*Current Research (1993) Newfoundland Department of Mines and Energy,
Geological Survey Branch, Report 93-1, pages 113-126*

ALKALI-AGGREGATE REACTIVITY IN NEWFOUNDLAND: FIELD AND LABORATORY INVESTIGATIONS

D. Bragg
Geochemistry, Geophysics and Terrain Sciences Section

ABSTRACT

Alkali reactivity is a problem found in some concrete structures, and although it may not be the main cause of their premature deterioration, it is often the catalyst for other forms of destruction. Samples for this report were generated from field work carried out during 1989, 1990 and 1991, which consisted of an assessment of bedrock to determine its quality and quantity for potential industrial use, and from work carried out by the Newfoundland Department of Work, Services and Transportation in 1990.

Petrographic analysis and rating of potential alkali reactivity were carried out on each sample. Standard chemical tests, such as the Accelerated Mortar Bar and the Concrete Prism were performed on most samples, and the Mortar Bar test was performed on selected samples.

An investigation of concrete structures from across the Island was also carried out to document evidence of alkali reactivity. It consisted of noting the date of construction, rock types used, types of cracking, and the degree and type of deterioration.

Results from testing of aggregate samples and from visual observations of concrete structures show that certain sedimentary and igneous rock types are alkali reactive. Although, the results of testing methods used are inconsistent, most of the concrete structures examined are in excellent condition.

INTRODUCTION

Alkali reactivity in Newfoundland was first investigated systematically in 1985, when CANMET contracted Golder Associates (Golder Associates, 1989) to investigate the potential alkali reactivity of a variety of rocks in Newfoundland. This author participated in the collection of samples and the petrographic analysis.

The demand for high-quality aggregate along the eastern seaboard of the United States, for concrete use, has led to the depletion of known reserves within this area, requiring new economic aggregate deposits to be found. There, aggregate producers are unable to meet the demand in such densely populated regions because of stringent environmental constraints and municipal regulations; hence new supplies of aggregate must be sought outside this heavily regulated and densely populated area. Because of this demand, surveys were carried out in 1989 and 1990 (Bragg *et al.*, 1990; Bragg 1991; Bragg and O'Driscoll, 1992) along the south coast of Newfoundland (Figure 1), and in Trinity Bay (Figure 2), to locate high-quality non-reactive aggregate at tide-water in order to supply potential markets in the United States. Samples from this field work and samples collected from existing quarries across the Island (Figure 3) by the Department of Work, Services and Transportation (Bragg and Foster, 1992) were used as a basis for this report, to determine the degree of alkali reactivity of potential bedrock aggregate for concrete. The Department of Work, Services and Transportation samples were supplied by private construction companies on condition that their locations be keep confidential.

GEOLOGY

Newfoundland's geology (Figure 4) includes a wide range of intrusive, volcanic, metamorphic and sedimentary rocks (Colman-Sadd *et al.*, 1990). These rocks have been structurally deformed to various degrees, and as presently exposed, they display varying degrees of alteration due to weathering.

A basic consideration in the choice of an aggregate for producing concrete for use in a field environment is the potential reactivity of the aggregate. A preliminary assessment in the field may be made by investigating the geology of an area to see if any rock types known to cause alkali reactivity are present, such as andesite, rhyolite, argillite, dacite, granite, greywacke, gneiss, schist, etc. (Dolar-Mantuani, 1983).

ALKALI REACTIVITY

There are three types of alkali-aggregate reaction known to occur: 1) alkali-silica; 2) alkali-silicate; and 3) alkali-carbonate.

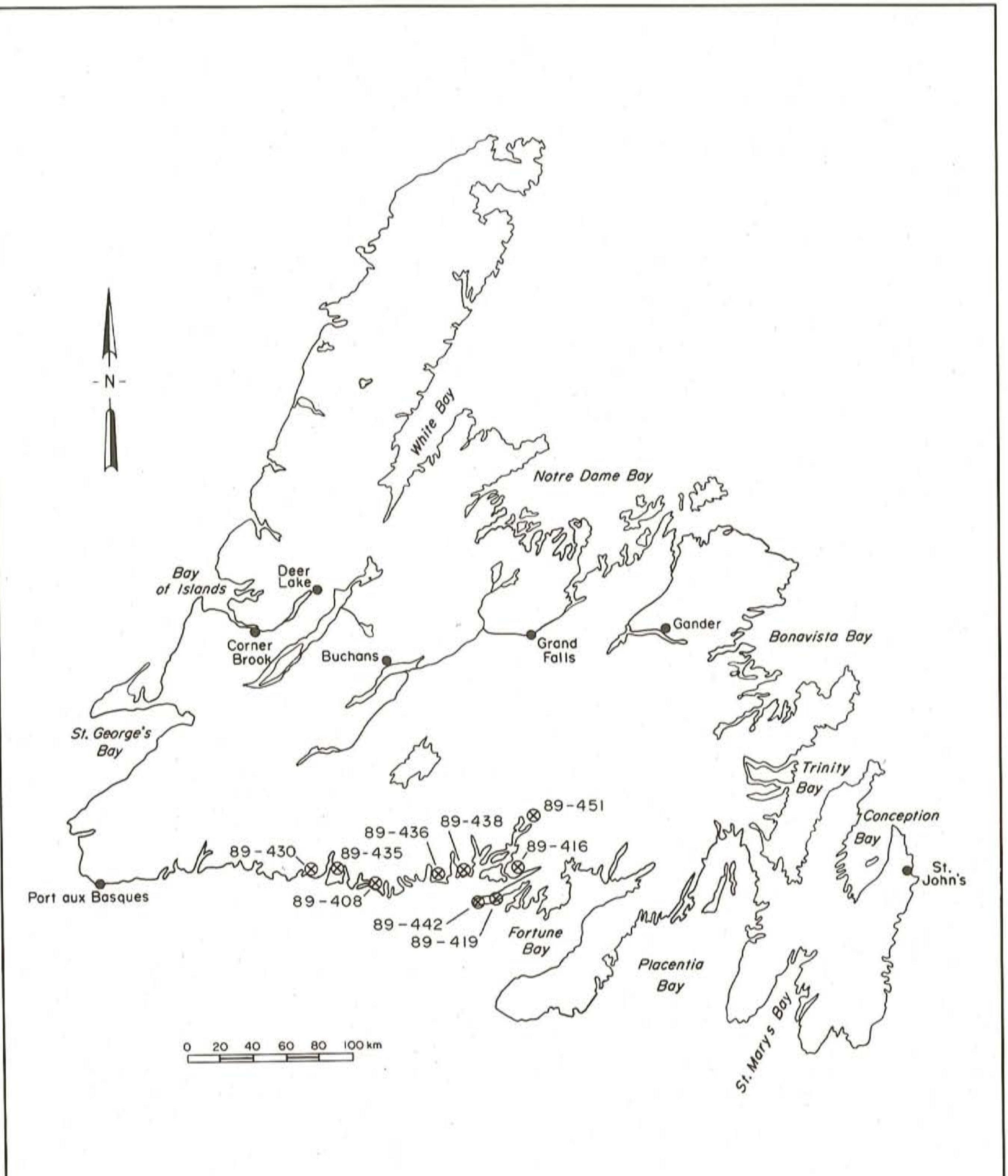

Figure 1. *Site locations on south coast.*

Alkali-silica reaction occurs when various forms of reactive silica, such as cryptocrystalline silica (e.g., chert, opal, flint, chalcedony), metastable crystalline (e.g., tridymite and cristobalite) and siliceous glass (e.g., volcanic glasses and manufactured glass) react with the hydroxide ions released from the alkalis in the cement during hydration. The reaction is associated with the formation of an expansive alkali-silica gel in the concrete.

