RELATIONSHIP BETWEEN PETROGRAPHY AND RESULTS OF ALKALI - REACTIVITY TESTING, SAMPLES FROM NEWFOUNDLAND, CANADA

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In 1990, a suite of samples were collected from all the major aggregate producers across Newfoundland, to determine if any material currently being used is potentially alkali-aggregate reactive when used in concrete. Each sample was petrographically analyzed and a rating of potential alkali-reactivity was made. Standard chemical tests, such as, Accelerated Mortar Bar Test and the Concrete Prism Test were performed on most of the samples, and the Mortar Bar Test was performed on selected samples.

The rating, based on the petrographic analyses, gave very similar results to the more expensive and time-consuming chemical tests. Thus, petrographic analyses may be a useful reconnaissance method when evaluating the potential alkali-reactivity of aggregate deposits.

INTRODUCTION

In 1990, a suite of 23 samples were submitted to the senior author for petrographic analyses; also, the senior author was requested to develop a petrographic rating system for their potential alkali-aggregate reactivity. The criteria used in the rating system is as follows. 1) Samples with no known alkali-reactive rocks or minerals (based on hand samples and their thin-section analyses) were rated as low (non-reactive or 1). 2) Samples with 1 to 15 percent of known alkali-reactive rocks or minerals were rated as fair (tending toward non-reactivity or 2). 3) Samples with greater than 15 percent, but less than 40 percent of known alkali-reactive rocks or minerals were rated as good (tending toward reactivity or 3, and 4) samples with greater than 40 percent known alkali-reactive rocks or minerals were rated as high (reactive or 4).

The samples consisted of 6 crushed stone (bedrock) samples and 17 granular (sand/gravel) samples. The sample sites or locations were unknown to the first author at the time of this analyses. Once the petrographic analysis was completed and the samples were sent to the laboratory for testing, the sample locations were made known to the senior author (Figure 1). The rating system developed here is not to be confused with the petrographic number rating system which was developed by Bayne and Greenland (1) and improved upon by the Ontario Ministry of Transportation. A complete history of the development of the Petrographic Number is given by Rogers (2).

GEOLOGY AND PETROGRAPHY

Newfoundland's geology (Figure 2) is very complex and consists of a variety of granitic, volcanic, metamorphic and sedimentary rocks in various degrees of weathering and tectonic alteration.

The granitic or intrusive rocks consists of granite, diorite, monzonite, syenite, gabbro, quartz diorite, quartz monzonite, granodiorite and anorthosite which range in age from the Precambrian to Devonian.

The volcanic or extrusive rocks consists mainly of acidic (rhyolite, flow-banded rhyolite, porphyritic rhyolite, rhyolitic tuff, breccia and agglomerate); intermediate (andesite, dacite, trachyte,and associated tuffs); and basic volcanic rocks (basalt, diabase, tachylite and associated tuffs).

The metamorphic rocks consists of gneiss, schist, slate, marble, phyllite, pelite, psammite, mylonite, amphibolite, quartzite, granulite, serpentinite and hornfels.

The sedimentary rocks consists of arkose, greywacke, siltstone, shale, mudstone, conglomerate, limestone, argillite micaceous sandstone and shale, siliceous siltstone and sandstone, tuffaceous siltstone and sandstone.

Petrographic analyses was performed on each sample and a general description of each sample is given in Table 1 along with its rating for potential alkali-aggregate reactivity.

Petrographic examination is used by most researchers (Rogers (2), Dolar-Mantuani (3), Soles (4), Sims (5), Grottan-Bellew (6) and Mielenz (7)) as a tool to investigate the physical properties of an aggregate used in concrete or asphalt. It is hoped by the senior author that the proposed rating system, which is still in its infancy, may be used as a preliminary test to predict the potential alkali-reactivity of an aggregate sample.

CHEMICAL TESTING

Alkali-aggregate reactivity testing such as Concrete Prism test (CSA A23.2 - 14A) (8), involves the making of a concrete prism and recording its rate of expansion over a period of 6 to 12 months, while it is stored in a moist room at 100 percent relative humidity; an expansion rate of 0.04 percent after 1 year is considered potentially reactive. The Mortar Bar test (ASTM 227) (9), which is the most often used test, involves the making of mortar bars and recording their rate of expansion, while stored over water at 38°C; an expansion of 0.10 percent after 1 year is consided potentially reactive. The Accelerated Mortar Bar test (Oberholster and Davies, 1986) (10), is similar to the Mortar Bar test, except that the bars are headed in water for 1 day at 80°C and then the are stored in a solution of 1N NaOH at 80°C for 14 to 16 days; an expansion of 0.15 percent is consided potentially reactive. The Concrete Prism and Accelerated Mortar tests were performed on most of the samples, while the Mortar Bar test was performed on randomly selected samples.

