Top Pond Brook Tonalite		
191	Costigan Lake Intrusion		
192	Tower Hill Intrusion		
193	Dawes Pond Pluton		
194	Salmon Pond Granite		
195	Mansfield Cove Complex		
196	Hall Hill Complex		
197	Loon Pond Pluton		
198	Main River Granite		
199	Lemottes Lake Granite		
200	Spread Eagle Gabbro		
202	Deepwater Point Granodiorite	5	0.11
202	Gander Lake West Pluton	3	0.06
-	No Pluton Number Assigned	203	4.35
	TOTAL NUMBER OF RECORDS	4670	100.00

NOTES: 1. As the database is presently being checked, many of these figures are subject to revisions.
2. Some 'plutons' are actually subdivisions of others within the database. For example, 'Hungry Grove Granite' (25) is a unit within the Ackley Granite Suite (15)
3. 'Plutons' with large amounts of data (e.g., Burgeo Intrusive Suite) are composite, and can be extensively subdivided.

A number of simple numerical tests will be performed. For major-element data, checking calculated totals will catch most data entry errors. Trace-element data errors are far more difficult to detect. The simplest and most effective procedure for detection is to examine element-frequency patterns for groups of 'outliers' that have extremely high or low concentrations, particularly where such values are inconsistent with major-element indices (e.g., SiO_2 content) or outside the normal range for granitoid rocks. Outlying trace-element values (notably for U, Mo, Cu, Pb, Zn, etc.) will also highlight mineralized samples that are not presently identified as such.

CHANGES TO DATABASE FORMAT AND ORGANIZATION

Developing a database of this size and complexity is an evolving process, as it is impossible to foresee all problems at the outset. A number of format modifications and additions are currently being considered.

There is a need for a method of identifying both the original source of samples (i.e., project, year, geologist), and the sources and analytical methods for geochemical data, as data for a single 'pluton' may come from a variety of sources. It is not good practice to compare trace-element data derived by different methods at different laboratories, particularly if precision and accuracy data are unavailable; the re-analysis program (see below) is the long-term solution to this problem. At present, using a series of numerical codes to cover all of the various analytical combinations seems to be the best solution, although it is unavoidably cumbersome. An alternative solution, which involves the creation of a series of variables such as Ba(XRF), Ba(AA), Ba(ICP) etc., would result in a huge increase in the size of the database, and consequent data-processing problems.

There is also a requirement for a consistent method for denoting subunit or map unit that will result in a unique value for each subunit of each 'pluton' to be labelled in the file description. Using existing map units is impractical, as their format varies so greatly (e.g., 10, 10a, 10.3, Dg, Og2, SDgp, etc.) and they are non-unique. The best option appears to be a decimal format where the integer portion is the 'pluton number', e.g., 10.01, 10.02, 10.03, 10.04 etc.

As Newfoundland incorporates portions of UTM zones 21 and 22, there may also be a need to add extra coordinate variables that provide a consistent framework for plotting, by recalculating to a single UTM zone. At the present time, data are converted to zone 21 coordinates by an in-house program prior to plotting, but it cannot be assumed that all end-users will be able to do this. If this approach is adopted, the original coordinates will also need to be retained, as these are essential in dealing with existing topographic maps. Alterations to database formats within SPSS-X are not difficult, but the 'nuisance factor' increases with the size of the file involved. It is therefore advisable to address such considerations, and minor matters such as revisions of variable names, before adding any newly acquired or assembled data.

RE-ANALYSIS OF OLDER SAMPLE POPULATIONS

As previously stated, there is considerable variation in the vintage and quality of geochemical data. An area of particular concern is the Strong *et al.* (1974) data, which are an important source of information.

REPRODUCIBILITY CHECK OF STRONG *ET AL.* (1974) DATA

In order to assess the reproducibility of the Strong *et al.* (1974) data, 50 sample powders were selected on a random basis, and re-analyzed via the NDME laboratory. Results suggested that some of the major-element and trace-element data may not be completely reliable. Some examples are illustrated in Figure 3; these cover a range from good reproducibility (e.g., Zr) to serious inconsistency (e.g., MgO).