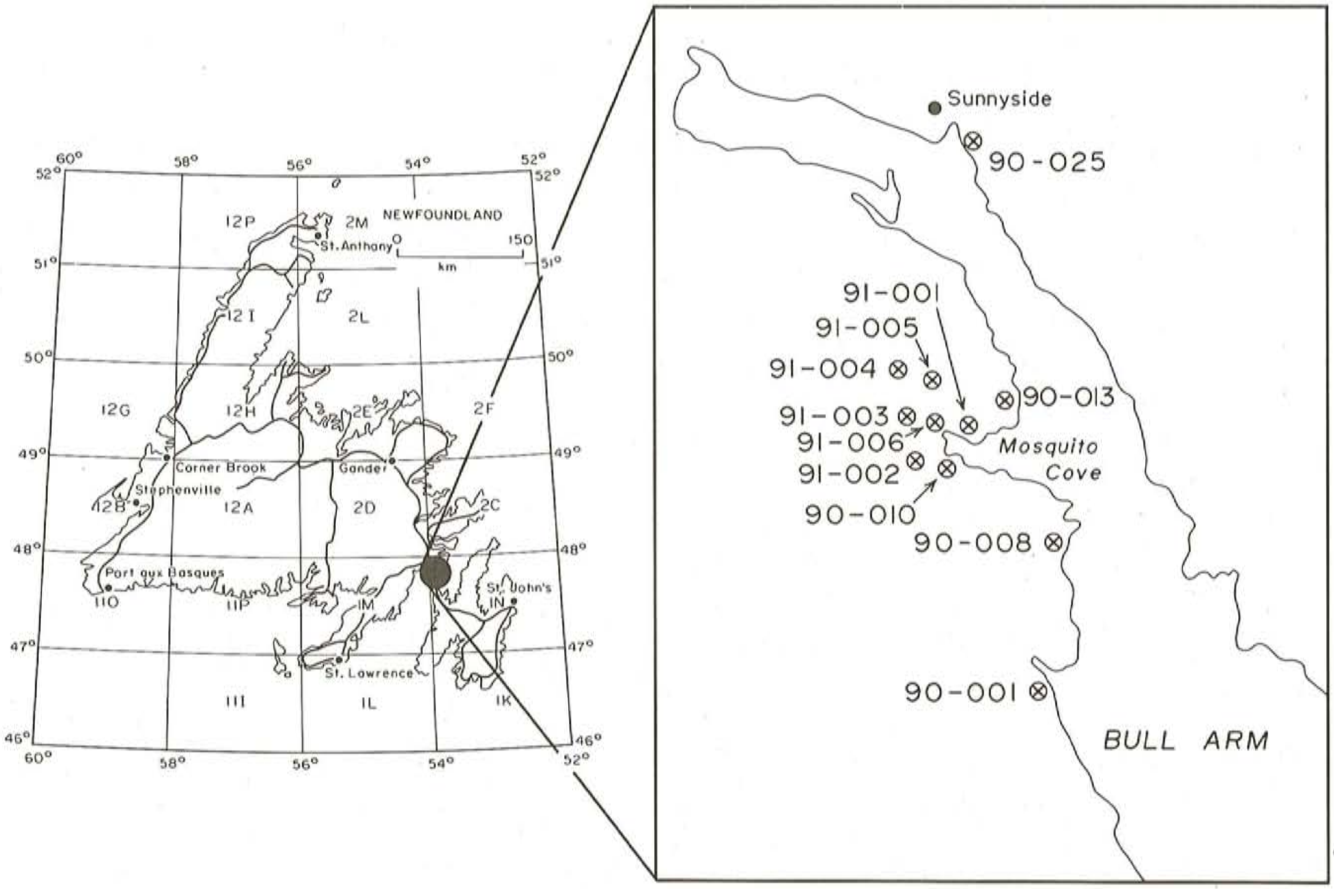

Figure 2. *Location map of study area in Trinity Bay.*

Alkali-silicate reaction occurs with various rock types such as greywacke, argillite, quartzwacke, quartz-arenite, quartzite, hornfels, gneiss, granite, phyllite, arkose and sandstone. These rock types may react with the hydroxide ions from the alkalis released from the cement during hydration. The reaction is known as a slow/late expansion and is associated with the expansion of coarse aggregate particles, in addition to gel formation. It is believed (by some researchers) that the above rock types contain various amounts of the reactive silica minerals and thus this reaction may be known as a silica reaction.

Alkali-carbonate reaction occurs between certain argillaceous dolomitic limestone and the alkaline pore solution in the concrete. The reaction is associated with the expansion of aggregate particles without gel formation.

FIELD INVESTIGATION

Field investigation consisted of a detailed examination of potential bedrock aggregate sites for the export market. Each site investigation consisted of rock identification, representative sampling, determination of type and thickness of overburden, and the recording of significant geological features such as: faults, folds, fractures, joints and veining (Plates 1, 2, 3, 4 and 5, respectively). These affect the breakage pattern of the rock and thus effect the cost of quarrying, i.e., amount of explosives required, and the amount of waste material; such as excessively oversized or undersized blast material. Microfractures (Plate 6) are also important because they may affect the compressive strength of the rock.

The following features are equally important when quarrying bedrock for aggregate use:

1) Grain size—generally, the finer the grain size the harder the bedrock.

2) Bedding planes—these are important because rocks tend to break more easily along bedding planes.

3) Flow structures—in igneous rocks, these tend to be planes of weakness.

4) Mineral alignments—these are common in metamorphic rocks and tend to be planes of weakness and thus important with regard to excessive rock breakage when blasting, crushing, and during the blending of the crushed rock with cement or asphalt binders.

5) Mineralization, veining and alteration zones—these are also noted because of their potential planes of weakness