Results of the alkali-reactivity testing were compared to the petrographic analyses results as shown in Tables 2, 3 and 4 and also to each other as shown in Tables 5, 6 and 7.

RESULTS AND DISCUSSION

Table 1, shows that 7 samples have a high (4) rating for potential alkali-aggregate reaction, 3 samples have a fair (2) rating and 4 samples have a good (3) rating; the latter two are both considered marginal for alkali-aggregate reaction. The remaining 9 samples have a low (1) rating for potential alkali-aggregate reactivity.

Tables 2, 3 and 4 show the relationships between petrography with the Accelerated Mortar bar, the Concrete Prism and Mortar Bar tests. Samples 1, 3, 5, 7, 8, 13, 16, 17 and 21 are all rated low (1) by petrography based on geology or rock types. Samples 1, 5 and 16, were rated non-reactive in the Accelerated Mortar Bar, and Concrete Prism tests. Samples 3 and 21 were both non-reactive in the concrete prism test, no accelerated mortar or mortar bar test were performed. Samples 7, 8 and 13 which were also rated low or non-reactive were varied in their rating or results as follows; sample 7 was rated reactive in the Accelerated Mortar Test and non-reactive in Concrete Prism test, no Mortar Bar test was performed on this sample. Sample 8 was non-reactive in the Accelerated Mortar and Concrete Prism tests and rated reactive in the Mortar Bar test. Sample 13 is rated reactive in the Accelerated Mortar Bar and Mortar Bar tests and non-reactive in the Concrete Prism test. Sample 17, was non-reactive in all three tests.

Samples 2, 11 and 15 are rated fair (2) or marginal tending toward non-reactive petrographically, however, only sample 2 is marginal, according to the Concrete Prism test, Accelerated Mortar and Mortar Bar tests were not performed on sample 2. Sample 11 was non-reactive in the Accelerated Mortar Bar test, and just within limit in the Concrete Prism and Mortar Bar tests. Only the Concrete Prism test was performed on sample 15 and results showed it to be just within the limit and thus non-reactive.

Samples 9, 10, 18, 20 are rated good (3) or marginal tending toward reactive petrographically. Sample 9 shows to be marginally reactive in the Accelerated Mortar and Mortar Bar tests and reactive in the Concrete Prism test. Sample 10 is rated reactive in the Accelerated Mortar Bar and Mortar Bar tests and non-reactive in the Concrete Prism test. Sample 18 is rated reactive in the Accelerated Mortar test and non-reactive in the Concrete Prism test, no Mortar Bar test was performed. Sample 20, is rated reactive in the Accelerated Mortar and Concrete Prism tests, no Mortar Bar test was performed.

Samples 4, 6, 12, 14, 19, 22 and 23, are rated as high (4) or reactive petrographically. Samples 4 and 23 were rated reactive in the Concrete Prism test, Accelerated Mortar Bar and Mortar Bar tests were not performed on these samples. Sample 6 was reactive in all three tests. Sample 12 was reactive in the Accelerated Mortar Bar and Mortar Bar tests, and non-reactive in the Concrete Prism test. Samples 14 and 19 were non-reactive in the Accelerated Mortar bar and Concrete Prism tests and reactive in the Mortar Bar test. Sample 22 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.

The percent accuracy rate between petrography and Accelerated Mortar bar test is 83 percent.

The percent accuracy rate between petrography and the Concrete Prism test is 63 percent.

The percent accuracy rate between petrography and Mortar bar test is 60 percent.

Tables 5, 6 and 7 show the comparisons of results between Accelerated Mortar Bar and Concrete Prism tests, Accelerated Mortar Bar and Mortar bar tests, Concrete Prism and Mortar Bar tests, respectively.

Table 5, shows an rate of accuracy of 64 percent between the Accelerated Mortar Bar test and Concrete Prism test.

Table 6, shows an accuracy rate of 80 percent, between the Accelerated Mortar Bar test and the Mortar Bar test.

Table 7, shows an accuracy rate of 40 percent between the Concrete Prism test and the Mortar Bar test.