On the basis of this investigation, it was decided to re-analyse the entire Strong *et al.* (1974) sample collection for nearly all the elements. This should eliminate reliability problems, and ensures that data are of comparable quality to more recent surveys. In addition, it provides a wide range of trace-element data (e.g., Li, Be, Ga, Y, Nb, Mo, La, Ce) that were not determined during the original survey.

WORK IN PROGRESS

Re-analysis of the Strong *et al.* (1974) data was mostly completed by December, 1990, with the exception of a small number of samples (< 5 percent), for there are insufficient quantities of the original powder. Data have been keypunched via NLCS, and await a series of integrity checks. Updating will not take place until location and identification problems with the existing database are eliminated (see above). If missing samples cannot be located in any form, their records will probably be eliminated.

It is anticipated that complete re-analysis will also be required for other sample populations of similar vintage. One obvious example is the DeGrace *et al.* (1976) survey of the eastern Baie Verte Peninsula, for which original sample powders are proving difficult to locate. It is intended that similar reproducibility checks be made on data from the late 1970's.

Although the trace-element suite determined since about 1980 is fairly consistent, there are some variations between workers, notably with regard to elements such as Be, Li and Cd, and external analyses of Sn and W. Ideally, these inconsistencies should be resolved by selective re-analysis of samples affected, but this will depend upon available resources. This applies particularly to Sn and W, which are external analyses, and may be better approached by analyzing sample subsets. In the case of W, widespread use of tungsten carbide pulverization tools prior to 1980 renders re-analysis for this element futile in many areas, unless unpowdered sample splits are available.

FIELD WORK DURING 1989 AND 1990 FIELD SEASONS

Very little field work has been conducted to date as part of this project. In 1989, approximately 1 month of field work was conducted to familiarize the senior author with the characteristics and settings of Newfoundland granites, and to provide a starting point for a subcollection of representative and reference samples for isotopic analysis and other work (see below). In 1990, some low-cost field work was accomplished in the Placentia Bay region of the Avalon Peninsula, with emphasis on probable Paleozoic intrusions. These are of interest, as they afford a chance to verify the presence or absence of older basement rocks beneath the Avalon Zone via Nd isotopic analysis. Several of these intrusions are also unrepresented or poorly represented in the present granitoid database.

FUTURE DIRECTIONS

In this final section, a number of future objectives and directions for this project are discussed briefly. It should be emphasized that this is by no means an exhaustive list, and that any additional ideas or proposals for work not specifically mentioned below are welcome. Some of the work discussed below is dependent upon the participation of interested outside researchers.

BUILDING A TRULY REPRESENTATIVE DATABASE

Although the present core of the database contains an impressive amount of geochemical information, it is far from representative (Figure 2). This problem has two aspects. First, the many plutonic suites that are not represented in the