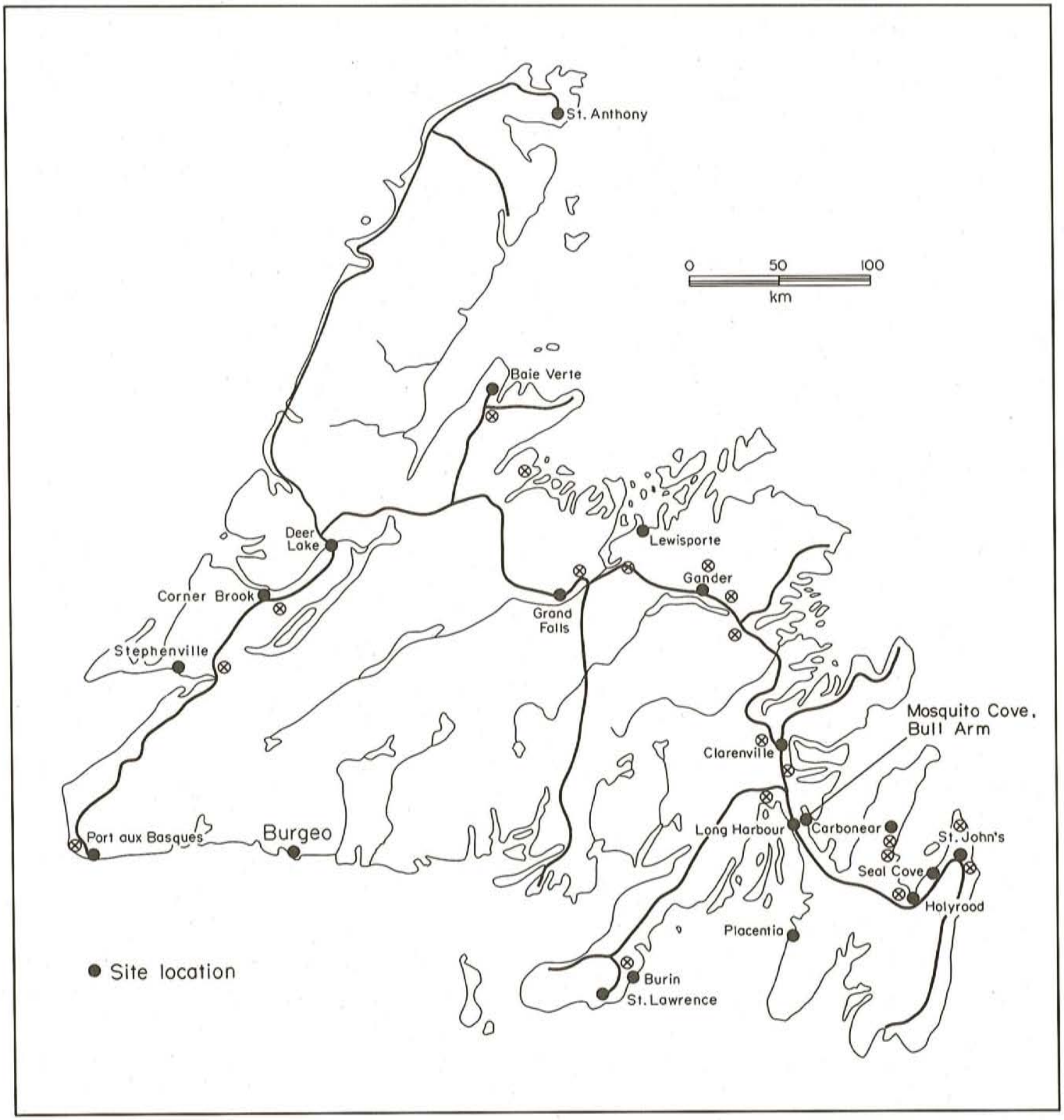

Figure 3. *Site locations across the Island.*

along boundary zones, which may cause a deleterious effect.

A second component of the field investigation was a visual assessment of concrete structures, taking note of the date of construction, rock types used, types of cracking, degree and type of deterioration. A large number (173) of concrete structures (bridges, building, retaining walls and breakwaters) were assessed over a three-year period and these structures ranged in age from two to eighty-six years; the degree of deterioration varied from intensive (Plate 7) to no deterioration (Plate 8). However most of the structures were generally, slightly to moderately weathered (Plates 9 and 10).

The oldest concrete structure investigated was the lighthouse at Cape Race, which was constructed in 1906 and is still in excellent condition (Plate 11). Most structures were

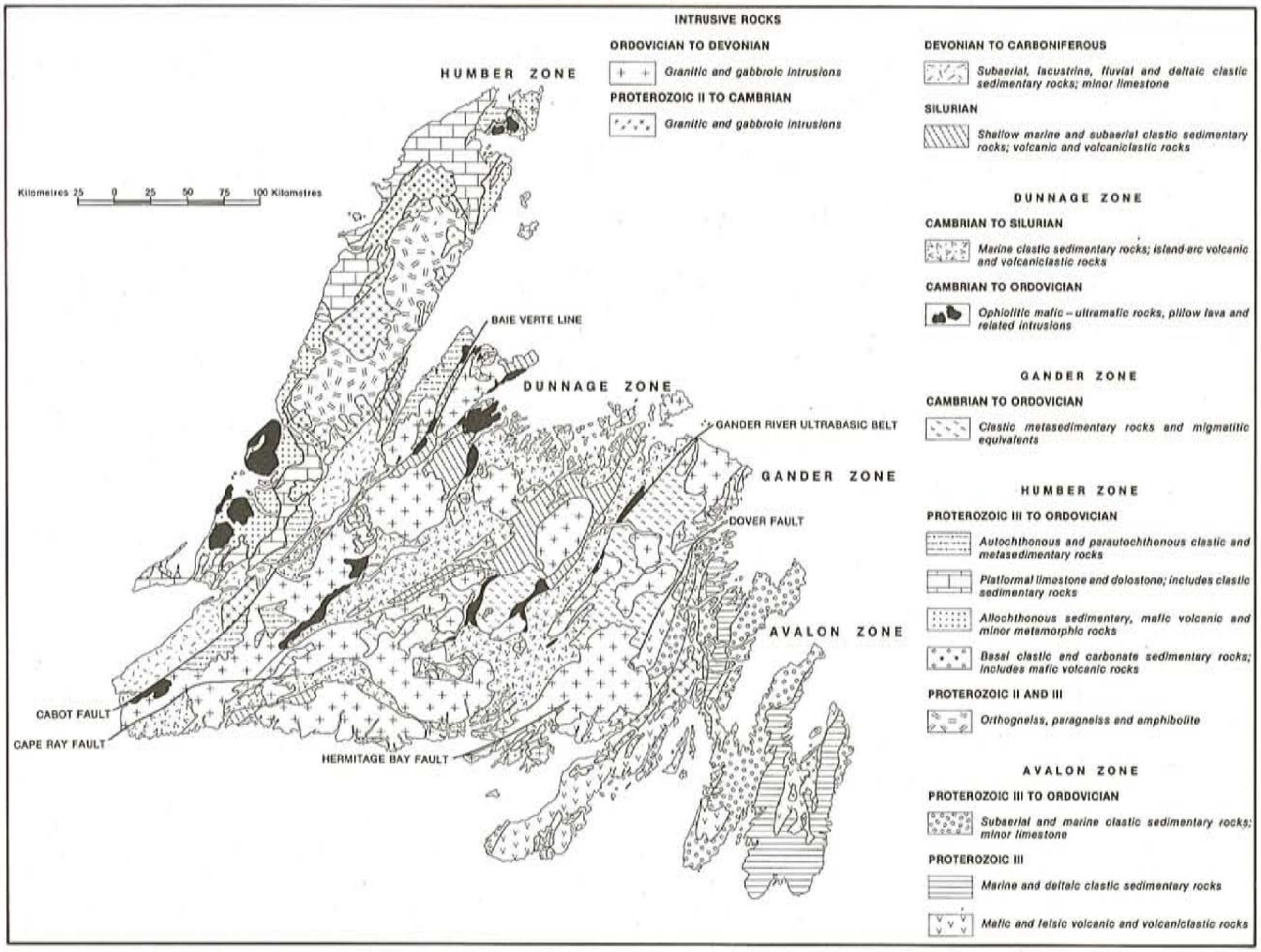

Figure 4. *Geology of the Island of Newfoundland compiled by J.P. Hayes in 1987.*

post-1930, with 70 percent built in the 1960's and 1970's, 20 percent built in the 30's and 40's and the remaining 10 percent built in the 1980's. Most of the problems with concrete deterioration were noted in structures built in the late 1960's and 1970's. Common types of deterioration were due to freeze/thaw (Plate 12) and alkali reactivity (Plate 13), although in extreme cases of deterioration, a combination of factors is believed to be involved such as freeze/thaw, alkali reactivity and quality control.

Cracking is a common feature noted in concrete structures. Several different types were noted, including shrinkage (Plate 14) caused by cement hydration. Tensional cracks (Plate 15) are caused by stress or load being applied to the concrete or rebar, and alkali-reactivity cracking (Plate 16) is caused by the reaction of the alkali in the cement with certain types of silica in the aggregate. Alkali reactivity was noted in a number of concrete structures and thus clearly shows that alkali-reactive aggregates were used commonly in the construction of concrete structures.

LABORATORY INVESTIGATION

The laboratory investigation consisted of petrographic analysis and chemical testing.