CONCLUSION AND RECOMMENDATIONS

The results from Tables 2, 3, 4, 5, 6 and 7 clearly show that the rate of accuracy for predicting alkali-aggregate reactivity is just as high or higher in some cases when using petrographic data, than using the chemical testing methods of the Concrete Prism, Mortar bar and Accelerated Mortar tests. Thus petrographic analysis, which is cheaper and less time consuming than these chemical tests, may be useful method in evaluating the potential alkali-reactivity of aggregate deposits.

It is recommended that further testing be carried out when investigating and analyzing acidic volcanic rocks, currently the literature suggest that all acidic volcanic (rhyolites) are alkali-reactive, but this is clearly not the case.

More emphasises must be put on the petrography of the samples; it is not enough any more to say that a particular rock type is alkali-reactive, i.e., sandstone, greywacke, rhyolite, gneiss, etc, without giving the mineralogy and geochemistry of the specific sample. Presently in Canada, a petrographer has to give a sample a good to high rating if it contains significant amounts of any of the chosen rock types known to cause alkali-reactivity in Ontario, Quebec, or the Maritimes; and this must change in order to give a more reliable rating to a sample irrespective of its location.

ACKNOWLEDGMENTS

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TABLE 1. General description of each sample and rating assigned to each sample.

Sample number	General description		% per sample	Rating on AAR potential
90-001	Rock fragments:	gabbro	(40%)	low (1)
		sandstone	(20%)	
		diorite	(15%)	
		basalt	(15%)	
		granite	(5%)	
		rhyolite	(5%)	
90-002	Rock fragments:	diorite	(50%)	Fair (2)
		granite	(35%)	
		siltstone	(15%)	
90-003	Rock fragments:	limestone	(85%)	low (1)
		dolomite	(10%)	
		sandstone	(5%)	
90-004	Rock fragments:	sandstone	(55%)	high (4)
		siltstone	(45%)	
90-005	Rock fragments:	granite	(45%)	low (1)
		sandstone	(30%)	
		basalt	(25%)	
90-006	Rock fragments:	dolomitic - limestone	(100%)	high (4)
90-007	Rock fragments:	granite	(100%)	low (1)
90-008	Rock fragments:	granite	(80%)	low (1)
		basalt	(17%)	
		gabbro	(2%)	
		rhyolite	(1%)	
90-009	Rock fragments:	siltstone	(45%)	good (3)
		granite	(30%)	
		psammite	(25%)	

TABLE 1. Continued

90-010	Rock fragments:	siltstone	(80%)	good (3)
		sandstone	(20%)	
90-011	Rock fragments:	granite	(85%)	fair (2)
		gneiss	(15%)	
90-012	Rock fragments:	siltstone	(100%)	high (4)
90-013	Rock fragments:	siltstone	(100%)	low (1)
90-014	Rock fragments:	granite	(40%)	high (4)
		rhyolite	(25%)	
		basalt	(30%)	
		diorite	(5%)	
90-015	Rock fragments:	phyllite	(45%)	fair (2)
		granite	(25%)	
		sandstone	(20%)	
		limestone	(5%)	
90-016	Rock fragments:	granite	(40%)	low (1)
		diorite	(35%)	
		basalt	(30%)	
		rhyolite	(5%)	
90-017	Rock fragments:	granitic gneiss	(98%)	low (1)
		gabbro	(2%)	
90-018	Rock fragments:	basalt	(35%)	good (3)
		sandstone	(30%)	
		granite	(25%)	
		rhyolite	(10%)	
90-019	Rock fragments:	basalt	(55%)	high (4)
		rhyolite	(45%)	
90-020	Rock fragments:	basalt	(35%)	good (3)
		quartzite	(25%)	
		sandstone	(15%)	
		granite	(10%)	
		gabbro	(5%)	
		rhyolite	(5%)	
90-021	Rock fragments:	limestone	(90%)	low (1)
		dolomite	(10%)	
90-022	Rock fragments:	greywacke	(65%)	high (4)
		siltstone	(25%)	
		basalt	(10%)	
		diorite	(5%)	
90-023	Rock Fragments:	dolomitic - limestone	(100%)	high (4)

TABLE 2. Comparison of results between petrography and and Accelerated Mortar Bar (NBRI).