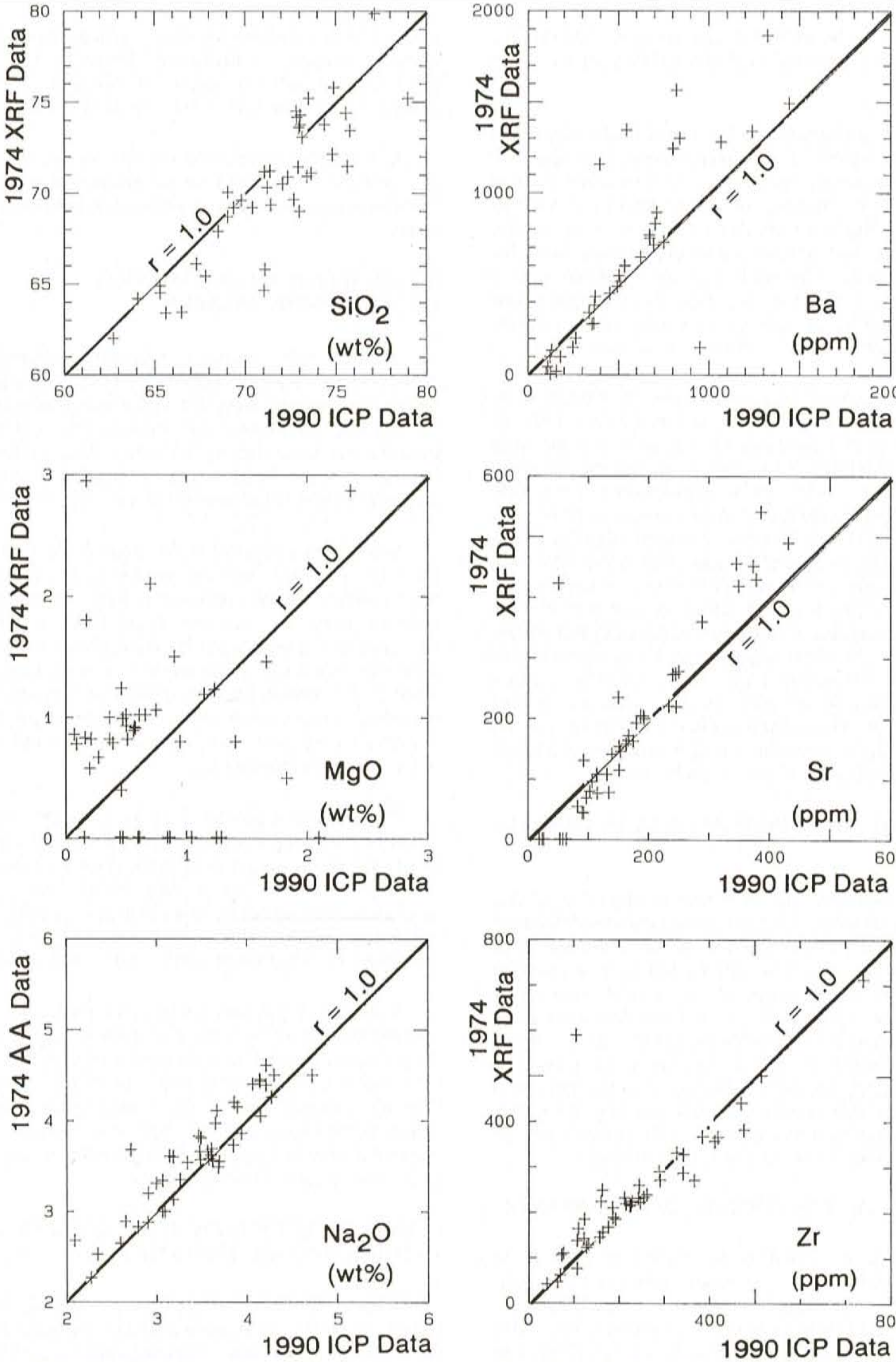

Figure 3. *Bivariate scattergrams illustrating the correlation between the XRF data for SiO_2, MgO, Na_2O, Ba, Sr and Zr of Strong et al. (1974) and ICP data acquired in 1990 as part of a reliability test based on 50 randomly selected powders from the original survey. The diagonal line (r=1.0) illustrates the relationship expected for perfect correlation of both sets of analyses.*

database need to be examined and sampled. Second, the coverage of many areas surveyed by previous studies requires upgrading.

There are advantages to having a numerical database that is truly representative, i.e., in which plutonic suites and rock types are represented in approximate proportion to their areal abundance. First, measures of central tendencies such as means and medians are not distorted in favour of specific areas. Second, and perhaps more importantly, extensive parameters such as frequency histograms and proportions of different rock types can be used as descriptive and comparative tools, in addition to conventional intensive parameters such as mean elemental concentrations.

Granitoid rocks of the south coast of Newfoundland are represented at an average density of 1 sample per 4 km^2 or better. Although it is anticipated that granites in some areas of proposed AMD 1990-1995 regional mapping projects (e.g., the Mount Peyton area) will be sampled on a comparable scale, it is unrealistic to expect that coverage can be brought to this level in all areas. However, it is hoped that field work in years to come, as part of this and other AMD 1990-1995 projects, will allow coverage of much of the island at densities of between 1 sample per 16 and 1 sample per 25 km^2. Although the database (on an island-wide scale) will still be unrepresentative, it will be simple to produce a representative version for interpretative purposes by selecting random subsets from densely sampled areas at a selection level of 20 to 25 percent. Alternatively, subsets could be selected on a purely geographic basis. In localized studies in such areas, the full complement of samples can be retained.