Petrography

Petrographic analysis was performed on all the aggregate samples collected. This consisted of examining hand samples with the aid of a hand lens and by thin-section examination using a petrographic microscope. After each analysis, a petrographic number (Bragg and Norman, 1988), which gives the initial physical quality of a rock or aggregate sample, was calculated. Table 1 shows different petrographic factor ranges for different rock types found in Newfoundland. A petrographic rating number (Bragg and Foster, 1992) was assigned to each sample; this number gives the initial chemical quality for alkali-aggregate reactivity (AAR) of a rock or aggregate sample and is to be used as a screening test. The criteria used for establishing a petrographic rating number is shown in Table 2.

A general petrographic description of each sample submitted by the Department of Work, Services and Transportation is given in Table 3. Tables 4 and 5 give a general petrographic description of selected samples from the 1989 and 1991 survey, in which alkali-reactivity testing was carried out.

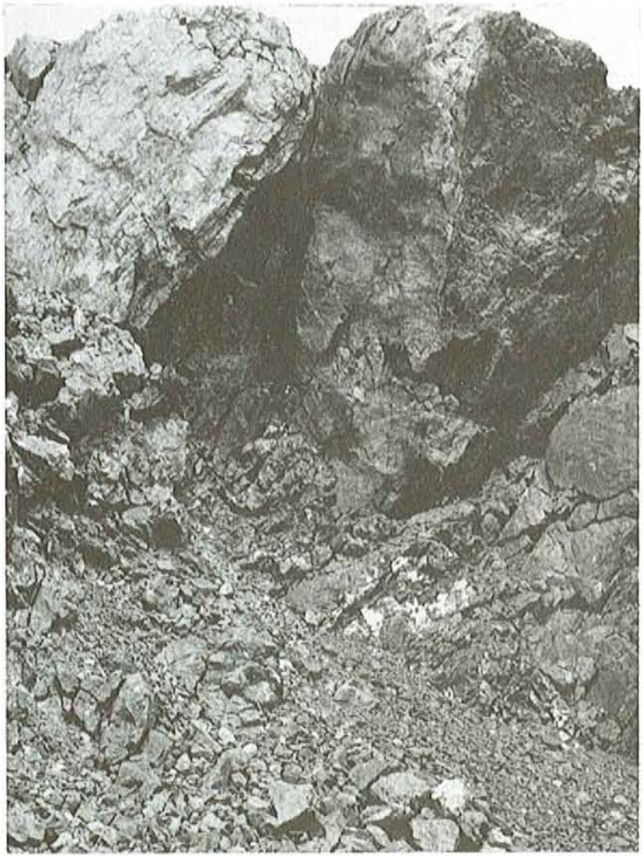

Plate 1. *Faulting in basalt, also fault contact basalt and granite.*

Plate 2. *Folding in limestone and shale beds.*

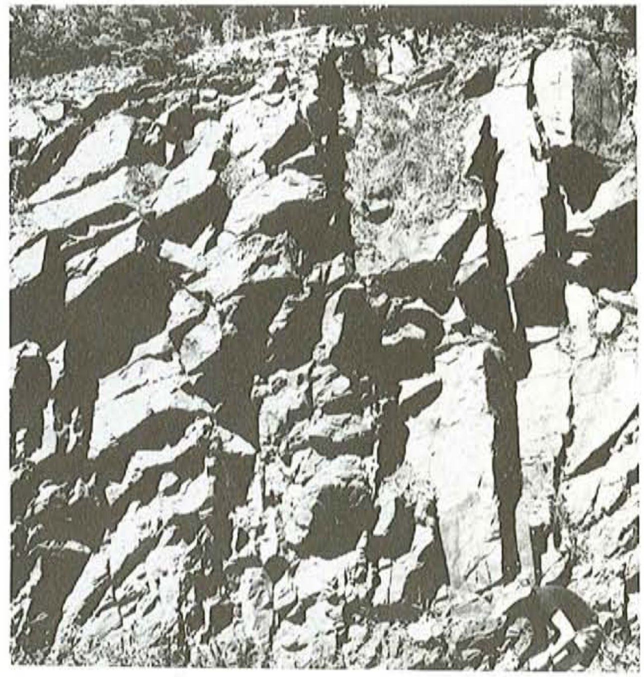

Plate 3. *Fracturing in massive sandstone beds.*

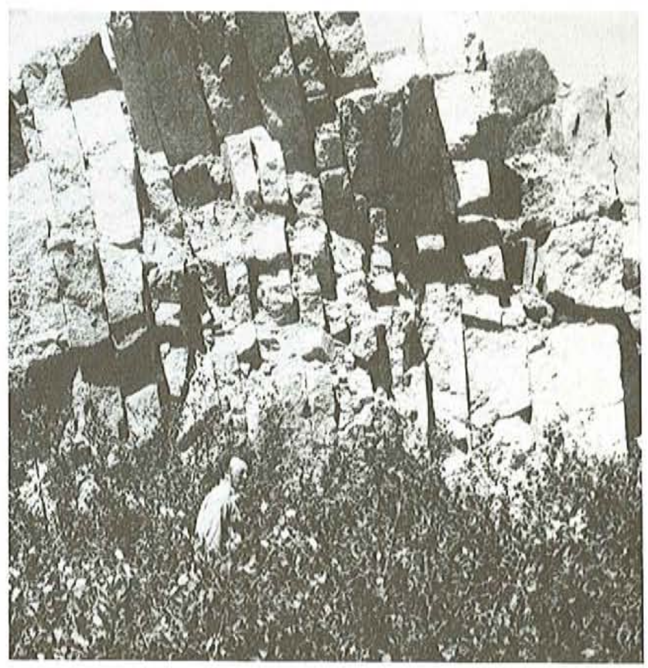

Plate 4. *Jointing in granite.*

Chemical Testing

Alkali-reactivity testing such as Concrete Prism (Canadian Standards Association, 1977), involves the making of a concrete prism and the recording of its rate of expansion over a period of 6 to 12 months, while it is stored in a moist environment at 100 percent relative humidity. An expansion rate greater than 0.04 percent after one year is considered to indicate potential reactivity. The Mortar Bar test (American Society for Testing and Materials, 1987), which is the most commonly used test, involves the making of mortar bars and recording their rate of expansion, while stored at 38°C and in an environment at 100 percent relative humidity; an expansion greater than 0.1 percent after 1 year is considered potentially reactive. The Accelerated Mortar Bar test

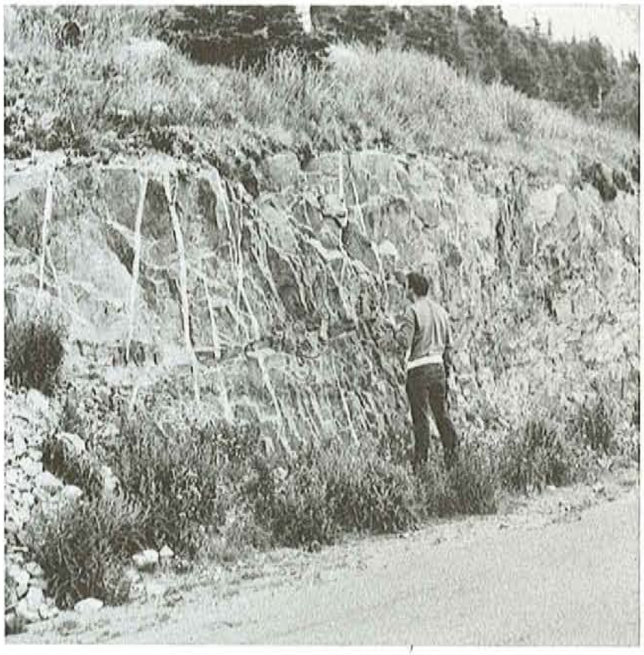

Plate 5. *Quartz veining in siltstone.*

Plate 6. *Microfractures in quartz and feldspars crystals.*

(Oberholster and Davis, 1986), is similar to the mortar bar test, except that the bars are submerged in water for 1 day at 80°C and then stored in a solution of 1N NaOH at 80°C for 14 to 16 days; an expansion greater than 0.15 percent is considered potentially reactive; this test should also be used as a screening test. The Concrete Prism and Accelerated Mortar Bar tests were performed on most of the samples, whereas the Mortar Bar test was performed on randomly selected samples.