Sample #	Petrography	Accelerated Mortar Bar % Expansion (0.15%)
90-001	low (1)	0.066
90-002	fair (2)	0.000 (no-results)
90-003	low (1)	0.129
90-004	high (4)	0.000 (no-results)
90-005	low (1)	0.060
90-006	high (4)	0.359
90-007	low (1)	0.213
90-008	low (1)	0.144
90-009	good (3)	0.161
90-010	good (3)	0.339
90-011	fair (2)	0.090
90-012	high (4)	0.232
90-013	low (1)	0.171
90-014	high (4)	0.198
90-015	fair (2)	0.000 (no-results)
90-016	low (1)	0.090
90-017	low (1)	0.046
90-018	good (3)	0.283
90-019	high (4)	0.149
90-020	good (3)	0.305
90-021	low (1)	0.000 (no-results)
90-022	high (4)	0.257
90-023	high (4)	0.000 (no-results)

TABLE 3. Comparison of results between Petrography and Concrete Prism test.

Sample #	Petrography	Concrete Prism % Expansion (0.04% limit)
90-001	low (1)	0.029
90-002	fair (2)	0.069
90-003	low (1)	0.000 (no-results)
90-004	high (4)	0.111
90-005	low (1)	0.043
90-006	high (4)	0.112
90-007	low (1)	0.047
90-008	low (1)	0.046
90-009	good (3)	0.084
90-010	good (3)	0.028
90-011	fair (2)	0.042
90-012	high (4)	0.041
90-013	low (1)	0.021
90-014	high (4)	0.028
90-015	fair (2)	0.042
90-016	low (1)	0.024
90-017	low (1)	0.034
90-018	good (3)	0.033
90-019	high (4)	0.031
90-020	good (3)	0.074
90-021	low (1)	0.024
90-022	high (4)	0.019
90-023	high (4)	0.191

TABLE 4. Comparison of results between Petrography and Mortar Bar test.

Sample #	Petrography	Mortar Bar % Expansion (limit 0.1%)
90-006	high (4)	0.392
90-008	low (1)	0.296
90-009	good (3)	0.111
90-010	good (3)	0.358
90-011	fair (2)	0.102
90-012	high (4)	0.267
90-013	low (1)	0.209
90-014	high (4)	0.116
90-017	low (1)	0.062
90-019	high (4)	0.203

TABLE 5. Comparison of results between Accelerated Mortar Bar test and the Concrete Prism test.

Sample #	Acelerated Mortar Bar % Expansion (0.15% limit)	Concrete Prism % Expansion (0.04%)
90-001	0.066	0.029
90-002	0.000 (no-results)	0.069
90-003	0.129	0.000 (no-results)
90-004	0.000 (no-results)	0.111
90-005	0.060	0.043
90-006	0.359	0.112
90-007	0.213	0.047
90-008	0.144	0.046
90-009	0.162	0.084
90-010	0.339	0.028
90-011	0.090	0.042
90-012	0.232	0.041
90-013	0.171	0.021
90-014	0.198	0.028
90-015	0.000 (no-results)	0.042
90-016	0-090	0.024
90-017	0.046	0.034
90-018	0.283	0.033
90-019	0.149	0.031
90-020	0.305	0.074
90-021	0.000 (no-results)	0.024
90-022	0.257	0.019
90-023	0.000 (no-results)	0.191

TABLE 6. Comparison of results between Accelerated Mortar Bar test and the Mortar Bar test.

Sample #	Accelerated % Expansion (0.15%)	Mortar Bar % Expansion (0.1%)
90-006	0.359	0.392
90-008	0.144	0.296
90-009	0.162	0.111
90-010	0.339	0.358
90-011	0.090	0.102
90-012	0.232	0.267
90-013	0.171	0.209
90-014	0.198	0.116
90-017	0.046	0.062
90-019	0.149	0.203

TABLE 7. Comparison of results between Concrete Prism test and Mortar Bar test.

Sample #	Concrete Prism % Expansion (0.04%)	Mortar Bar % Expansion (0.1%)
90-006	0.112	0.392
90-008	0.046	0.296
90-009	0.084	0.111
90-010	0.028	0.358
90-011	0.042	0.102
90-012	0.041	0.267
90-013	0.021	0.209
90-014	0.028	0.116
90-017	0.034	0.062
90-018	0.031	0.203