RELEASE OF GEOCHEMICAL DATA IN DIGITAL FORMAT

This is, of course, one of the prime objectives of this project. It is intended to release accumulated geochemical data in digital format, progressively between 1991 and 1993, commencing with data from eastern and parts of southern Newfoundland, where much of the present database is localized (Figure 2). Data releases will include existing high-quality geochemical data, re-analysed data from early surveys, and data from mapping and sampling under the auspices of this project. Each release will be accompanied by printed documentation that summarizes the geology, petrology, geochemistry and economic potential of the plutonic suite(s), based on previous mapping and new field work.

EXPANSION OF THE GEOCHEMICAL DATABASE

In addition to expanding the number of records, to provide more representative coverage, attempts will be made to broaden the spectrum of elements for which data are available. Recent Departmental projects incorporate a wide trace-element suite, but some elements are beyond present analytical capabilities. These include Au, As, Sb, W, Sn (ore elements or indicators of such) and Hf, Ta, Cs, Yb and Sc (important in classification and petrogenetic modelling). From a petrogenetic and economic viewpoint, full rare-earth element (REE) analyses are also a valuable asset. The ICP mass-spectrometer at Memorial University is capable of providing a significant portion of this data, but external analysis by NAA or XRF will be needed for some elements.

It is clearly unrealistic to expect that data for all these elements can be obtained for the entire database, but it is intended to analyze a representative subset from most plutonic suites.

MINERALOGICAL AND MINERAL GEOCHEMISTRY STUDIES

This aspect remains virtually untouched in Newfoundland, but is of interest for several reasons. First, variations in mineral chemistry within individual plutons may be valuable pathfinders for mineralizing systems. For example, systematic changes in biotite, chlorite and muscovite compositions are effective in discrimination of mineralized and barren areas of the Ackley Granite Suite (Tuach, 1987).

Second, on a regional scale, mineralogical studies can provide information about a number of physico-chemical factors such as source components, depths of emplacement, volatile contents, oxygen fugacities and liquidus temperatures—areas that are largely unknown quantities for most Newfoundland intrusions, except in the most general sense. In this context, the work of Ague and Brimhall (1988a, b) on biotite compositions in the Sierra Nevada batholith is of particular relevance, and a similar study could easily be initiated in Newfoundland.

Third, mineral geochemistry is a valuable adjunct to classification schemes based upon petrology and whole-rock geochemistry. In strongly porphyritic granitoid rocks that are probably 'cumulates' (in a very broad sense), mineral geochemistry trends are far better indicators of differentiation trends than whole-rock compositions, which are strongly influenced by retention of phenocrysts and sample size.

Work of this type that can be accomplished by electron microprobe techniques is fairly straightforward; however, at the present time, such methods are not capable of providing trace-element data that are better than semi-quantitative. Conducting mineral separations is extremely time-consuming and labour-intensive, and thus expensive. Work of this type can probably only be practically accomplished via a thesis or similar research contract project.

INTEGRATION OF LITHOGEOCHEMICAL AND OTHER REGIONAL DATABASES

Since the mid-1980's, a growing emphasis has been placed at NDME toward development of computer databases for a range of spatial data, including surficial geochemistry (e.g., lake and stream sediments) and geophysical information. This has been coupled with acquisition of technology that permits integrated display and analysis via image-analysis and geographic information systems.

Integration of lithogeochemical and surficial geochemical information is a direction of considerable promise, as regional multi-element lake-sediment data have considerable utility in mapping bedrock characteristics (e.g., Davenport, 1982; Kerr and Davenport, *in press*). The availability of lithogeochemical data at a similar (or closer) spacing should allow the definition of surficial signatures for specific plutonic associations, and aid in developing geological maps for poorly-exposed areas. Similar arguments apply to integration of geochemical and geophysical data.

ISOTOPIC GEOCHEMISTRY

In 1988, a project to investigate the isotopic systematics of Newfoundland granites was established, with funding from LITHOPROBE supporting science grants to workers at Memorial University. The objectives are to establish the probable source material(s) for individual plutonic suites, and to identify the nature and extent of various lower crustal blocks beneath the Newfoundland Appalachians. Obviously, this type of information is also important in assessing the significance of various plutonic suites with reference to the Appalachian tectonic cycle.