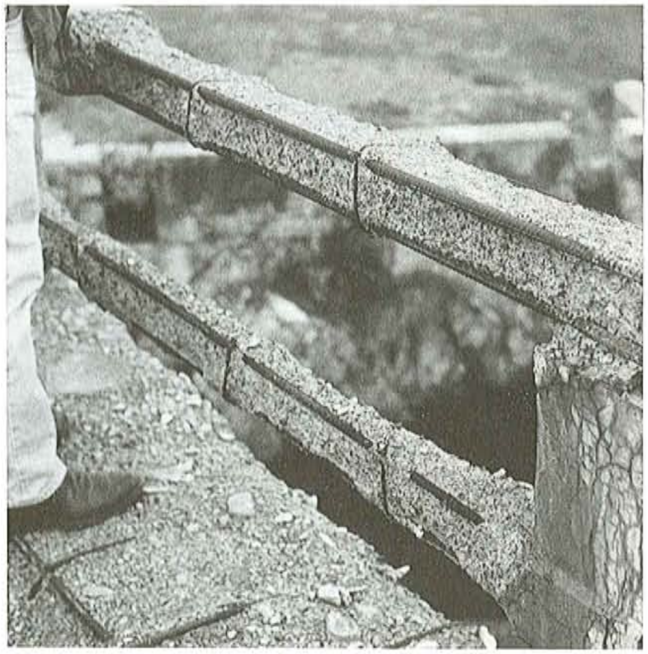

Plate 7. *Intensive deterioration in bridge.*

Plate 8. *Bridge in excellent condition, no cracking or weathering observed.*

Plate 9. *Bridge abutment showing only minor cracking.*

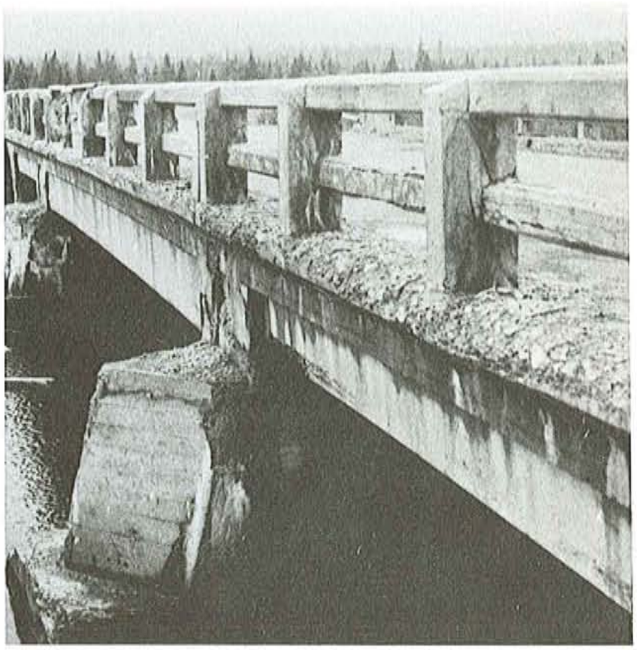

Plate 10. *Moderately weathered bridge.*

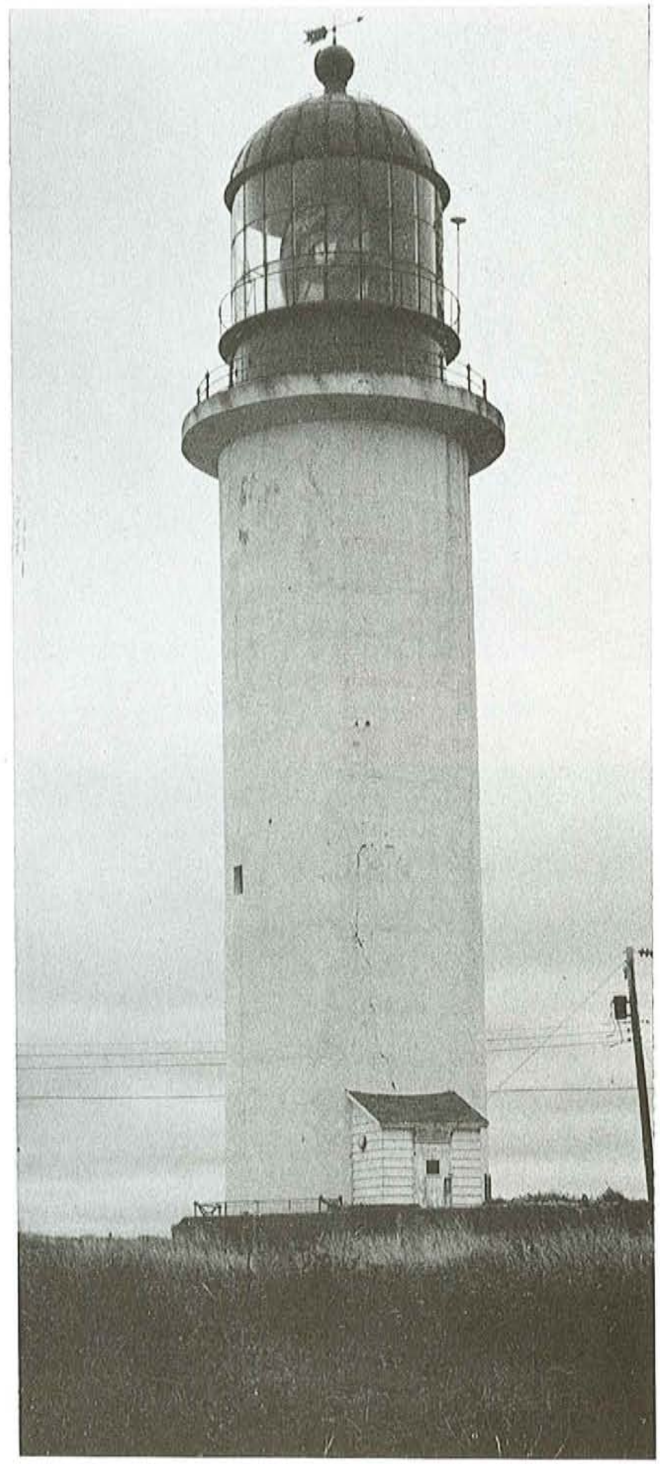

Plate 11. *Lighthouse at Cape Race. Built in 1906.*

RESULTS

Tables 6, 7, 8 and 9 show the results from petrographic analysis, Accelerated Mortar Bar, Mortar Bar and Concrete Prism tests respectively; while Table 10, shows the comparison of results from these tests.

DISCUSSION

Table 10 shows the relationships between petrography, Accelerated Mortar Bar, Mortar Bar and Concrete Prism tests.

Samples 90-101, -103, -105, -107, -108, -113, -116, -117 and -121, 89-408, -419, -430, -435, -436 and -442, 90-008 and -010, 91-001, -002, -004 and -006 were all rated low (1) or non-reactive by petrography based on mineral content and rock types. All the above samples were rated non-reactive in the Accelerated Mortar Bar test, except for samples 90-107 and -113, which were rated reactive. Samples 90-101, -105, -113, -116, -117 and -121 were all rated non-reactive in the concrete prism test. Sample 90-008 was rated reactive in the mortar bar and concrete prism tests, while 90-113 was rated reactive in the concrete prism.