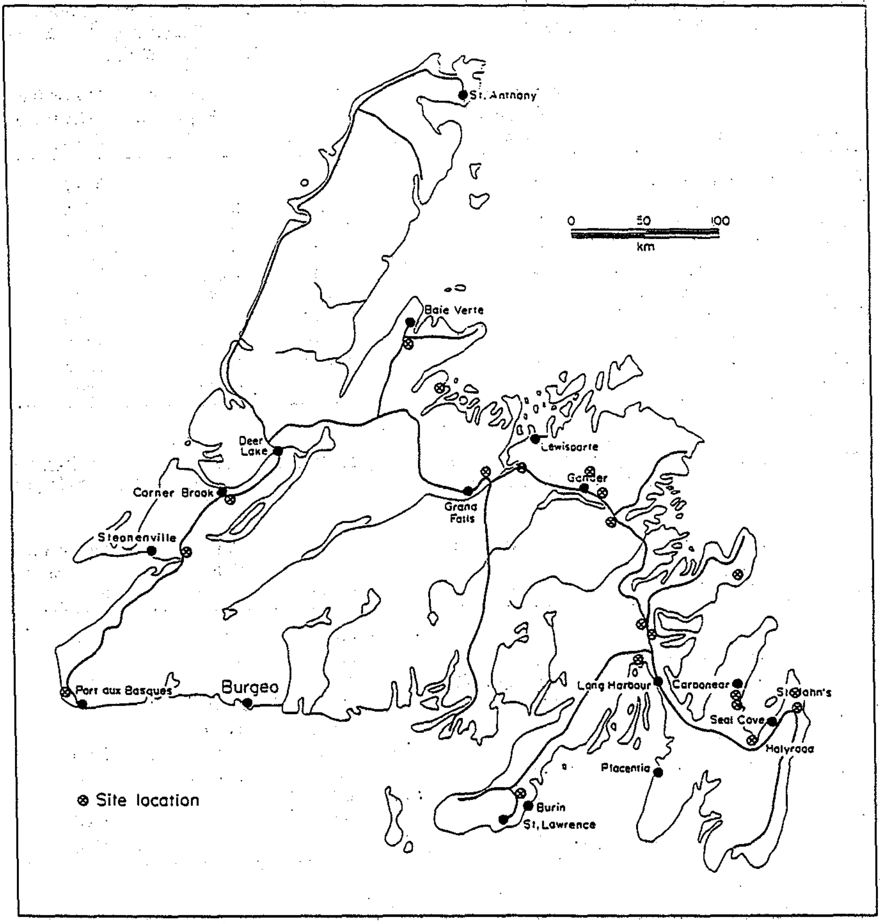

Figure 1. *Site locations.*

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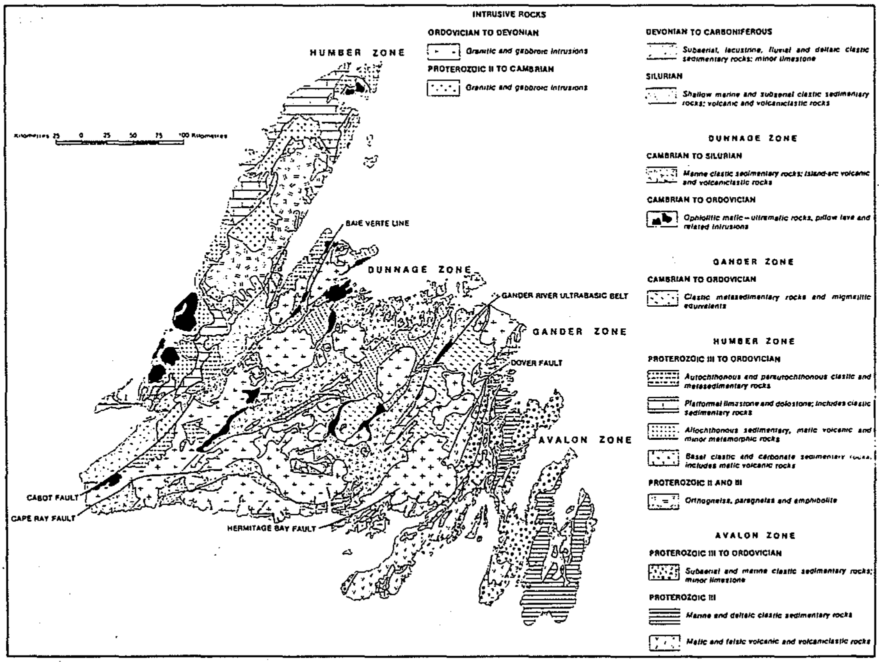

Figure 2. *"Geology of Newfoundland" by John P. Hayes, 1987.*

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