Samples archived from previous NDME mapping projects (and external sources) were analyzed in 1988 and 1989 for Nd and oxygen isotopic compositions. These preliminary results are discussed by Fryer *et al.*, (1989) and Kerr *et al.*, (1990b), and have a number of important implications for crustal structure beneath Newfoundland. Numerous additional samples were collected for isotopic investigation during the 1989 and 1990 field seasons. These are presently being processed through chemical separations to collect Nd for mass-spectrometry, and results should be available during 1991. Further sampling for isotopic analysis will be conducted in conjunction with field work in 1991 and 1992.

In addition to Nd and oxygen, a number of other isotopic systems are of potentially great importance in assessing the origins of these magmas. Initial Sr isotopic ratios are already available from many intrusions via Rb–Sr isochron studies. However, U–Pb geochronology has shown that many Rb–Sr ages are erroneously young, suggesting isotopic disturbance, and initial ratios from such sources may not be reliable. An alternative approach may be to use mineral separates for Sr analysis–Sr-rich, Rb-poor species such as apatite may be insensitive to processes that affect whole-rock Sr-isotope systematics. Clinopyroxene might also be a possible candidate in some plutonic suites of more mafic composition.

Hafnium isotopic compositions have to date been utilized only by a very small number of studies utilizing granitoid rocks (e.g., Patchett *et al.*, 1981), but have found wider application in studies of mantle evolution. The Lu–Hf system is similar in principle to the more widely used Sm–Nd system and provides similar evidence regarding crustal residence periods, but with greater sensitivity. The best materials for initial Hf isotopic analysis are widely acknowledged to be zircon separates, as these contain abundant Hf, but no Lu. Uranium–lead geochronology over the last few years has created a substantial inventory of zircon separates, and the idea of obtaining regional Hf isotope data from this material should be investigated. Common Pb isotope data, normally obtained on K-feldspar separates, may also be a valuable source of information relating to source terranes.

GEOCHRONOLOGICAL STUDIES

Geochronological control is of great importance in any attempt to group Newfoundland granitoid suites by association or setting, and precise age determinations are important in interpreting isotopic signatures in terms of petrogenesis and source(s). Since 1980, the focus of geochronology programs has been on U–Pb zircon techniques, mostly via the Royal Ontario Museum laboratory. A large number of granitoid plutons have been dated by T.E. Krogh, G.R. Dunning and coworkers, and the stratigraphic framework for Appalachian plutonism has become much clearer as a result. As part of this project, U–Pb ages were obtained by R.D. Tucker in 1989 from the Middle Ridge Granite, the Cape Freels Granite and the François Granite. Both the Cape Freels and Middle Ridge granites have given Silurian ages, adding to the large body of data suggesting an important period of Silurian magmatic activity in Newfoundland (Dunning *et al.*, 1988). The François Granite has been shown, not surprisingly, to be of Middle Devonian age. It is anticipated that U–Pb dating of granitoid plutons will continue to be conducted as part of regional mapping programs under AMD 1990-1995 as they are commonly important in establishing regional age relationships. It is also hoped that this granitoid database project will also be able to fund small amounts of geochronological work directly over the next few years.

Although the conventional U–Pb zircon technique commonly used in North America provides precise ages of emplacement for many granitic rocks, it is less effective in identifying and unravelling complex inherited components that may yield valuable information regarding potential source material(s) for magmas. The Sensitive High-Resolution Ion MicroProbe (SHRIMP) developed in Australia can analyze single grains and even portions of grains (e.g., growth zones and inclusions) *in situ*. Recent work by I.S. Williams and others in Australia (personal communications, 1990), illustrates the great potential of this instrument to resolve some long-standing problems in granite petrology.

In summary, there is no doubt that ion microprobe studies would make an extremely valuable contribution to a project concerned partly with the origins of granitoid magmas. As a long-term objective, this idea should definitely be further explored, as the SHRIMP technology will have an increasingly important role in years to come, and is ideally suited to the types of problems that granitoid rocks present.

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