Mortar Bar and Concrete Prism tests were not performed on samples 89-408, -419, -430, -435, -436, -442, and 90-008, -010, and 91-001, -002, -004 and -006.

Samples 90-102, -111, -115 and 89-416 and -436 are rated slight (2) or marginal, tending toward non-reactive, petrographically. Sample 90-102 is considered marginally reactive in the Concrete Prism test. No Accelerated Mortar or Mortar Bar tests were performed on this sample. Sample 90-111 was considered non-reactive in Accelerated Mortar Bar, Mortar Bar and Concrete Prism tests. Sample 90-115 was rated non-reactive in the Concrete Prism; no Accelerated Mortar Bar and Mortar Bar test were performed on this sample. Samples 89-416 and -436 were rated non-reactive in the Accelerated Mortar Bar test; no Mortar Bar or Concrete Prism tests were performed on this sample.

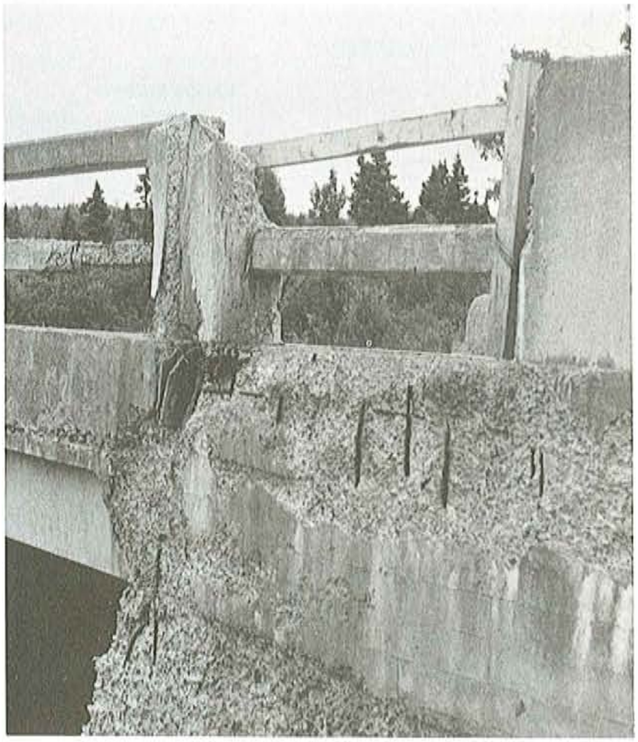

Plate 12. *Deterioration due to freeze/thaw.*

Plate 13. *Deterioration due to alkali-reactivity.*

Samples 90-109, -110, -118, -120, and samples 89-451, 90-013 are all rated moderate(3) and tending toward reactive, petrographically. Sample 90-109 is moderately reactive in the Accelerated Mortar Bar and Mortar Bar tests and reactive

Plate 14. *Dry shrinkage cracks in concrete bridge railing.*

Plate 15. *Cracking due to tension.*

in the Concrete Prism tests. Sample 90-110 is reactive in the Accelerated Mortar and Mortar bar tests and non-reactive in the Concrete Prism test. Sample 90-118 is reactive in the Accelerated Mortar Bar test and non-reactive in the Concrete Prism test; no Mortar Bar test was performed on this sample. Sample 90-120 was rated reactive in the Accelerated Mortar Bar and Concrete Prism test; no Mortar Bar test was performed on this sample. Sample 89-451 was rated non-reactive in the accelerated mortar Bar test; no Mortar Bar or Concrete Prism test was performed on this sample. Sample 90-013 was rated reactive in the Accelerated Mortar Bar test, the other two chemical tests were not performed on this sample.

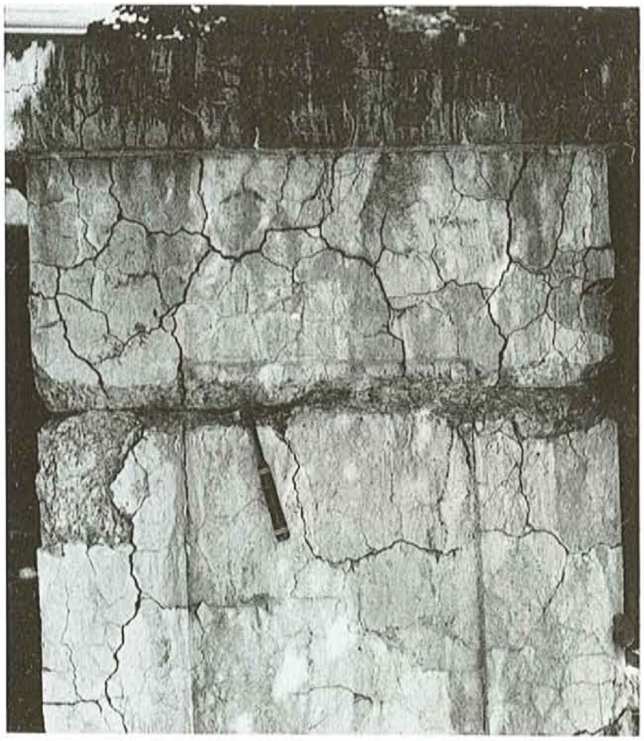

Plate 16. *Cracking due to alkali-reactivity.*

Samples 90-104, -106, -112, -114, -119, -122, -123, -001, -025 and 91-003 and -005 were all rated high petrographically. Sample 90-104 was rated reactive in the Concrete Prism test; no Accelerated Mortar bar or Mortar bar tests were performed on this sample. Samples 90-106 and 90-112 were rated reactive in all three chemical tests. Sample 90-119 was rated non-reactive in all three chemical tests. Sample 90-122 was reactive in the Accelerated Mortar bar test and non-reactive in the Concrete Prism test; no Mortar Bar test was performed on this sample. Sample 90-123 was reactive in the Concrete Prism test; no Accelerated Mortar Bar or Mortar Bar tests were performed on this sample. Samples 90-001, 91-003 and 91-005 all rated reactive in the Accelerated Mortar Bar test; no Mortar Bar or Concrete Prism tests were performed on this sample. Sample 90-025 was non-reactive in the Accelerated Mortar Bar test; the other two chemical tests were not performed on this sample.

The results from these tests show that the following rocks of Newfoundland are non-reactive: sedimentary rocks (sandstones and limestone), igneous rocks (granite, diorite, gabbro, basalt) and metamorphic rocks (granitic gneiss and phyllite) of western Newfoundland; igneous rocks (granite, diorite, gabbro,) of the south coast of Newfoundland; igneous rocks (granite, gabbro, diorite and basalt) of central Newfoundland; igneous rocks (basalt and rhyolite) on the Burin Peninsula and igneous rocks (basalt, granite and rhyolite) on the Avalon Peninsula, Newfoundland.

Reactive rocks also come from around the Island, but the majority of them are found on the Avalon Peninsula. The reactive rocks are certain dolomitic limestones of the west

Table 1. Petrographic factors for different rock types found in Newfoundland

Rock Type	Petrographic Factor Range	Usual Factor
1. Sandstone	1-6	1
2. Shale	10	10
3. Mudstone	3-6	6
4. Siltstone	1-6	1
5. Conglomerate	1-10	6
6. Arkose	1-6	1
7. Greywacke	1-6	1
8. Chert	1-3	1
9. Limestone	1-6	1
10. Dolomite	1-6	1
11. Quartzite	1-6	1
12. Granite	1-6	1
13. Gabbro	1-6	1
14. Diorite	1-6	1
15. Felsic volcanic rocks	1-6	1
16. Mafic volcanic rocks	1-6	1
17. Intermediate volcanic rocks	1-6	1
18. Pyroclastic rocks	1-6	3
19. Metavolcanic rocks	2-6	3
20. Gneiss	1-6	3
21. Schist	3-10	6
22. Phyllite	3-10	6
23. Marble	1-6	1
24. Slate	10	10
25. Amphibolite	3-10	6
26. Ultramafic	3-10	6
27. Metasediments	1-6	3
28. Argillite	3-6	3
29. Iron Formation	6-10	6
30. Drift deposits	1-10	1-10

Table 2. Petrographic rating system of aggregates for their potential alkali-aggregate reactivity

Rating	Criteria	Comments
Low (1)	No known alkali-reactive rocks or minerals	Non-reactive
Slight(2)	*1 to 10% of known alkali-reactive rocks or minerals	Marginal (tending towards non-reactivity)
Moderate(3)	>10%, but less than 20% of known alkali-reactive rocks or minerals	Marginal (tending toward reactive)
High(4)	** >20% of known alkali-reactive rocks or minerals	Reactive

* Very low amounts (less than 1%) of microcrystalline quartz (chert, opal, cristobalite) may cause alkali reactivity due to pessimum effect.

** Some reactive rocks and minerals have a pessimum effect (amount of material which causes maximum expansion), therefore, these rocks or minerals would not react deleteriously with the cement paste if the pessimum amount is not reached, which can be 5 to 50 percent for some rock types and less than 1 percent for certain minerals.

Table 3. General description of samples submitted for analyses by Department of Works, Services and Transportation

Sample Number	General Description		% per sample
90-101	Rock fragments:	gabbro	(40)
		sandstone	(20)
		diorite	(15)
		basalt	(15)
		granite	(5)
		rhyolite	(5)
90-102	Rock fragments:	diorite	(50)
		granite	(35)
		siltstone	(15)
90-103	Rock fragments:	limestone	(85)
		dolomite	(10)
		sandstone	(5)
90-104	Rock fragments:	sandstone	(55)
		siltstone	(45)
90-105	Rock fragments:	granite	(45)
		sandstone	(30)
		basalt	(25)
90-106	Rock fragments:	dolomitic limestone	(100)
90-107	Rock fragments:	granite	(100)
90-108	Rock fragments:	granite	(80)
		basalt	(17)
		gabbro	(2)
		rhyolite	(1)
90-109	Rock fragments:	siltstone	(45)
		granite	(30)
		psammite	(25)
90-110	Rock fragments:	siltstone	(80)
		sandstone	(20)
90-111	Rock fragments:	granite	(85)
		gneiss	(15)
90-112	Rock fragments:	siltstone	(100)
90-113	Rock fragments:	siltstone	(100)
90-114	Rock fragments:	granite	(40)
		rhyolite	(25)
		basalt	(30)
		diorite	(5)
90-115	Rock fragments:	phyllite	(45)
		granite	(25)
		sandstone	(20)
		limestone	(10)
90-116	Rock fragments:	granite	(40)
		diorite	(35)
		basalt	(30)
		rhyolite	(5)

Table 3. *Continued*

Sample Number	General Description		% per sample
90-117	Rock fragments:	granitic gneiss	(98)
		gabbro	(2)
90-118	Rock fragments:	basalt	(35)
		sandstone	(30)
		granite	(25)
		rhyolite	(10)
90-119	Rock fragments:	basalt	(55)
		rhyolite	(45)
90-120	Rock fragments:	basalt	(30)
		quartzite	(25)
		sandstone	(15)
		granite	(10)
		gabbro	(5)
		rhyolite	(5)
90-121	Rock fragments:	limestone	(90)
		dolomite	(10)
90-122	Rock fragments:	greywacke	(55)
		siltstone	(25)
		basalt	(15)
		diorite	(5)
90-123	Rock Fragments:	dolomitic limestone	(100)

Table 4. General description of samples collected from the south coast of Newfoundland

Sample Number	General Description		% per sample
89-408	Rock Fragments:	Gabbro	(100)
89-416	Rock Fragments:	Granite	(100)
89-419	Rock Fragments:	Diorite	(100)
89-430	Rock Fragments:	Granite	(100)
89-435	Rock Fragments:	Granite	(100)
89-436	Rock Fragments:	Granite	(100)
89-438	Rock Fragments:	Granite	(100)
89-442	Rock Fragments:	Diorite	(100)
89-451	Rock Fragments:	Sandstone	(100)

Table 5. General description of samples collected in the Trinity Bay area

Sample Number	General Description		% per sample
90-001	Rock Fragments:	Tuff	(100)
90-008	Rock Fragments:	Basalt	(100)
90-010	Rock Fragments:	Basalt	(100)
90-013	Rock Fragments:	Sandstone	(100)
90-025	Rock Fragments:	Rhyolite	(100)
91-001	Rock Fragments:	Basalt	(100)
91-002	Rock Fragments:	Basalt	(100)
91-003	Rock Fragments:	Tuff	(100)
91-004	Rock Fragments:	Basalt	(100)
91-005	Rock Fragments:	Tuff	(100)
91-006	Rock Fragments:	Basalt	(100)

Table 6. Results from petrographic analysis

Sample #	Petrographic Rating	
90-101	low	(1)
90-102	slight	(2)
90-103	low	(1)
90-104	high	(4)
90-105	low	(1)
90-106	high	(4)
90-107	low	(1)
90-108	low	(1)
90-109	moderate	(3)
90-110	moderate	(3)
90-111	slight	(2)
90-112	high	(4)
90-113	low	(1)
90-114	high	(4)
90-115	slight	(2)
90-116	low	(1)
90-117	low	(1)
90-118	moderate	(3)
90-119	high	(4)
90-120	moderate	(3)
90-121	low	(1)
90-122	high	(4)
90-123	high	(4)
89-408	low	(1)
89-416	slight	(2)
89-419	low	(1)
89-430	low	(1)
89-435	low	(1)
89-436	low	(1)
89-438	slight	(2)
89-442	low	(1)
89-451	moderate	(3)
90-001	high	(4)
90-008	low	(1)
90-010	low	(1)
90-013	moderate	(3)
90-025	high	(4)
91-001	low	(1)
91-002	low	(1)
91-003	high	(4)
91-004	low	(1)
91-005	high	(4)
91-006	low	(1)

coast of Newfoundland; siltstones and psammites of central Newfoundland; and siliceous siltstones, sandstones, greywackes, tuffs and arkoses of the Avalon Peninsula. Further investigation is necessary to determine the geological units from which the above rock types originated.

CONCLUSIONS

Results from testing of the collected samples show an 85 percent accuracy rate between petrography and Accelerated Mortar test, 65 percent accuracy rate between petrography

Table 7. Results from the Accelerated Mortar Bar test

Sample #	Accelerated Mortar Bar % Expansion (0.15% limit)
90-101	0.066
90-102	0.000 (no-results)
90-103	O.129
90-104	0.000 (no-results)
90-105	0.060
90-106	0.359
90-107	0.213
90-108	0.144
90-109	0.162
90-110	0.339
90-111	0.090
90-112	0.232
90-113	0.171
90-114	0.198
90-115	0.000 (no-results)
90-116	0.090
90-117	0.046
90-118	0.283
90-119	0.149
90-120	0.305
90-121	0.000 (no-results)
90-022	0.257
90-123	0.000 (no-results)
89-408	0.025
89-416	0.092
89-419	0.038
89-430	0.053
89-435	0.073
89-438	0.052
89-442	0.023
89-451	0.064
90-001	0.365
90-008	0.020
90-010	0.029
90-013	0.404
90-025	0.078
91-001	0.053
91-002	0.037
91-003	0.254
91-004	0.015
91-005	0.286
91-006	0.018

Table 8. Results from the Mortar Bar test

Sample #	Mortar Bar % Expansion (limit 0.1%)
90-106	0.392
90-108	0.296
90-109	0.111
90-110	0.358
90-111	0.102
90-112	0.267
90-113	0.209
90-114	0.116
90-117	0.062
90-119	0.203

Table 9. Results from Concrete Prism test

Sample #	Concrete Prism % Expansion (0.04% limit)
90-101	0.029
90-102	0.069
90-103	0.000 (no-results)
90-104	0.111
90-105	0.043
90-106	0.112
90-107	0.047
90-108	0.046
90-109	0.084
90-110	0.028
90-111	0.042
90-112	0.041
90-113	0.021
90-114	0.028
90-115	0.042
90-116	0.024
90-117	0.034
90-118	0.033
90-119	0.031
90-120	0.074
90-121	0.024
90-122	0.019
90-123	0.191

and Mortar Bar test, and a 60 percent accuracy between petrography and Concrete Prism test. Comparisons of results from the three chemical tests show accuracy rates as follows: 64 percent accuracy rate between Accelerated Mortar Bar and Concrete Prism tests, 80 percent accuracy rate between Accelerated Mortar Bar and Mortar Bar tests; and 40 percent accuracy rate between the Concrete Prism and Mortar Bar tests.

These results show that the rate of accuracy for predicting alkali-aggregate reactivity of the collected samples is just as high or higher in some cases when using the proposed petrographic rating system, than using the chemical testing methods of Concrete Prism, Mortar Bar and Accelerated Mortar Bar tests. Thus petrographic analysis, which is cheaper and less time consuming than the chemical tests, may be a useful screening method in evaluating the potential of alkali reactivity of aggregate deposits.

Results from the concrete assessment show that alkali reactivity is present in a number of concrete structures (10 to 15 percent), and the reactive aggregate in these structures were greenish-grey siliceous siltstones, arkosic sandstone, greywacke, dolomitic-limestone, and acidic tuff. The majority (85 to 90 percent) of concrete structures show freeze/thaw deterioration, and a combination of factors such as freeze/thaw, alkali reactivity and quality control.

ACKNOWLEDGMENTS

The author would like to thank Mr. Brain Luffman for his capable assistance in performing the chemical testing methods on the samples for this report. Martin Batterson and Peter Davenport are thanked for their critical reviews of this report.

REFERENCES

American Society for Testing and Materials
1987: Standard test method for potential alkali-reactivity of cement-aggregate combinations (mortar bar method). Annual ASTM standards, C227-87.

Bragg, D.
1991: Bedrock aggregate surveys in the Bull Arm-Mosquito Cove, Trinity Bay and central Newfoundland. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 91-1, pages 13-18.

Bragg, D., Dickson, W.L. and St. Croix, L.
1990: A preliminary assessment of the south coast of Newfoundland as an area having potential for bedrock aggregate exports. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 90-1, pages 13-18.

Bragg, D. and Foster, K.
1992: Relationship between petrography and alkali-reactivity testing, samples from Newfoundland, Canada. Proceedings of the Ninth International Conference on Alkali-Aggregate Reactions in Concrete, London, England, July, 1992.

Bragg, D. and Norman, G.
1988: Aggregate potential of bedrock on the Avalon Peninsula. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 88-1, pages 367-372.

Bragg, D. and O'Driscoll C.F.
1992: Bedrock aggregate potential of the Great Mosquito Cove area, Bull Arm. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 92-1, pages 17-21.

Canadian Standards Association
1977: Test method for alkali-aggregate reaction. National Standard of Canada CAN 3-A23.2-M77, Canadian Standards Associations, A23.2-14A.

Colman-Sadd, S.P., Hayes, J.P. and Knight, I (compilers)
1990: Geology of the Island of Newfoundland. Newfoundland Department of Mines and Energy, Geological Survey Branch, Map 90-01, Scale 1:1 000 000.

Table 10. Comparison of results from different tests

Sample #	Deposit Type	Petrographic Rating	Accelerated Mortar Bar	Mortar Bar	Concrete Prism
90-101	Aggregate	Low (1)	0.066	0.000	0.029
90-102	Aggregate	Slight (2)	0.000	0.000	0.069
90-103	Bedrock	Low (1)	0.129	0.000	0.000
90-104	Bedrock	High (4)	0.000	0.000	0.111
90-105	Aggregate	Low (1)	0.060	0.000	0.043
90-106	Bedrock	High (4)	0.359	0.392	0.112
90-107	Bedrock	Low (1)	0.213	0.000	0.047
90-108	Aggregate	Low (1)	0.144	0.296	0.046
90-109	Aggregate	Moderate (3)	0.162	0.111	0.084
90-110	Bedrock	Moderate (3)	0.339	0.358	0.028
90-111	Aggregate	Slight (2)	0.090	0.102	0.042
90-112	Bedrock	High (4)	0.232	0.267	0.041
90-113	Bedrock	Low (1)	0.171	0.209	0.021
90-114	Aggregate	High (3)	0.198	0.116	0.028
90-115	Aggregate	Slight (2)	0.000	0.000	0.042
90-116	Aggregate	Low (1)	0.090	0.000	0.024
90-117	Bedrock	Low (1)	0.046	0.062	0.034
90-118	Aggregate	Moderate (3)	0.283	0.000	0.033
90-119	Aggregate	High (4)	0.149	0.119	0.031
90-120	Aggregate	Moderate (3)	0.305	0.000	0.074
90-121	Bedrock	Low (1)	0.000	0.000	0.024
90-122	Aggregate	High (4)	0.257	0.000	0.019
90-123	Bedrock	High (4)	0.000	0.000	0.191
89-408	Bedrock	Low (1)	0.025	0.000	0.000
89-416	Bedrock	Slight (2)	0.092	0.000	0.000
89-419	Bedrock	Low (1)	0.038	0.000	0.000
89-430	Bedrock	Low (1)	0.053	0.000	0.000
89-435	Bedrock	Low (1)	0.073	0.000	0.000
89-436	Bedrock	Low (1)	0.085	0.000	0.000
89-438	Bedrock	Slight (2)	0.052	0.000	0.000
89-442	Bedrock	Low (1)	0.023	0.000	0.000
89-451	Bedrock	Moderate (3)	0.064	0.000	0.000
90-001	Bedrock	High (4)	0.365	0.000	0.000
90-008	Bedrock	Low (1)	0.020	0.000	0.000
90-010	Bedrock	Low (1)	0.029	0.000	0.000
90-013	Bedrock	Moderate (3)	0.404	0.000	0.000
90-025	Bedrock	High (4)	0.078	0.000	0.000
91-001	Bedrock	Low (1)	0.053	0.000	0.000
91-002	Bedrock	Low (1)	0.037	0.000	0.000
91-003	Bedrock	High (4)	0.254	0.000	0.000
91-004	Bedrock	Low (1)	0.015	0.000	0.000
91-005	Bedrock	High (4)	0.286	0.000	0.000
91-006	Bedrock	Low (1)	0.018	0.000	0.000

Dolar-Mantuani, L.
1983: Handbook of Concrete Aggregate: A Petrographic and Technological Evaluation. Noyles Publications, Park Ridge, N.J., 345 pages.

Golder Associates
1989: Study of the alkali reactivity of potential concrete aggregates of Newfoundland. Report submitted to the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources, CANMET File No. 14Q.2344O-5-9255.

Oberholster, R.E. and Davis, G.
1986: An accelerated method for testing the potential alkali-reactivity of siliceous aggregate. *In* Cement and Concrete Research, Volume 16, pages 181-189.